

Teacher's Motivation for and experience with using Flipped Classroom in a PBL-Environment

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Published in:
Proceedings of 46th SEFI Annual Conference 2018

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Publication date:
2018

Document Version
Publisher's PDF, also known as Version of record

[Link to publication from Aalborg University](#)

Citation for published version (APA):

Kristensen, N. S., Kofoed, L., Andreasen, L. B., Bruun-Pedersen, J. R., & Høeg, E. R. (2018). Teacher's Motivation for and experience with using Flipped Classroom in a PBL-Environment. In R. Clark, P. M. Hussmann, H.-M. Järvinen, M. Murphy, & M. E. Vigild (Eds.), *Proceedings of 46th SEFI Annual Conference 2018: Creativity, Innovation and Entrepreneurship for Engineering Education Excellence* (pp. 253-260). Société européenne pour la formation des ingénieurs (SEFI). <https://www.sefi.be/wp-content/uploads/2018/10/SEFI-Proceedings-2-October-2018.pdf>

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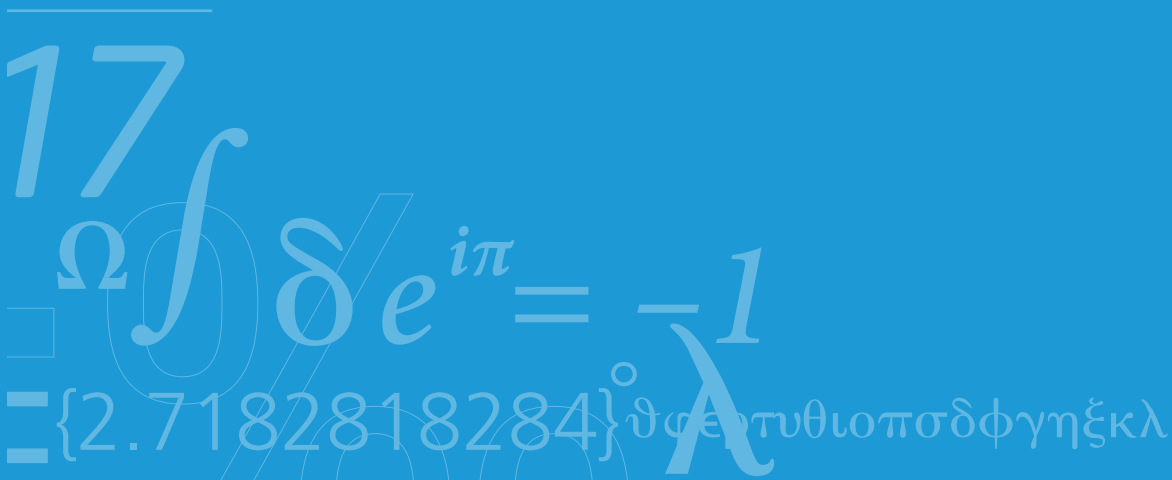
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ANNUAL CONFERENCE 17-21 SEPTEMBER 2018
COPENHAGEN, DENMARK

Proceedings



**Proceedings
of the 46th SEFI Annual Conference 2018**

**Creativity, Innovation and Entrepreneurship for
Engineering Education Excellence**

Co-organized by SEFI and Technical University of Denmark

@SEFI Brussels, Belgium

SEFI - Société Européenne pour la Formation des Ingénieurs

39 rue des Deux Eglises, 1000 Brussels, Belgium

Editors: Robin Clark, Peter Munkebo Hussmann,
Hannu-Matti Järvinen, Mike Murphy & Martin Etchells Vigild

ISBN: 978-2-87352-016-8

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SEFI - European Society for Engineering Education

SEFI is the largest network of higher engineering education institutions and engineering stakeholders in Europe. As an international NGO, it was officially created in 1973 and therefore celebrates its 45th anniversary this year. SEFI contributes to the development and improvement of higher engineering education in Europe, reinforces the position of the engineering professionals in society, promotes information about higher engineering education and improves communication between teachers, researchers and students, reinforces the university-business cooperation and encourages the European dimension in higher engineering education. SEFI is an international Forum composed of higher engineering education institutions, academic staff and teachers, students, related associations and companies from 49 countries. Our activities: Annual Conferences, Ad hoc seminars/workshops organized by our working groups, councils and ad hoc committees, organization of the European Engineering Deans Conventions, Scientific publications (including the European Journal of Engineering Education), European cooperation projects, position papers, cooperation with other major European associations and international bodies such as the European Commission, the UNESCO, the Council of Europe or the OECD. SEFI also participated in the creation of several organizations such as ENAEE, IFEEES, EuroPace, IACEE, IIDEA, and of the European Engineering Deans Council. SEFI is based in Brussels. For further information please visit our website www.sefi.be or contact office@sefi.be

Welcome to the 46th SEFI annual conference in Copenhagen 17 - 21 September 2018

"Creativity, Innovation and Entrepreneurship for Engineering Education Excellence"



Creativity, innovation and entrepreneurship must obviously be part of any engineering educational program. These three items are pillars of the engineering identity. However, we argue that they are more than just pillars, they also present ***the perfect context for excellent engineering education***. Creativity, innovation and entrepreneurship offer a perfect pedagogical framework and an authentic envelope to teach all aspects of engineering with a holistic systems approach.

It follows the philosophy:

"You do not have to be an engineer to become one - but to become an engineer, you have to be like one."

Engineering programmes and courses where students work with real life challenges create a strong environment for learning. Students acquire the core disciplinary knowledge through heavy scientific and technical subjects as well as methods of synthesis. This knowledge is integrated with the learning of personal, interpersonal, professional and innovative skills. Students face problem solving, critical thinking, team work, management, collaboration and communication skills.

This is why ***creativity, innovation and entrepreneurship*** are not just parts of engineering education - they are the powerful means to ***engineering education excellence*** in itself.

We will be exploring this theme through keynote sessions and our conference tracks.



At SEFI we are very much aware of the responsibility of engineering education in connection with the global challenges that are facing the world. Thus, we recognize the [UN 2030 Agenda for Sustainable Development](#) and support the UN Sustainability Development Goals. SEFI sees ***creativity, innovation and entrepreneurship for engineering education excellence*** as part of the right strategy to cross the finishing line in just 12 years from now.



The SEFI and Technical University of Denmark (DTU) invite everyone to join the SEFI Annual Conference in wonderful Copenhagen. The conference takes place at the DTU Campus in Lyngby just north of Copenhagen. We have mowed the lawn, fed the gold fish and there is a spot in the sun for everybody.

Looking forward to spending some valuable time together with you in September!

Yours sincerely,

Prof. Mike Murphy
SEFI President
Dublin Institute of Technology
Dublin, Ireland

Prof. Martin Etchells Vigild
SEFI Immediate past President,
2018 SEFI Conference Chairman
Technical University of Denmark
Lyngby, Denmark

General Tracks

- Continuing Engineering Education and Lifelong Learning
- Curriculum Development
- Discipline-specific Teaching and Learning
- Educational and Organizational Development
- Engineering Skills
- Ethics in Engineering Education
- Gender and Diversity in Engineering Education
- Open and Online Engineering Education
- Quality Assurance and Accreditation
- Recruitment and Retention
- The teacher as a supervisor

Conference Thematic Tracks

- Fostering entrepreneurship
- How Learning Spaces support innovative Teaching and Learning
- Innovation as the context for Engineering Education
- Innovative Teaching and Learning Methods
- Philosophy and Purpose of Engineering Education
- Sustainable Development Goals in Engineering Education
- Teaching Creativity and Innovation
- University-Business cooperation

Keynote speakers

Ruth Graham

Higher Education Consultant



A Mechanical Engineer by training, Dr Ruth Graham specialized in aeronautical fatigue, working with BAE SYSTEMS for a number of years. In 2002 she moved to Imperial College London and later became Director of the EnVision project, which sought to transform the undergraduate education across all nine departments in the Faculty of Engineering and improve its culture of support and reward for teaching excellence.

Ruth has worked as an independent higher education consultant since 2008. Her work is focused on fostering change in higher education across the world; helping to improve engineering teaching and learning worldwide and supporting the emergence of technology-driven entrepreneurship within universities. Ruth's recent projects have included: (i) a global benchmarking study on the future of engineering education, on behalf of MIT; and (ii) the development of a new framework for evaluating and rewarding university teaching achievement, sponsored by the Royal Academy of Engineering, which is currently being adopted at universities across the world. Further details can be found on Ruth's website (<http://www.rhgraham.org/>), which provides an outline of recent projects as well as copies of her published reports.

Multiple keynote session:

Interactive Community Dialogue on: "The Shapes of Innovation"

Session Chairs: Ruth Graham, Martin Vigild

Creativity, innovation and entrepreneurship can take many different shapes in engineering education, and together are a major driver for far-reaching educational reform. This session will explore how creativity, innovation and entrepreneurship are shaping engineering education excellence.

Opening the session, Dr. Ruth Graham will discuss how some of the world's most exciting new engineering programmes have embedded creativity, innovation and entrepreneurship across and beyond their curricula.

She will then introduce five perspectives on this process of transformational change. Each of these invited guests represents a different 'agent of change' in engineering education; namely national government, university leadership, programme leadership and students:

- **Marcela Angulo González, Head of Technological Capabilities Division at CORFO, the Chilean Economic Development and Innovation Agency:** Marcela is leading a government-funded programme of curricula reform in Chilean engineering schools, designed to nurture a new generation of technology-based innovators and entrepreneurs.
- **Pey Kin-Leong, Associate Provost Education, Singapore University of Technology and Design (SUTD):** Kin Leong has overseen and guided the development and delivery of a new student-centred engineering curriculum at SUTD that emphasises hands-on exploration, innovation and entrepreneurship.
- **John Mitchell, Associate Vice Dean Education, UCL Engineering:** John has led a root-and-branch reform to the curriculum across the school of engineering at UCL that allows students to apply their engineering learning through intensive, authentic and cross-disciplinary industrial and societal challenges.
- **Anne Sofie Larsen, master student, DTU:** As an engineering student at both Aalborg University and DTU, Anne Sofie has engaged in a wide range of appointments, internships, courses and experiences – from within and beyond the curriculum – that have focused on the development of entrepreneurship and innovation capabilities.
- **Eva Smeets, masters student, TU Delft:** Eva was the team leader of the Eco-Runner team at TU Delft – a highly innovative and creative team that is entirely student-run – and is also a student representative on the TU Delft's Board of Studies.

The missing voice on the panel is the voice of the educator, the teaching professor, who sits in the audience, the SEFI community of colleagues united by the common task of educating young engineers for a professional life to the benefit of the individual and society. The interactive session is designed to draw out a lively and insightful dialogue between the audience of engineering educators and the invited guests.

Marcela Angulo González

Head of Technological Capabilities Division at CORFO, the Chilean Economic Development and Innovation Agency



Marcela Angulo is a Civil Engineer and Doctor in Environmental Sciences from University of Concepción, Chile. She has 20 years of professional experience in technology transfer and innovation in public and private organizations.

She is currently Head of the Technological Capabilities Division at CORFO, responsible for designing and implementing programs aimed to strength technological capabilities for innovation and competitiveness in key strategic sectors, as well as enhancing technology development and commercialization skills in the local innovation ecosystem. The Division is supporting programmes for 20 R&D+i Centers, more than 30 university-industry Consortia, 30 Technology Transfer Offices and 3 tech transfer collaborative Hubs.

Marcela is currently leading the Engineering 2030 initiative, a government-funded programme of curricula reform in Chilean engineering schools, designed to nurture a new generation of technology-based innovators and entrepreneurs. The programme includes 13 universities, impacting around 75% of the civil engineering students at national level.

Pey Kin-Leong

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Kin-Leong Pey is currently the Associate Provost (Education, SUTD Academy and Digital Learning) and a Professor at the Singapore University of Technology and Design (SUTD). Kin-Leong was appointed by the Singapore Ministry of Education to take up the current position in setting up SUTD in January 2010. He was previously the Head of the Microelectronics Division, Director of the Nanyang NanoFabrication Center and Director of the Microelectronic Centre in the School of EEE at the Nanyang Technological University. A senior member of IEEE and an IEEE Electron Devices Society Distinguished Lecturer, Kin-Leong was the General Chair of IPFA2001, Singapore and the co-General Chair of IPFA2004, Taiwan. Kin Leong is a Fellow of the ASEAN Academy of Engineering & Technology. He is an Editor of IEEE Transactions on Devices and Materials Reliability. Kin-Leong has published more than 175 international refereed publications, 185 technical papers at international meetings or conferences and 3 book chapters, and holds 38 US patents. Kin-Leong has supervised 32 PhD and more than 15 Master theses.

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Associate Vice-Dean Education, UCL Engineering



Professor John Mitchell is Vice-Dean, Education in the Faculty of Engineering Sciences at UCL, Professor of Communications Systems Engineering and Co-director of the Centre for Engineering Education (CEE). He recently led a major undergraduate curriculum development programme across the UCL Faculty of Engineering Sciences. The revised programmes, called the Integrated Engineering Programme (IEP) launched in September 2014 and introduced a connected curriculum emphasising practical, research-based activities in all programmes with an integrated development of key skills. The programme has introduced a common framework across all departments and developed a set of core modules, which are being delivered to over 650 first year students. He has published on curriculum development within engineering education. Professor Mitchell is a Chartered Engineer, Fellow of the IET, a Senior Member of the IEEE, Fellow of the Higher Education Academy and Board Member of SEFI.

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A highlight in Anne Sofie's Master programme was taking part of the curricular course, Hardtech Entrepreneurship; a 10 ECTS point course, that works as an incubator, focusing on creating a spin-out from an existing invention or patent with focus on the business plan through learning about prototyping, product development, market analysis, pitching, finances and more. This course got her team in the Venture Cup Copenhagen finals and earned her a trip to UC Berkeley for the Berkeley Method of Entrepreneurship bootcamp as part of the courses' top 10 techpreneurs.

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The Eco-Runner Team is a highly innovative and creative team that is entirely student-run. The team consists of around 30 students, of which 5 are full-time members. It is one of the 12 "dream teams" based at TU Delft. The goal is to build a highly efficient hydrogen car to participate in the Shell Eco-Marathon, a European race with around 200 other universities and high school teams. Eva's team realized a mileage of 671 km/m³ hydrogen, which corresponds to about 2000 km/l gasoline. The car is the one with the lowest aerodynamic drag in the world.

Stephanie Farrell

Professor and Founding Chair of Experiential Engineering Education at Rowan University (USA) and the 2018-19 President of the American Society for Engineering Education



Dr. Farrell has been recognized nationally and internationally for contributions to engineering education through her work in experiential learning and promoting diversity and inclusion. Stephanie was the 2014-2015 Fulbright Scholar in Engineering Education at Dublin Institute of Technology (Ireland). She was awarded *Honoris Causa* in Engineering Education from the Internationale Gesellschaft für Ingenieurpädagogik (IGIP). She has been honored by the American Society of Engineering Education (ASEE) with several teaching awards such as the National Outstanding Teaching Medal and the Quinn Award for experiential learning. Her research interests include inductive teaching methods and the development of spatial visualization skills.

Keynote talk:

"Revolutionizing Engineering Diversity"

The engineering profession today is practiced in a world where society and technology are changing faster than ever - where population growth, limited natural resources and global warming create enormous challenges, and technological breakthroughs present an abundance of opportunities. To solve these 21st century technological challenges, society will rely upon today's undergraduate engineering and computer science programs and their ability to prepare communities of students with professional skills. In 2015, the U.S. National Science Foundation (NSF) launched a new program called REvolutionizing engineering and computer science Departments (RED). Over three years, NSF granted 19 RED awards totaling \$38 million to departments across the U.S. in a variety of engineering disciplines as well as computer science. The goal of these projects is to effect cultural and organizational change to address a wide array of enduring challenges in engineering education; these projects

are changing the landscape of engineering education in the U.S. This talk will examine Revolutionizing Engineering Diversity, an exciting RED project at Rowan University which will redefine and expand our traditional conceptions of diversity. It aims to increase participation of all underrepresented and underserved groups in engineering such as LGBTQ+ students, students with disabilities, and low income / first generation to college students.

Charlotte Mark

Managing Director at Microsoft Development Center Copenhagen



Charlotte Mark is the Managing Director at Microsoft Development Center Copenhagen, focusing on the development of (Dynamics 365) Business Applications for the global market. Charlotte joined Microsoft in 2004 following a career with Accenture leading significant transformation projects in Danish and International companies. She earned her Cand. phil. in Human Centered Informatics from Aalborg University in 1990. Charlotte holds several trusted positions focusing on how we can increase the STEM talent pool to position Denmark in the global competition, including Engineer the Future, TEKTANKEN, DI Research & Education and DI Global Talent.

Keynote talk:

"How can we build the right competencies for the future when 65% of today's students will have jobs that don't even exist yet?"

The potential of IT is tremendous. Technologies like the Cloud, AI, VR and Quantum open a completely new world of business opportunities. Companies that were traditionally defined as banking, transportation, retail, etc. now define themselves as IT companies. IT is in everything. Moreover, the demand for STEM capabilities is enormous and continually increasing. In fact, more and more companies are struggling so much to find the right ICT specialists that the European Commission predicts the gap between demand and supply to be 500.000 in Europe by 2020. However, how do we build the right competencies when 65% of today's students will have jobs that do not exist yet?

Andre´ Rogaczewski

CEO, Netcompany



André Rogaczewski founded Netcompany back in 2000. Today, 18 years later, he is leading one of the most successful international IT companies in the Nordics with more than 1,700 passionate IT talents and offices in 5 countries. With his technical background, a master's degree in computer science from Aalborg University and a true vision for Denmark's digital future, he has led the company through tremendous growth and built a delivery model that no one in the IT industry has ever matched. André is a strong advocate for digitization and digital competencies and has several influential positions, among these chairman of DI Digital and member of the Government's Disruption Council where he influences the agenda for the benefit of society's growth. André feels strongly for Denmark's digital foundation, and in particular IT talents, whom he calls the heroes of our future.

Keynote talk:

"How do we build successful companies and sustainable societies driven by the right talent?"

The world is currently in the middle of one of the most significant changes as digital transformation is fundamentally changing societies, businesses and the way we live our lives. Until now Denmark has been particularly successful in driving the digital agenda. Recently Denmark was ranked number 1 country for digital public services by United Nations for e-Government Survey 2018.

But we know that retaining this frontrunner position requires talent and skills. The journey ahead is definitely a people agenda.

We have much to gain as a country from the digital transformation. If we want to create the right conditions for Danish business, utilizing the newest technologies we need to educate, attract and maintain the right talent. We must balance the need for specific competencies in the industry with those that our educational institutions foster.

At Netcompany we have our own way of attracting, educating and maintaining talent.

This keynote will focus on: **how do we build successful companies and sustainable societies driven by the right talent?**

Research papers

DEEP OR SURFACE APPROACHES TO STUDYING, WHICH IS APPLIED? COMPARING STUDY SKILLS OF FIRST YEAR ENGINEERING STUDENTS

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Conference Key Areas: Engineering Skills, Curriculum Development

Keywords: Study strategy, deep & surface learning, mindset, engineering students

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1 INTRODUCTION

Most engineers love the disciplinary content of their work, and have no problem throwing themselves into it. The technical content is and will always be very important for engineers, but the industry nowadays asks for engineers with both technical and soft skills [1] [2]. One of the soft skills is learning how to acquire new information. In case of students; learning how to study, or put differently learning how to learn. By gaining this specific soft skill, it can contribute to learning the technical knowledge engineering students need.

Soft skills education is not popular amongst engineering students, and keeping them engaged is not an easy job [3]. So how can engineering students learn these skills? To answer this question it is important to have a closer look at learning; learning is a process that occurs within students. Learning involves change in knowledge, beliefs, behaviour or attitude, which occurs as a result of experience and increases the potential for improved performance and future learning' [4]. How people think about learning, has an influence on their willingness to make those changes and improvements. Dweck [5] showed that students' conceptions on the ability of developing their own qualities and abilities, influence how these will develop. She makes a distinction between two different types of mindsets, a growth and a fixed mindset.

A growth mindset is needed to increase the learning motivation. Students with a fixed mindset believe that intelligence is static, as students with a growth mindset believe that intelligence can be developed. Briefly and black and white stated; students with a fixed mindset avoid challenges, give up easily, see effort as fruitless, ignore useful negative feedback and feel threatened by the success of others. As a result, they may plateau early and achieve less than their full potential. This confirms a deterministic view of the world. Students with a growth mindset embrace challenges, persist in the face of setbacks, see effort as the path to mastery, learn from criticism and find lessons and inspiration in the successes of others. As a result, they reach higher goals of achievement. All this gives them an increased feeling of free will.

At the University of Twente (UT) lecturers of the engineering programmes noticed that skills education was usually evaluated below average and students often did not see the necessity of skills education. The study choice questionnaires filled out by high school students (results 2016) show that the self-assessment of the students relating their study skills prior to starting their study is quite positive. 51% of the students are placed in the category 'low risk' based on their answers.

The same questionnaires show that, despite having a 'low risk' on failure overall, the majority of the students' scores on study skills are not sufficient. This is affirmed by the lecturers who notice that many of the students lack the skill to properly plan their time to study or applying strategies that actually improve their knowledge. As a response to these observations, a project was set-up to improve the skills education of engineering students, with an initial focus on bachelor students of Civil Engineering.

The engineering programmes of UT would like to see their students to start their studies by taking responsibility for their own learning and working actively on their studies. Which is also one of the underlying principles of the Educational Model [6]. For the

majority of the students this only starts later on in the bachelor programme. The engineering programmes would like to see their students starting to work more effectively and motivated earlier in their studies to prevent delay and drop out.

To be able to properly improve skills education, it is important to get a clear overview of the current state. Are the observations of the teachers correct? Therefore the following research questions are assessed: what do engineering students think about learning? Which study approaches do they apply and how do they prefer to be taught? And how does this differ between the different study programmes?

2 METHODOLOGY

2.1 SETTING

The current research is aimed at first year engineering students of the Bachelor programmes of Civil Engineering, Mechanical Engineering and Industrial Design. The data was collected at the end of several lectures during the end of the second and third quartile of the year, to receive the largest amount of responds. Afterwards a link to the questionnaire was spread using the digital learning environment the students use for their study programmes. Prior to filling in the questionnaire the students received a short explanation about the research, and were encouraged to answer the questions truthfully and not socially desirable.

2.2 INSTRUMENTS

The students filled out a questionnaire regarding their mindset, study approach and preferred teaching approach. This questionnaire was a combination of two validated questionnaires.

To identify the students' mindset a questionnaire based on the theory Dweck [5] has been used. In this section 16 multiple choice questions are asked about views on intelligence and talent, a Likert scale of 6 points was used.

To be able to measure different study approaches and preferred teaching style, the questionnaire the ASSIST [7] is used. This questionnaire was first designed by Marton and Saljö [8] and later on adapted by Tait, Entwistle and McCune [9]. The part of the questionnaire containing the ASSIST questions consists of 60 (multiple choice) questions, of which 52 questions cover the study approaches and 8 questions the preferred teaching style. A Likert scale of 5 points was used.

2.3 STATISTICAL ANALYSIS

In analysing the data, the following correlations and comparison are investigated:

- Is there a correlation between mindset and applied study approach?
- Is there a correlation between applied study approach and preferred teaching style?
- What are the differences and similarities between students from the different programmes?

The results of the analyses are presented in Section 3.

The current identification of the different study approaches of this group of students supports lecturers when making their education more adaptive, and to determine the resources they offer to these students [10].

3 RESULTS

In total 419 first year engineering students filled out the questionnaire, 40 responses were excluded from the results due to not answering all the questions of the questionnaire. The number of responses, percentages and distribution over the three different bachelor programmes can be found in Table 1. On a population size of 600 a sample size of minimum 316 (52,7%) is needed to have a margin of error of 0.5 when handling categorical data [11]. The total population size was 622 students, table 1 shows that this minimum percentages has been met.

<i>Number of students...</i>	<i>who filled in the questionnaire</i>	<i>Percentage of responds of the total population</i>
Total complete responses	N = 378	60,7%
Responses from Civil Engineering students	n = 111	64,9%
Responses from Industrial Design students	n = 63	31,3%
Responses from Mechanical Engineering students	n = 204	81,6%

Table 1. Overview of the number of respondents

In the following subsections, results are presented. Results are called statistically significant when the p-value (significance level) is smaller than 0.05. Note that average scores plus minus the standard error (as one time the standard deviation of the sample average) and a t-test to indicate whether average scores are significantly different are presented.

3.1 MINDSET

The first part of the questionnaire is dedicated to measure the mindsets of the students. Figures 1 and 2 show the distribution over the different mindset categories and the difference between the bachelor programmes. As can be seen in Figure 1, most students are in category 3 of the mindsets, which means they have a growth mindset with a couple of fixed ideas.

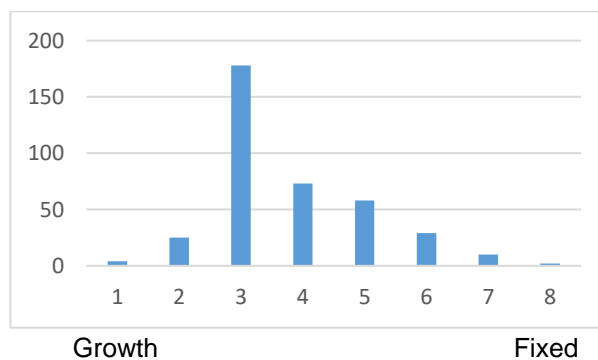


Figure 1. Absolute numbers of students per mindset category, from growth (1) to fixed (8).

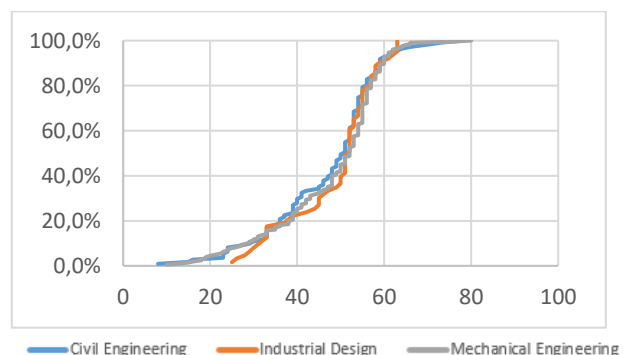


Figure 2. Cumulative distribution of the mindset scores for the three bachelor programmes.

Figure 2 shows a cumulative distribution of the mindset scores of the three bachelor programmes. There is no significant difference between the bachelor programmes, the spread of the results from the Industrial Design students is smaller, but this could be due to a smaller sample group, and is not significant according to the KS2 test. When comparing the distribution of the mindset scores and the learning approaches applied by the students, no significant correlation was found. This indicates that there is no relation between the mindset students have about learning and intelligence and the study approaches they apply during their studies.

3.2 LEARNING APPROACHES AND PREFERENCE IN TEACHING

The next results present the study approaches and the preferred styles in which students are taught. When comparing the three different approaches, on average the surface approach is applied most and the deep approach is applied least (see Table 2). When looking at preferred teaching styles, on average the students prefer deep teaching over surface teaching (see Table 3). The maximum score a student could get for the approach and preference is 20.

Table 2. Average scores per applied approach

Deep approach	Strategic approach	Surface approach
10,1	10,6	12,7

Table 3. Average score per preferred teaching style

Preference for deep teaching style	Preference for surface teaching style
10,6	8,7

As can be expected a correlation can be found between these two elements. Table 4 shows the correlation between the learning approaches and preferred teaching styles.

Table 4. Correlations between applied study approaches and preferred teaching styles

	Preferred deep teaching style	Preferred surface teaching style
Deep approach	0,43	-0,10
Surface approach	-0,16	0,14

Students who apply deep study strategies prefer to be taught by a lecturer incorporation deep teaching activities. For students who apply a surface learning approach the opposite is shown. Although all correlation coefficients are statistically significant (albeit barely for deep approach vs. surface teaching), correlation coefficients are rather weak, which is slightly surprising. For the strategic approach, no significant correlations were found with the preferred teaching styles.

3.3 DIFFERENCES BETWEEN THE BACHELOR PROGRAMMES

When comparing the three bachelor programmes, differences can be found in relation to the study approaches applied by the students. Figure 3, shows the cumulative distribution of the scores for the study approaches (top) and teaching styles (bottom).

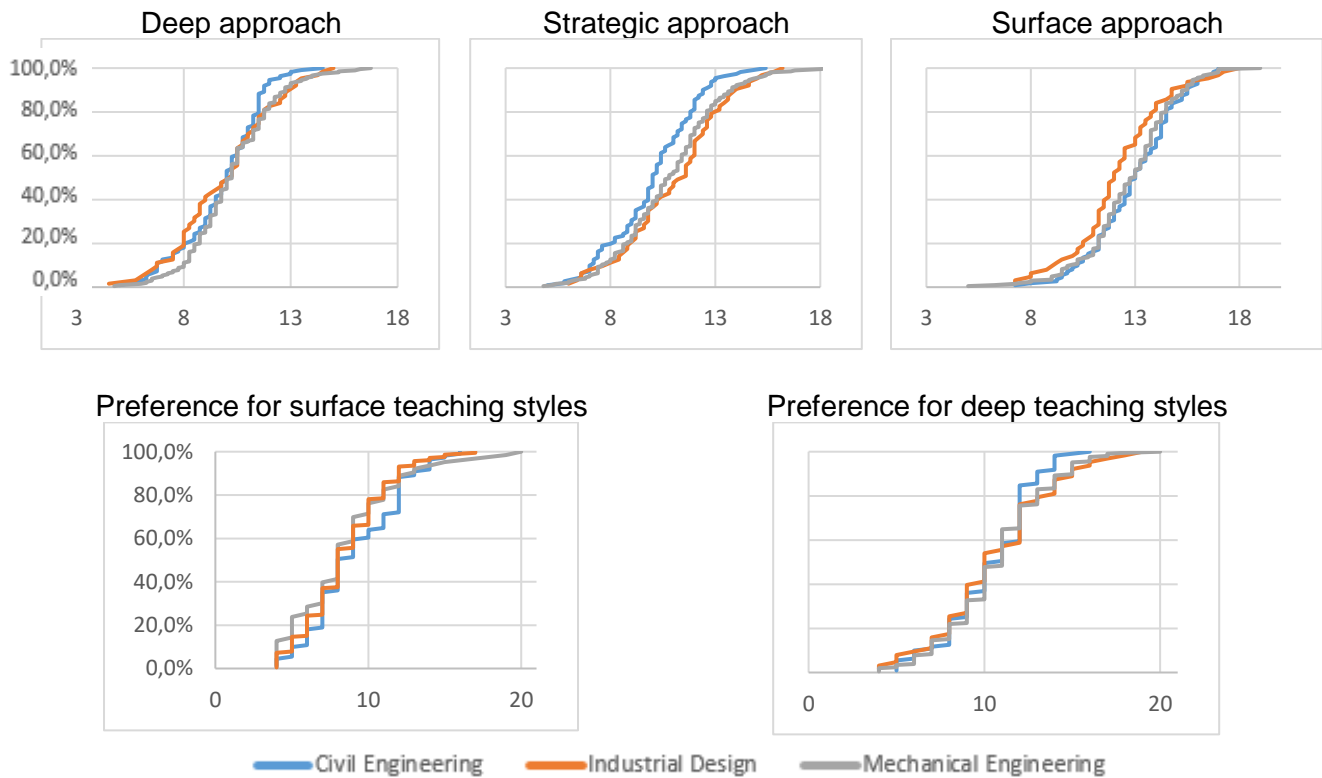


Figure 3. The cumulative distributions of the applied deep, strategic and surface approach and their preference in teaching style.

For the study approaches there are some clear differences between bachelor programmes. The upper left panel of Figure 3 shows that Mechanical Engineering students apply most deep study approaches (average scores of 10.25 ± 0.14 versus 9.78 ± 0.18 and 9.91 ± 0.29 for Civil Engineering and Industrial Design students respectively). The difference with Civil Engineering students is significant. The upper centre panel shows that Civil Engineering students stand out. They apply on average significantly less strategic study approaches (average score of 10.01 ± 0.20) than Industrial Design students (11.09 ± 0.30) and Mechanical Engineering students (10.80 ± 0.17). Finally, the upper right panel shows that Industrial Design students apply on average less surface study approaches (12.19 ± 0.29) than Mechanical Engineering (12.75 ± 0.15) and Civil Engineering students (12.97 ± 0.19). Note that the difference with Civil Engineering is significant. For the teaching styles, differences between bachelor programmes are less distinct. Civil engineering students prefer slightly more surface and slightly less deep teaching styles compared to other students. This is not unexpected given the results for the learning approaches. However, differences with other students are not statistically significant. In fact, for the teaching styles, we found no statistically significant differences between the bachelor programmes.

4 DISCUSSION & CONCLUSION

The results of this study show that the study approach that the student apply most is the surface approach, which indicates that the students do not fully comprehend the skill to study for deep learning or see the necessity of applying deep learning strategies. This is in line with the observations made by the lecturers. Of the three different bachelor programmes, the Civil Engineering students apply the surface study approach most often.

There is a silver lining, because overall the students do express that they have a preference in deep teaching styles. This could indicate that the students don't know or are not aware of the effect of their study approaches. This is strengthened when looking at the mindset of the students, most students have a growth mindset with a couple of fixed ideas. This indicates that the students do believe that putting in effort will have a positive effect on their learning, the engineering students do know that studying equals hard work.

Although the correlations are not that strong, they are the correlations that were expected. Especially the correlations between the deep and surface study approaches and there corresponding preferences in teaching styles. Which was a surprise is that no correlations were found between the mindset of the students and their study approach. This could also be a result of students not knowing what the effect is of the study strategies they apply or not knowing which activities are part of which strategy. For example that student think underlining text in their books is a proper way to study structural mechanics.

The results of the two questionnaires have not been compared to the study results of the individual students. Nor a comparison of genders has been made. Both analysis would be interesting to do in further research.

It would also be interesting to do further research to see whether making students more aware of their study strategies and mindset, and teaching them strategies that support deep learning will support them in adapting a more deep study approaches. Currently interventions to execute this are implemented in the bachelor programme of Civil Engineering.

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How do science and engineering students approach revisions? A self-regulated learning tool for supporting the transition from secondary to higher education.

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Conference Key Areas: Innovative Teaching and Learning Methods, Educational and Organizational Development, Recruitment and Retention of students

Keywords: Study skills, Self-Regulated Learning, Analytics, Transition from secondary to higher education

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INTRODUCTION

Transition from secondary school to higher education is an issue worldwide [1]. For students, part of the struggle in staying in higher education is to adapt their study skills from those that were effective in a highly supported secondary school environment to the more autonomous environment of higher education. As an example, students integrating an engineering curriculum need to adopt a methodological approach allowing them to solve problems previously unseen, where the solution method needs to be created by the student [2]. Actually, in order to make this transition from secondary school to engineering education, students will not only need to develop their learning strategies but more importantly their capacity for self-regulated learning.

Self-regulated learning is defined as involving self-generated thoughts, feelings, and actions that are systematically guided by personal goals [3]. Actions, for example, include planning, monitoring and evaluating, behaviours that students display when they study. Students who, when solving a mathematical problem, start by analysing the problem and making a plan are demonstrating self-regulated learning behaviours. Students who, when revising, clarify what they need to learn and then chose revision techniques which are directed towards these learning goals are also demonstrating self-regulated learning behaviours. Alongside these behaviours self-regulated learning also involves a particular pattern of thinking in which the learner will mentally monitor their own progress on learning and adapt their strategies as appropriate [4].

Students can be helped to develop self-regulated learning and training for self-regulated learning has been in place for many years. Panadero, Klug and Järvelä have recently argued that one interesting area for development is the use of measurement tools for self-regulated learning as intervention tools [5]. Thought of in this way, the process of reflecting on one's self-regulated learning, through undertaking a task such as a learning diary or a self-report questionnaire can trigger students to adapt their practices. This has already have some positive results, see Schmitz and Perels [6].

In order to help engineering students develop their self-regulated learning skills, we aimed to develop a self-report questionnaire which could be used as a feedback and intervention tool with students. The questionnaire was developed based on three evidence-informed learning strategies. In collaboration with a physics teacher in a secondary school, the questionnaires have been administered to a large cohort of science and engineering students in both higher education and secondary school settings, and was tested for factorial validity and reliability. The results of this questionnaire development process are reported on in this paper.

1 RELATED WORK

When reaching higher education, students have succeeded thanks to their study habits until this point. However, many do not realise they need to adapt those habits to this new context (until they eventually fail, after one or even two semesters). Therefore, helping students to make the transition from secondary to higher education

requires first to make them think about how they learn. The questionnaire and associated feedback is designed so that students have to review and reflect on their study habits. By developing their metacognitive abilities, this questionnaire aims at making students become progressively self-regulated learners [7]. As a number of meta-analyses have shown that teaching self-regulated learning has an positive impact on student attainment [8], this, in it-self, can help students succeed.

A study habit that students need to adapt when integrating an engineering college is revisions. A survey of around 600 students at the Ecole Polytechnique Fédérale de Lausanne (EPFL) has shown that the two techniques they use most frequently are a) re-read their course notes and b) re-do exercises. Strikingly, Dunlosky et al. have shown that re-reading is among the revision techniques frequently used by students which are ineffective [9]. Therefore, the questionnaire presented in this paper aims at making students aware of the revision techniques they use simply by force of habit and making them conscious that there exist more effective revision techniques.

We have selected three categories of revision techniques shown to have a reasonable impact on achievement across disciplines and assessment formats, without requiring specific training: elaboration, organization and retrieval. In elaboration techniques, learners identify the connections among pieces of information and actively relate new knowledge to prior knowledge. Concept mapping is one of these [10]. In organization techniques, learners select and structure important points in the material to study. Summarization is an example of an organization technique (whose effectiveness typically varies depending on the quality of the produced summaries [11]). In a more recent study [12], Karpicke and Blunt have shown that the third category of revision techniques called “retrieval practice” gives remarkable results and even outperforms concept mapping for instance. In retrieval practice, students reconstruct knowledge by trying to recall information (using cues or not) instead of trying to re-memorize it.

To be able to provide students with instant and individual feedback on the revision techniques they use, we chose to implement a self-reporting questionnaire. Despite relying on students to accurately report their own work, self-reporting questionnaires such as the Motivated Strategies for Learning Questionnaire (MSLQ) [4] have shown good reliability and validity with reasonable correlations with attainment. Simple to implement and to use in autonomy by students, self-reporting questionnaires help promote self-regulated learning. In the following, we present the structure of the questionnaire and report how it was administered to students.

2 METHODOLOGY

2.1 Questionnaire

The questionnaire consists of eleven items where students rate to which extent an affirmative statement corresponds to their study habits on a seven-point Likert scale. The items form three subscales corresponding to the three categories of revision techniques presented earlier: A-Relate information, B-Organise information and C-

Practice recall. Four items are borrowed from the MSLQ. We had to design the other items as retrieval practice was not covered by the MSLQ and the questions also had to match the study context of our students. Examples of questions are: for subscale A “I try to see how exercises relate to real life applications.” (Q3), for subscale B “When I study for this course, I write short summaries with the most important points.” (Q4) and for subscale C “I try to test myself to see if I can remember the key ideas of the course.” (Q8). The questionnaire has been kept short on purpose, since its first and foremost goal is to be a quick feedback tool for students.

2.2 Data collection

A paper based data collection phase has been organized in the middle of the spring semester² in four classes of first year engineering bachelor (hereafter called BA1, N = 346), with students from seven science and engineering departments. In addition, a group of students who had failed their autumn semester and were attending a reboot semester during the spring were also included in the study (BA1-Reboot, N = 31).

In parallel, the questionnaire has been administered to four different classes of secondary students in the context of a physics course given by the same teacher. Three classes are from the lower senior cycle in fundamental sciences (SEC-Low, N = 80). One class is from the upper senior cycle (SEC-Up, N = 21) with a specialization in physics and applied maths. The students taking this specialization are typically intending to undertake studies in engineering, science or medicine.

3 RESULTS

3.1 Reliability and validity

We carried out a Principal Component Analysis, which indicated that the emergent factor structure matched the three proposed subscales. However, some questions had low reliability scores affecting the reliability of the scale. After the exclusion of two questions, Cronbach's alpha for the different subscales ranges from .62 (subscale A-Relate information) to .69 (subscale B-Organise information). As a result, the questionnaire counts nine questions (three questions per subscale). Cortina and Schmitt both identify that the alpha is associated with the number of test items and so a scale with a small number of test items may well have an alpha lower than the typically cited cut off of .7 [13, 14]. Such scales can be reported, however with the caveat that reliability is questionable. In line with practice in other tests, we propose that it is acceptable to use these scales for reflection purposes but that they would need further development to be accepted as a reliable measure. The following sections present the quantitative results obtained with the questionnaire.

3.2 Overall scores

The mean score over the questionnaire, all groups included, is $M = 4.30$, $SD = .925$ on a scale of seven. Table 1 and Fig. 1 report the detail of the overall score for the

² The data collection has been managed by a group of master students as part of their project in a course on learning sciences during the spring semester.

different groups. It is interesting to notice that the score obtained by students attending the reboot semester is the lowest of all groups. In particular, it is lower than that of the students attending the standard engineering curriculum even if the difference is not significant, $t(375) = -1.76$, $p = .08$. This may indicate that these students, who have failed their autumn semester, are less likely to use effective revision techniques.

Group	N	M	SD
SEC-Low	80	4.39	.914
SEC-Up	21	4.44	.701
BA1	346	4.30	.929
BA1-Reboot	31	3.99	.999
Total	478	4.30	.925

Table 1. Overall score per group

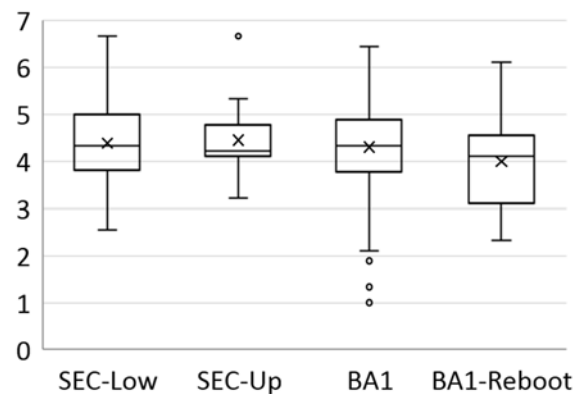


Fig. 1. Score distribution per group

3.3 Relate information (subscale A)

Fig. 2 presents the mean score per subscale for the different groups. On subscale A-Relate information, engineering students score significantly lower than secondary students, $t(476) = -3.09$, $p < .01$. More specifically, BA1 students score significantly lower than SEC-Up students, $t(365) = -2.19$, $p = .03$. A possible reason for such a difference is that the physics teacher in the secondary classes coaches his students on the use of the different resources he makes available for his class [15]. Therefore, these students might have specifically developed their ability at relating information from different sources compared to other secondary students.

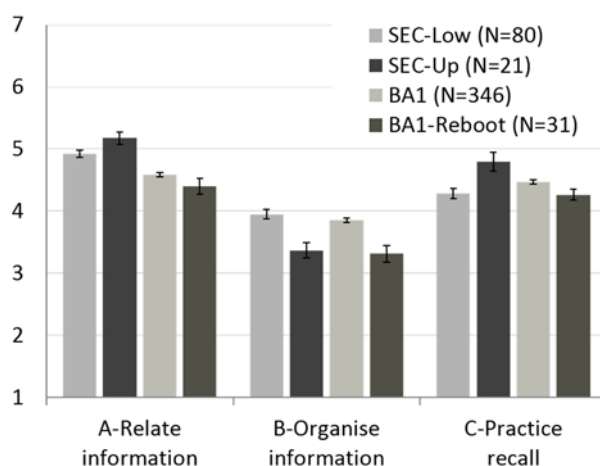


Fig. 2. Mean score per subscale and per group

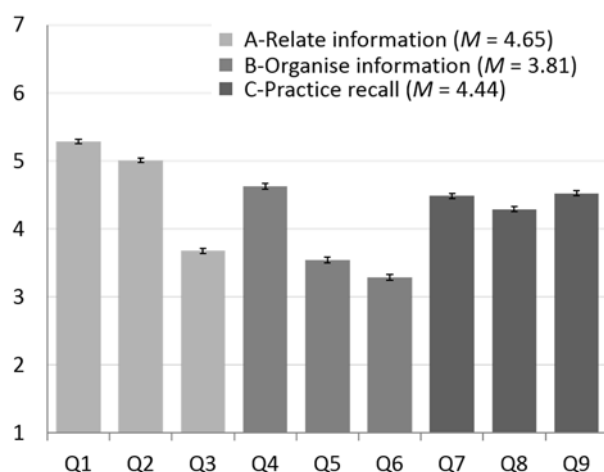


Fig. 3. Mean score per question

As Fig. 3. illustrates, question 3 stands out as having a particularly low mean score in subscale A, and again bachelor students score significantly lower than secondary students on this question, $t(474) = -3.77$, $p < .001$. Interestingly, this question

assesses whether students try to identify how exercises relate to real life applications. An important factor here might lie in the nature of the core courses in the propaedeutic year of the bachelor of engineering. Transversal to all departments and generally given by professors from the School of Basic Sciences, these courses are designed to introduce the formalisms necessary in the following years. Aiming at developing students' abstraction, some of these courses include few examples of applications. Students would then have to work them out by themselves.

3.4 Organise information (subscale B)

The mean score on subscale B-Organise information ($M = 3.81$, $SD = 1.44$) is the lowest of all three subscales, and the difference is significant when comparing with subscales A and C. The particularly low mean scores on questions 5 and 6 (see Fig. 3) are interesting to consider. While question 4 assesses whether students write summaries of the course content, question 5 tests whether they outline the content of course resources and question 6 tests whether they use some kind of schematics to represent how information is organised. This could tend to indicate that while summarizing is a frequently used technique for students, they seem not to use more elaborated techniques to organise information.

Among bachelor students, the BA1-Reboot students score significantly lower than the BA1 group, $t(375) = -1.96$, $p = .05$. The context does not provide information to explain this result. It is possible that these students (who have failed their first semester), have a weak ability to organise information and that this might be a factor in their failure.

3.5 Practice recall (subscale C)

We found the mean score on subscale C-Practice recall ($M = 4.44$, $SD = 1.25$) to be higher than expected given the preference of students on rereading over other revision techniques. Secondary students from the upper cycle obtain the best score on this subscale ($M = 4.79$, $SD = 1.38$), although the difference with the other groups is not significant. Bachelor students in reboot semester score again lowest.

One possible hypothesis to explain the relatively high score on this subscale, in particular in the case of the engineering students, is that students practice a lot redoing exercises and consider it as a recall activity. A question is whether they maximise their practice of recall in that context. Because two of the questions are framed using the term "I try to (recall / test myself) ...", it is not possible to evaluate how long students persist in recalling information before checking their notes or looking up information. Data collected on campus shows, for instance, that when the solution of an exercise is available, many students look at the solution right away when they have a difficulty during the resolution (actually, a non-negligible proportion of students even tends to look at the solution before trying to solve the exercise).

4 DISCUSSION

Our goal is to help engineering students to develop self-regulated learning skills by developing a self-report reflection tool. The data suggests that we have made progress

towards developing such a tool. The results obtained by the secondary and bachelor groups, albeit on a non-random sample, show similar tendencies on lowest and highest subscales and items as well as clear differences between populations.

Of course, as for all self-reporting questionnaires, the conclusions have to be taken carefully as students' response might not accurately reflect their actual practices. On one hand, self-report measures are widely used and show good reliability and validity, but on the other hand, we know that students have difficulties assessing their own learning practices. However, this is not a major concern since the purpose here is to develop a tool for self-reflection, not to objectively measure learning practices.

One limitation regarding this study is that the secondary students are all from the same secondary school and have the same physics teacher. Our hypothesis was that first year engineering students use the study skills they have developed in high school but the results of our study tend to show a difference. It is well possible that these secondary students are not representative of secondary students in Switzerland, in particular because of the specific instructional methods of their physics teacher.

5 CONCLUSIONS AND PERSPECTIVES

We have developed a self-report questionnaire to help engineering students to develop self-regulated learning skills, specifically in the area of regulation of study (revision techniques). The results of the test phase presented in this paper show that the tool has factorial validity and is moving towards reliability. We conclude that it is suitable for self-reflection, while not yet a reliable measure. Further development is necessary, in particular the design of additional questions in subscales to enhance the overall reliability. In a preliminary phase, we have used this tool in different self-regulated learning interventions with personalized feedback for both secondary students and engineering students. A MOOC with videos, quizzes and reflective activities has been put in place to provide students with evidence-based support for the different study skills. We are currently developing a web-based "learning companion" integrating different self-regulated learning questionnaires with the MOOC resources.

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46th SEFI Annual Conference
Are Team Member Contributions Correlated with Cohesion and Performance
Behaviors for Software Engineering Students?

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Software engineering is an activity quite depending of team work nowadays. In the last decades, this aspect has raised the interest of software engineering educators. In academic contexts, team work can be affected when team members (students) are not contributing equally. In other contexts, team member contributions have been found correlated with the cohesion of teams, the last one being a good predictor of performance. Although some researches have studied the performance of student teams, they mostly have been focused on measures related with outcomes rather than behaviors. This work presents a study on the relations between these variables, with a sample of 95 Cuban software engineering students performing in teams. The student teams were exposed to the “*Stick-Together*” approach, a proposal grounded on the Input Mediators Outcomes Input (IMOI) model. The aim of this approach is to improve team cohesion which leads to better team performance behaviors. In this approach self and peer assessment of team member contribution is considered in order to avoid the free-ride problem. This paper describes the way in which students’ contribution is related to cohesion and performance behaviors in order to better understand the relationships between these variables in regard to the adoption of this approach.

Conference Key Areas: Engineering Skills, Discipline-specific Teaching & Learning and Curriculum Development

Keywords: team work, member contribution, cohesion, performance behaviors, software engineering education

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INTRODUCTION

In modern software development teamwork is a critical success factor. Developers have to work together performing independent task to produce quality products in a continuous changing technological environment. During this process they have to adapt in an agile way for reaching the team's goals, experimenting complex relationships while interacting under project restrictions of time, budget, and others. Thus, to prepare software engineers to effectively perform on teams is an important matter nowadays.

Some studies in economics reveal that peers stop cooperating when they believe they are being exploited by a free-rider [1]. A free-rider is an individual with a conscious decision to withhold effort when the ability to contribute is present. Similarly, in academic contexts students express a dislike for team work because of increased pressure when team members are not performing equally [2]. Some authors state that free-riding is one of the most important cause of student dissatisfaction within team work [3], [4]. Balance on team member contributions is critical in software teams with members who have expertise in different areas (core development, GUI development, system architecture, testing, etc.) [5].

Team member contributions have been found correlated with the cohesion of teams [6]. The last one has being found strongly correlated with performance when this is measured as behaviors [7]. These three variables were included in our *Stick-Together* approach, a proposal grounded on the Input Mediators Outcomes Input (IMOI) model [8], [9]. Several studies were conducted to observe if this proposal leads to improve team cohesion pursuing the aim of obtaining better team performance behaviors [10][11]. In *Stick-Together* approach self and peer assessment of team member contributions are considered in order to avoid the free-ride problem. In this paper we focus on describing the way in which students' contribution was related to the cohesion and performance behaviors during the series of experiments conducted.

The remainder of this paper is structured as follows: Section 1 describes the context of the study, the method of intervention and the variables. Section 2 refers to the results observed. Section 3 discusses some limitations of the study and Section 4 concludes the paper.

1 METHODOLOGY

Ninety five software engineering students from the University of Holguin participated in the study. It was conducted over five study cases during one year till February 2018. They were performing in twenty two teams of 3-6 members, all using agile methodologies to develop software.

The main objective in this series of experiments was to observe if the *Stick-Together* approach was effective to make teams more cohesive leading to improve team performance behaviors. Fig. 1 shows an overview of this approach, which consists of three phases, and is conducted over periods of ten to twelve weeks.

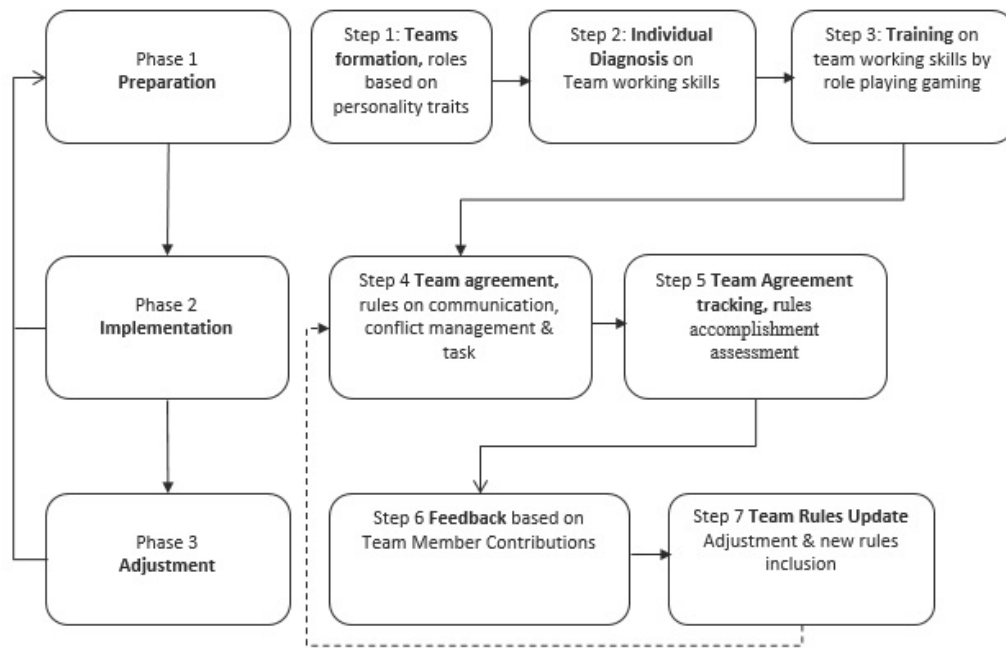


Fig. 1. Our *Stick-Together* approach

Team member contributions were evaluated on five areas, according to low, medium and high levels of team performance behaviors, by means of the questionnaire proposed by [6]. This instrument uses a behaviorally anchored rating scale to measure team member contributions in five areas. The areas include 1. contributing to the team's work, 2. interacting with team mates, 3. keeping the team on track, 4. expecting quality and 5. having relevant Knowledge, Skills, and Abilities (KSAs).

Team performance is seen as behaviors related to the tasks and team learning. Team performance is usually measured with indicators for effectiveness and efficiency. However, [1] differentiated between performance behaviors and performance outcomes. Team performance behaviors are actions relevant to achieving goals, whereas outcomes are the consequences or results of performance behaviors. In this study we assume the criteria of [12] who define team learning as the “activities carried out by team members through which a team obtains and processes data that allow it to adapt and improve”. Performance on task is assessed following the criteria of the same author as the degree in which the team satisfies client needs and expectations. Team performance behaviors as a variable is then studied in these two aspects: “Team Performance Behaviors on Task” and “Team Learning”.

Team cohesion is thought of in two very different ways, as proposed by [13]: the social attachment within the team and the team's connection to the project itself (calling these social “S” and task “T”); and at two levels of granularity: at the individual level and for the team as a whole (calling these Individual Attractions to the Group (ATG) and Group Integration (GI)). The combination of these two dimensions and two levels result in measuring four aspects of team cohesion:

- GI-T: The team's attachment to the task
- GI-S: The team's social connection
- ATG-T: Individual attachment to the task
- ATG-S: Individual connection to the team

It is beyond the scope of this study to examine the effectiveness of the *Stick-Together* application. Some works have previously discussed that matter [10], [11]. In this paper we

focus on the way in which students' contribution is related to cohesion and performance behaviors before and after the application of the *Stick-Together* approach. In particular, we examine the following research questions:

RQ1: Are team member contributions correlated with team performance behaviors on task?

RQ2: Are team member contributions correlated with team learning?

RQ3: Are team member contributions correlated with team cohesion?

2 FINDINGS

The analysis of the research data was performed with the SPSS 20.0 software package. Shapiro-Wilk test confirmed non-normal distribution for all variables. All the tables in this section show the Spearman correlation coefficient and p-values. For each analysis are shown the values before (marked in tables with sub-indices 1) and after (marked in tables with sub-indices 2) the application of the *Stick-Together* approach.

The coefficients of the significant correlations (99% confidence) are marked with '***', i.e. they have a significance level of 0.01, meaning that the error probability is less than 1%. The coefficients of correlation confirming positive relationships between the factors at a confidence level of 95% are marked with '**', that is, they have a significance level of 0.05, and the error probability is <5%.

A first analysis did not indicate any correlation between team member contribution and performance behaviors before the application of *Stick-Together*. However, it was found that team member contribution positively correlates with the final team learning ($r=0,358^{**}$, $p=0,000$). A specific analysis for each area is presented in *Table 1*. It shows the values for each area of team member contribution and team performance behaviors, this last variable presented as team performance behaviors on task (TPBT) and team learning (TL).

Table 1. Correlation between team member contributions and team performance behaviors

Team Member Contributions' areas		TPBT ₁	TPBT ₂	TL ₁	TL ₂
Contributing to the team's work	<i>r</i>	0,105	0,079	0,072	0,021
	<i>p</i>	0,312	0,445	0,485	0,837
Interacting with teammates	<i>r</i>	0,058	0,113	0,015	0,015
	<i>p</i>	0,579	0,275	0,887	0,884
Keeping the team on track	<i>r</i>	-0,057	0,008	-0,004	0,014
	<i>p</i>	0,585	0,937	0,971	0,894
Expecting quality	<i>r</i>	-0,192	0,222*	-0,189	0,559**
	<i>p</i>	0,063	0,031	0,067	0,000

Having relevant Knowledge, Skills, and Abilities (KSAs)	<i>r</i>	-0,076	0,238*	-0,139	0,247*
	<i>p</i>	0,462	0,020	0,180	0,016

* $p < 0.05$.

** $p < 0.01$.

As can be seen in the table above, not any team member contributions' area was correlated with performance behaviors before the application of *Stick-Together*. Nevertheless after that, *Expecting quality* and *Having relevant Knowledge, Skills, and Abilities (KSAs)* were found correlated with team performance behaviours on task ($r=0,222^*$, $p=0,031$ for *Expecting quality*; $r=0,238^*$, $p=0,020$ for *KSAs*) and team learning ($r=0,559^{**}$, $p=0,000$ for *Expecting quality*; $r=0,247^*$, $p=0,016$ for *KSAs*).

A first analysis concerning cohesion indicated correlation between this variable and performance behaviors in both moments, before ($r=-0,459^{**}$, $p=0,000$) and after ($r=-0,218^*$, $p=0,034$) the application of *Stick-Together*. Table 2 shows the values for the analysis of each area of team member contribution and cohesion. Before the application of *Stick-Together* none relationships were found. However after the application, a positive correlation was found between cohesion and the areas *Expecting quality* and *Having relevant Knowledge, Skills, and Abilities (KSAs)*.

Table 2. Correlation between team member contributions and cohesion

Team Member Contributions' areas		Cohesion ₁	Cohesion ₂
Contributing to the team's work	<i>r</i>	0,116	0,017
	<i>p</i>	0,264	0,868
Interacting with teammates	<i>r</i>	0,092	0,034
	<i>p</i>	0,378	0,740
Keeping the team on track	<i>r</i>	0,028	0,022
	<i>p</i>	0,786	0,831
Expecting quality	<i>r</i>	0,002	0,676**
	<i>p</i>	0,986	0,000
Having relevant Knowledge, Skills, and Abilities (KSAs)	<i>r</i>	0,010	0,288**
	<i>p</i>	0,925	0,005

* $p < 0.05$.

** $p < 0.01$.

A second analysis over cohesion and team member contributions is shown in *Table 3*. Here are displayed the values for each area of team member contribution and each of the four cohesion's aspects.

Table 3. Correlation between team member contributions' areas and cohesion's aspects for both dimensions

Team Member Contributions' areas		Cohesion's aspects							
		GI-T ₁	GI-T ₂	GI-S ₁	GI-S ₂	ATG-T ₁	ATG-T ₂	ATG-S ₁	ATG-S ₂
Contributing to the team's work	<i>r</i>	0,087	-0,128	0,010	0,027	0,152	-0,123	0,089	0,162
	<i>p</i>	0,403	0,216	0,9240	0,799	0,141	0,237	0,393	0,118
Interacting with teammates	<i>r</i>	0,047	-0,153	0,003	0,000	0,097	-0,093	0,091	0,165
	<i>p</i>	0,650	0,138	0,978	1,000	0,350	0,372	0,378	0,110
Keeping the team on track	<i>r</i>	0,025	-0,172	-0,030	0,140	-0,067	-0,172	0,077	0,013
	<i>p</i>	0,813	0,096	0,774	0,177	0,521	0,096	0,461	0,900
Expecting quality	<i>r</i>	-0,150	0,220*	-0,160	0,429**	0,126	0,412**	0,146	0,504**
	<i>p</i>	0,147	0,032	0,122	0,000	0,225	0,000	0,158	0,000
Having relevant Knowledge, Skills, and Abilities (KSAs)	<i>r</i>	-0,068	0,015	-0,149	0,106	0,049	0,139	0,108	0,374**
	<i>p</i>	0,514	0,885	0,150	0,305	0,641	0,180	0,299	0,000

* $p < 0.05$.

** $p < 0.01$.

The values in *Table 3* show no correlations before the application of *Stick-Together*. However after the application, *Expecting quality* was correlated with all the aspects of cohesion ($r=0,220^*$, $p=0,032$ for GI-T; $r=0,429^{**}$, $p=0,000$ for GI-S; $r=0,412^{**}$, $p=0,000$ for ATG-T; $r=0,504^{**}$, $p=0,000$ for ATG-S). The area *Having relevant Knowledge, Skills, and Abilities (KSAs)* was also found correlated with *Individual connection to the team* ($r=0,374^{**}$, $p=0,000$).

3 LIMITATIONS

The validity of the results presented here is limited by the fact that it uses a questionnaire-based approach and peer evaluation research. Students were asked to assess their own behaviors and their teammates', and that might go against the reality as some students could rate themselves with the highest scores or mark others with unfair criteria. However, in order to avoid this, they were informed that this assessment would not influence their grades. On the other hand, the correlations found might also be explained by other variables involved in the *Stick-Together* approach, such as the level of conflicts, task characteristics or personality

traits [14]. In addition, characteristics of the context such as students differences with regard to computers and other resources required for the development of their projects, limitation of information sources, among others factors, could affect the way in which they contribute and perceive the others' work.

4 CONCLUSIONS

This work presented a study on the correlational relationships exhibited by software engineering student teams between team member contributions and the cohesion and performance behaviors during a series of experiments along one year. The findings show that *Expecting quality* and *Having relevant knowledge, skills, and abilities (KSAs)*, are important areas of team member contribution for cohesion and performance behaviors of software engineering students teams. Contrary to the results found by [6], our findings didn't confirm the importance of *Contributing to the team's work*, *Interacting with teammates* and *Keeping the team on track* for cohesion. However, some correlations between areas could explain undirected effects on team cohesion and performance behaviors. For instance, *Having relevant knowledge, skills, and abilities (KSAs)* was found correlated with *Contributing to the team's work* ($r=0,319^{**}$, $p=0,002$), *Interacting with teammates* ($r=0,351^{**}$, $p=0,000$) and *Expecting quality* ($r=0,213^{*}$, $p=0,038$). This finding is consistent with the reports by the same authors in the study aforementioned. They explain that team members with strong relevant knowledge, skills, and abilities are more likely to contribute highly to the team's work than students who lack the necessary skills to contribute. In the same way it has been stated that team members who are highly skilled in areas related to the team's work also display better social skills and contribute more to team discussions [15]. Thus, while *Expecting quality* and *Having relevant knowledge, skills, and abilities (KSAs)* would be the most important areas in our study, we shouldn't ignore surfacing effects of *Contributing to the team's work* and *Interacting with teammates* areas. Moreover, comparing the results before and after the application of *Stick-Together*, it seems that this approach has an influence on the students' expectations about team's success and production of high-quality work, besides the role of knowledge, skills and abilities required for getting excellent results. Thus, further studies will explore other involved variables and their influences enabling a better clarification.

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Merging STEM Education with Brain Science: Breaking the Silo Mentality

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Conference Key Areas: Philosophy & Purpose of Engineering Education, Educational and Organizational Development

Keywords: Engineering Education Research Methods

INTRODUCTION

Learning has been long studied through different disciplines, such as neuroscience, cognitive psychology, brain science, and education; all these fields, however, often operate in silos, using different research methods and following different professional practices. Therefore, learning is not frequently reviewed through a holistic lens, and findings can remain available within narrower academic communities instead of being shared broadly. Although the Engineering Education (ENE) field is cross disciplinary by nature, so far it appears that its scholars approach the learning aspect mainly by adopting the culture, practices and methods developed by the education community; however, ENE rarely appears to get informed by developments in other learning-related fields [1]. Many authors

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have argued that it is the “siloe nature of many engineering schools and universities that inhibits collaboration and cross-disciplinary learning” [2]. The pilot study discussed in this paper suggests new research approaches on learning, while at the same time bridging the gap between the disciplines of education, brain science, and beyond.

1 TRANSFORMING LEARNING THROUGH RESEARCH APPLIED PRACTICES

1.1 The Learning Across Scales Project

As technology and research regarding learning advance faster than ever, “there is a pressing need in higher education for deeper integration of research across the fields that impact learning” [3]. MIT has taken actions to address this need, including the founding of the MIT Integrated Learning Initiative (MITili) in 2016 [4] “through rigorous and interdisciplinary research on the fundamental mechanisms of learning and how we can improve it” [4]. A founding principle of MITili is that it, “draws from fields as wide ranging as cognitive psychology, neuroscience, economics, health, design, engineering, architecture and discipline-based education research (DBER)” [4].

The Learning Across Scales (LxS) Project was initiated in February 2016 to assess the level of integration across the silos of research. The goal was to:

- **Explore** the cross-disciplinary landscape of learning at different scales [Neuron, Brain, Classroom, MOOCs, Global Education].
- **Map** the existing learning related research approaches and identify unexplored areas that will allow for cross-disciplinary research opportunities.
- **Create** interdisciplinary pathways, such as a cross-disciplinary research repository, to inform new MIT educational & research initiatives.
- **Bridge** the gap between traditional education and the brain sciences.
- **Highlight** actionable implementations for the real world.

2 RESEARCH STUDY

In the summer of 2016, the first pilot study within the LxS project was designed and implemented. The scope of this pilot study was to provide an initial understanding of the most commonly researched topics within the communities of education and brain science, to explore potential common research ground, and to use both infographics and a website to communicate the results.

2.1 Data Collection

Data collection for this study involved recording and examining “call(s) for papers” of conferences and journals representing numerous subfields of education as well as brain science. A maximum of 5 conferences and/or 5 journals were first identified for each of the following subfields: mathematics education, physics education, engineering education, biology education, history education, music education, computer science education; 7 conferences and journals were identified which had the generic term of “education” in the title; 11 conferences and journals were identified under the field of “brain and cognition”; and 3 additional conferences and journals were identified and included under the term “neuroscience.” A different data set was collected for the fields of e-learning and MOOCs due to the very special nature of the latter, that calls for a distinct pedagogical approach. The conferences and journals were identified through a Google search via relevant terms such

as *[subject name] education conference call for papers*, or *[subject area] education journal call for papers*. Experts in every field were also contacted within MIT in order to contribute towards identifying the most appropriate conferences and journals. To further establish validity, in this first pilot study, only conferences organized by universities or entities formally related to education were included. For every conference or journal included in the data set, the research topics identified under the “call for papers” section were further catalogued.

2.2 Data Analysis

Mixed methods were used during data analysis. As a first step, the data was split into 2 groups, namely data from the fields of education and data from brain science. Due to the particular nature of the subfield, a separate group emerged out of the *education* data that included data related to e-learning with MOOCs. A general inductive open coding qualitative method [5] was used to identify thematic research categories. *Table 1* presents a sample of 3 conferences on engineering education and includes identified research topics along with highlighting the color-coding scheme that was first applied.

Table 1. Color-coded data sample representing research topics identified by 3 conferences in the field of engineering education

Conferences	SEFI	ASEE	IEDEC
Research Topics	Engineering Education Research	College Industry Partnerships	Student Projects and Internships
	Entrepreneurship in Engineering Education	Design in Engineering Education	Learning Environments, Technology and eLearning/e-Assessment
	Gender in Engineering Education	Engineering and Public Policy	Distance Learning and Distance Teaching
	Curriculum Development	Educational Research and Methods	Innovation and Creativity in Engineering Design
	The Importance of Internships	Engineering Ethics	Women in Engineering
	Ethics in Engineering Education	Continuing Professional Development	Social Media in Engineering Education

The two researchers then met with an expert who had separately analyzed a sample of the data. The thematic categories were further discussed and redefined until the whole group came to a consensus with regards to the definitions. At the end, as presented in *Table 2*, 16 thematic categories were defined, and the whole data set was again analyzed according to the new definitions. Research topics that did not fit in any of the thematic categories were not included in this pilot study but will be incorporated at a future point.

Table 2. The 16 thematic categories that emerged from the data analysis

Research Thematic Category	Definition Used
Technology	Research regarding how technology can be used to enhance the learning experience.
Sociocultural Issues	Research regarding sociocultural issues (of, or relating to, to a combination of social cultural elements such as socioeconomic status, race, religion, age, etc.).
Gender	Research regarding how gender affects education.
Innovations	Research regarding innovations that develop within/for the delivery or creation of content and curriculum in the classroom.
Ethics	Research regarding ethical considerations in education (both regarding the practice and the content to be taught).
Student Psychology	Research regarding student psychology factors, such as motivation, that influence students while they are learning and ultimately affect retention and understanding.
Assessment of Learning	Research regarding how teachers or a MOOCs platform test whether someone has learned their material.
Assessment of Teaching	Research regarding how a teacher can be assessed for the way he/she maintains a classroom and teaches.
Assessment & Accreditation of Programs	Research regarding program assessment or accreditation.
Teacher Development	Research topics related to how teachers get further educated with regards to development of new content, or new delivery and assessment methods.
Collaborative Learning	Research regarding collaborative learning.
Curriculum Design	Research regarding curriculum design.
Business Opportunities	Research topics related to business models, partnerships, and opportunities for funding that emerge within education, especially through e-learning.
Connections with Industry/Job Market	Research regarding how education connects to the real world, and how education translates to the job market or further employment.
Policy	Research regarding principles and government policy-making in the educational sphere, as well as the collection of laws and rules that govern the operation of education systems.
How Learning Works	Research regarding how the brain processes the information received to form learning.

3 FINDINGS AND INTERPRETATIONS

3.1 Interactive Maps

As the point of this pilot study was to identify potential research ground of common interest between different fields studying learning, an info-graphic was selected as a medium to communicate the results. The first set of maps independently present the research in the field of brain science, education, and MOOCs in relation to the 16 thematic categories. The second set presents comparative interactive maps across the Learning fields. As a sample of our findings, *Fig 1* and *Fig 2* illustrate the interactive graphs created for the field of education. In these Figures, blue represents conferences and journals on STEM education, pink represents Music and Language education, green represents Online Education in class, while red represents all remaining conferences and journals. The 16 gray circles represent the 16 research thematic categories identified.

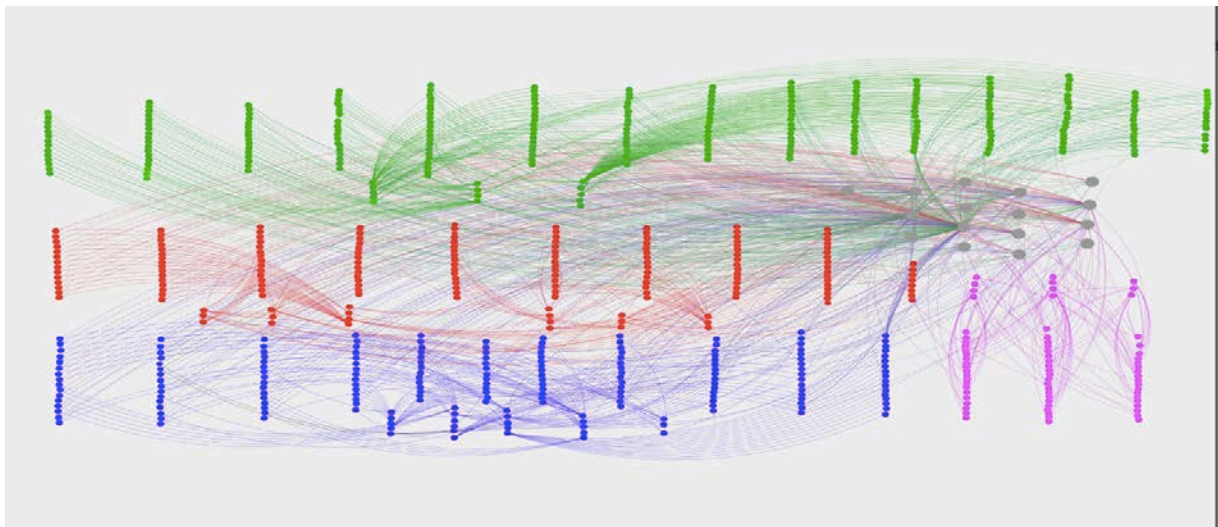


Fig 1. Interactive map presenting all data gathered for the field of education.

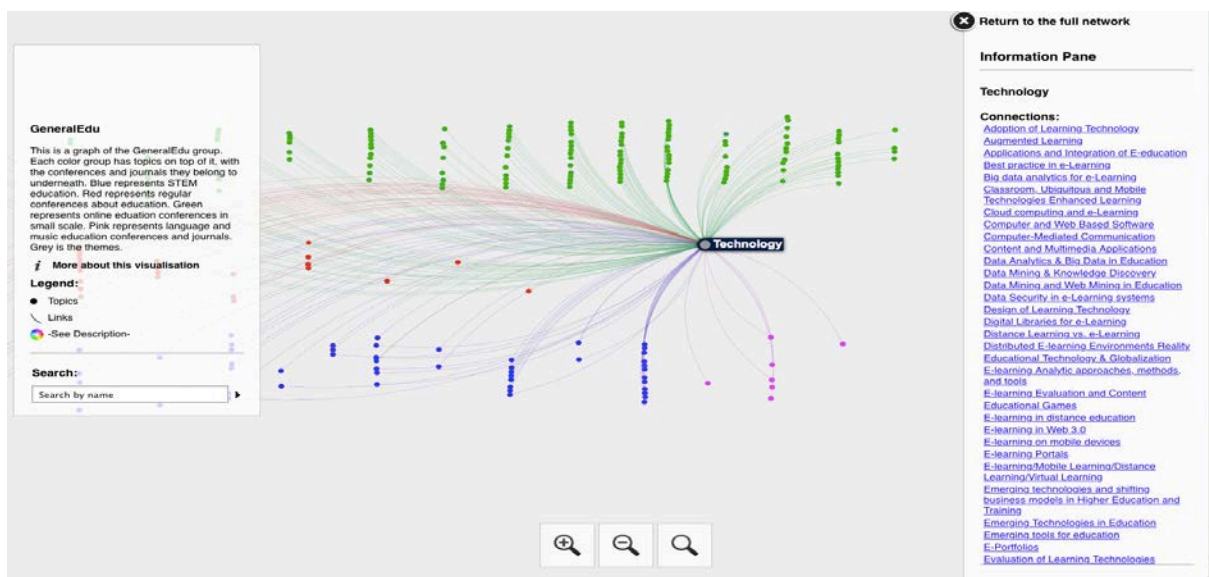


Fig 2. Interactive graph highlighting conferences and journals that include the research theme of technology

When examining the common ground among fields, *Fig 3* and *Fig 4* present the comparative interactive graphs between the fields of brain science, education, and MOOCs. In the following figures, yellow represents conferences and journals from the field of brain science, green represents conferences and journals from the field of education, and orange represents conferences and journals on MOOCs. The 16 gray circles represent the 16 research thematic categories identified.

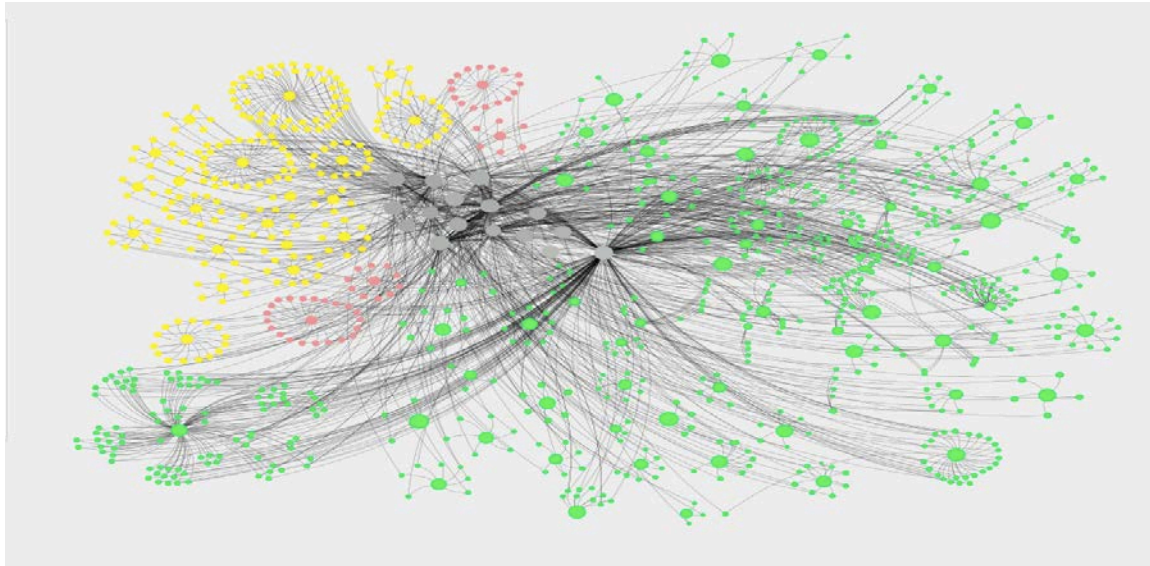


Fig 3. Comparative interactive map representing all conferences and journals gathered for the fields of brain science, education, and MOOCs

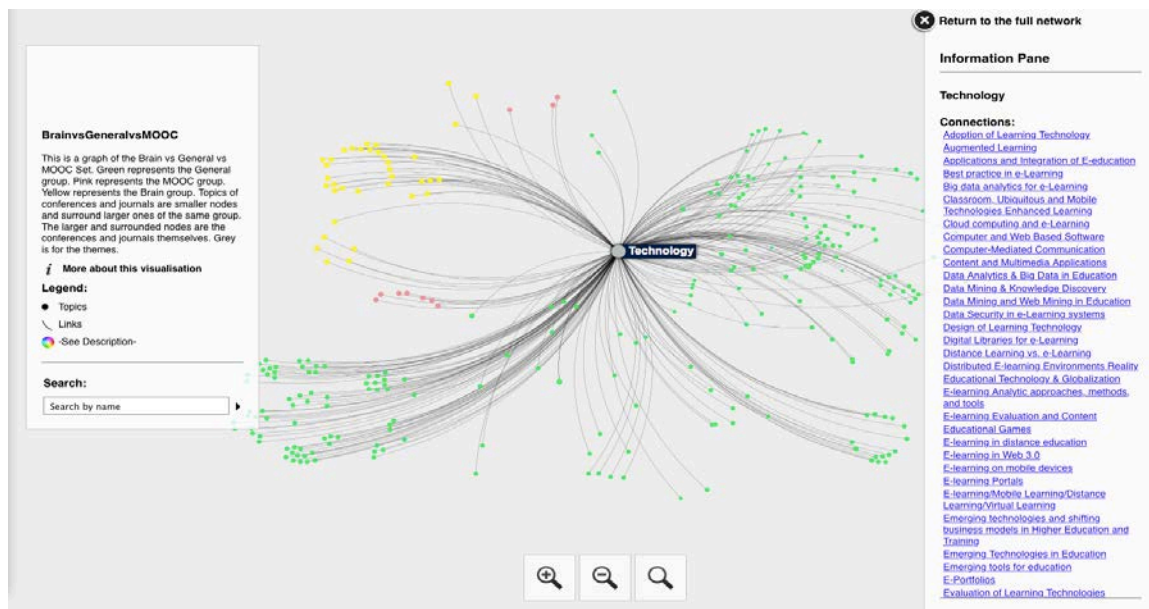


Fig 4. Interactive comparative graph highlighting all conferences and journals within the 3 fields that include the research theme of technology

3.2 The Common Ground

In this first pilot study a total of 217 different research topics were identified in the field of brain science, a total of 652 topics were identified in the field of education, and 53 were specifically identified as research topics in MOOCs.

Examining research that appears to be more prominent within the STEM education community, as shown in Fig 5., *Technology*, and *Teacher Training* appear to be the most popular themes followed by *Curriculum* and *Assessment of Learning*.

However, while taking a more holistic comparative view across the Brain Science, Education and MOOCs fields, as shown in Fig 6., research themes of common interest appear to be slightly different. Considering that the scope of this project is to identify and highlight possible research themes that can serve as a starting ground for collaboration across the different fields that study learning, the topics of *Technology*, *Assessment of Learning*, *Policy*, *Sociocultural Issues*, *Student Psychology*, *Teacher Training* and *Collaborative Learning* appear to be of interest to all fields. Taking a closer look at the overlap, *Technology*, *Teacher Training* and *Assessment of Learning* appears to be the common ground between the Brain Science, the STEM Education and the MOOCs communities.

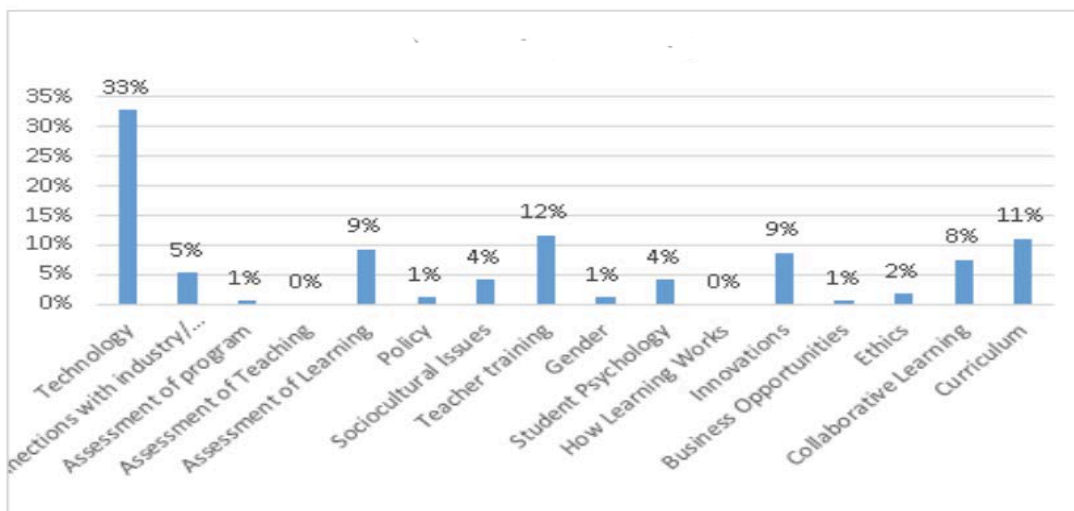


Fig 5. Popular research themes within the STEM Education Community.

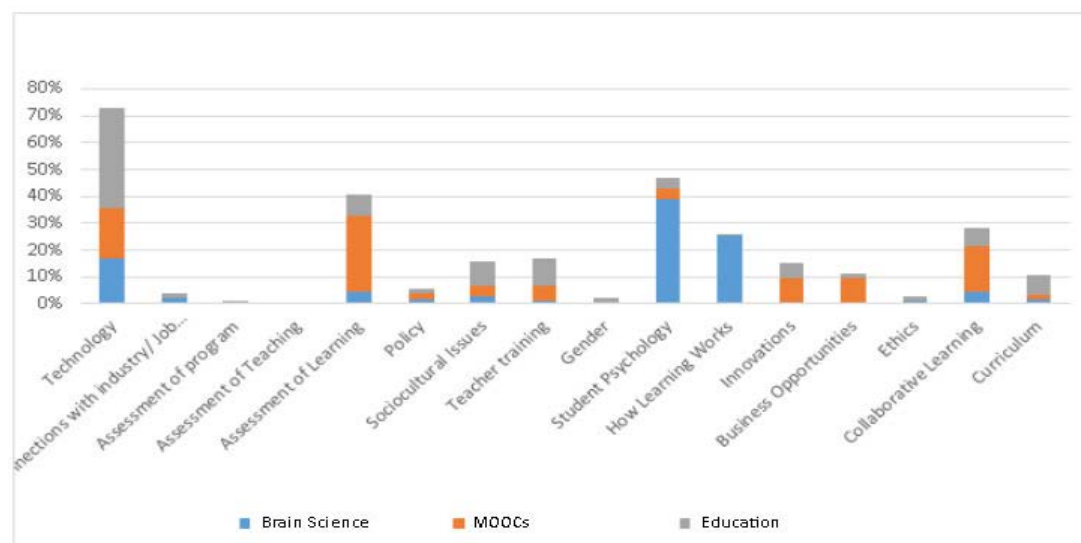


Fig 6. Research themes of common interest across the brain science, education, and MOOCs fields.

4 FUTURE WORK

As this is a pilot study with a limited set of data collected for each field, a study including a more comprehensive data collection is required. Furthermore future work of the research group includes development a digital platform that will automatize the process of data collection and analysis, as well as provide a richer set of visuals.

5 SUMMARY AND ACKNOWLEDGMENTS

The research team would like to thank A.J. Chabowski, J. Moksh, and S. Sahu for assisting this project, as well as the MIT Office of Open Learning for funding the LxS Project.

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Improving First-Year Engineering Students' Spatial Reasoning through Interactive Animation Training and Virtual Objects

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Conference Key Areas: Discipline-specific Teaching & Learning, Engineering Skills, Innovative Teaching and Learning Methods

Keywords: spatial reasoning, interactive animation, virtual objects, engineering education

INTRODUCTION

Spatial reasoning research has a long history in various fields including engineering, design, geology, chemistry, dentistry and medicine. Spatial reasoning refers to being able to mentally represent and manipulate visual-spatial information. Spatial reasoning involves several subskills – visualization, spatial relation, mental rotation, and mental cutting [1]. Mental cutting enables someone to imagine the interior of an object; mental rotation enables one to envision how an object appears in different positions (views); spatial relation enables one to understand how objects relate to each other in space.

Even though similar processes are involved in each of the subskills, researchers encourage looking at each of them separately [2].

Spatial reasoning ability has been linked to success in STEM disciplines, specifically in relation to mathematics conceptualization, design thinking, graphical representation and problem solving. There is a vast amount of research regarding individual and gender differences in spatial ability. For the last decade, spatial visualization training has been offered to freshman engineering students, as many incoming engineering students need development and enhancement of spatial reasoning. Difficulty recognizing cross sections of three-dimensional structures can place individuals with low spatial ability at a learning disadvantage in engineering, and particularly engineering design.

In the current study we designed an intervention with the aim to improve participants' mental cutting subskills as the ability to recognize and mentally manipulate the cross-sectional structure of materials and mechanisms is a fundamental skill in engineering [3]. In this experimental study, we investigated the efficacy of a brief training protocol which used interactive animation and virtual objects to train low spatial ability participants to recognize the two-dimensional shapes of primitive three-dimensional geometric solids. We also investigated transfer of learning from the trained geometric figures to novel stimuli. One goal of this study was to replicate the results of a previous experiment with a different population (engineering students vs. liberal arts students).

1 RELATED WORK

1.1 Spatial ability training

Several meta-analysis studies suggest that spatial reasoning can be develop and enhanced through training [4, 5]. Various contributors in engineering graphics research have used numerous approaches to develop spatial visualization skills [6]. Scholars claim that even short instruction can substitute for 3 years of untutored development in spatial visualization [7]. One of the major initiatives in spatial skills, led by Sorby and Wysocki, was the development and implementation of a structured training program, situated within the first-year engineering curricula, for undergraduate engineering students with identified low spatial skills [8]. Regardless of all the efforts done in this area, educators are still looking for best practices for developing spatial reasoning skills and for instructional methods and educational tools that lead to performance gain and transfer.

1.2 Physical and virtual objects

Studies have shown that manipulation of physical objects can improve performance gains and transfer in the context of spatial visualization training [9, 10]. The Enhancing Visualization Skills-Improving Options and Success (EnVISION) project was introduced in 2007 to test and enhance the spatial visualization skills of incoming engineering students. The EnVISION curriculum incorporates booklet exercise materials in a traditional classroom environment and its approach was initially used by seven U. S. universities, including our institution. The EnVISION course is targeted to students who have been identified as needing remedial instruction in spatial visualization. Materials developed for the project include a student workbook, software and teacher's resource guide, quizzes and lecture materials (power point slides). Snap blocks, physical cubes that can be snapped together, were used to create models of

the objects students are asked to sketch. Foam hexagonal prisms with longitudinal hole (pool noodles), cut along several different axes, were also used at our institution as a class aid to help students see how an object's features may appear elongated, shortened, or unaltered on the section created by the cutting plane.

In addition to physical objects, scholars have been using virtual models to effectively represent three-dimensional structures in spatial reasoning training [11]. The software developed for the EnVISION program incorporated virtual geometric objects that could be rotated and sliced, and was shown to be successful in training spatial visualization in a semester-long course.

1.3 Animation as a tool for spatial training

Animation, in which an object is presented in a series of static images each slightly changed from the previous, can be used to depict spatial transformation. The dynamic nature of animation correlates well with the dynamic cognitive processes found by cognitive scientists to occur in visuospatial working memory when one envisions a spatial transformation. However the speed of the animation can make it challenging to isolate individual images in ways that allow one to incorporate the result in their long term memory and thus learning. Providing opportunity for the learner to control the speed and direction of the animation through an interactive interface may help. The ability to pause an animation within an interactive interface also provides for the opportunity to have the learner perform a complementary learning activity, such as drawing.

2 METHODOLOGY

This work is collaborative, bridging cognitive psychology, engineering education and engineering design graphics. We are motivated by evidence of the malleability of spatial thinking and by a need to develop new methods to train spatial thinking skills. In this study, we utilized an intervention that we previously developed and tested with science students, to develop mental cutting (or cross-sectional) skills of first-year engineering students with low spatial skills. The stimuli in our experiment are derived from simple geometric solids (cone, cube, cylinder, prism and pyramid), which are among the most elementary recognizable three-dimensional forms. We hypothesized that effective training for this task would permit participants to recognize and visualize the shapes of two-dimensional cross sections of geometric solids.

2.1 Training protocol using virtual models and interactive animation

In this proof-of-concept study the intervention used interactive animation, integrated with drawing and feedback, to train first-year engineering students to identify the two-dimensional cross sections of three-dimensional objects. The participants in the study were first shown a simple geometric figure and a cutting plane to be used to slice the object and were asked to draw the resulting cross section. Next, participants checked the accuracy of their drawings by advancing an interactive cutting plane through a virtual three-dimensional solid that represented the object shown in the drawing trial. As the participant advanced the cutting plane, the correct cross-sectional shape of the drawing trial was revealed and the participant copied the correct shape adjacent to

their drawing. We hypothesized that visual feedback provided by observing the correct cross-sectional shape would improve performance. We predicted that participants who received the intervention would significantly outperform a control group on visualizing cross section for the test figures they viewed during training. We also hypothesized that this result would transfer to new figures they had not trained on.

Participants were assigned to an experimental (N=18) and a control (N=18) group. In the experimental group, participants spent approximately 10-15 minutes with minimal feedback from an experimenter interacting with the virtual objects. Participants in the control group spent the same amount of time playing Tetris.

All participants had completed a cross-section solid test – The Santa Barbara Solid Test (SBST) and some demographics questions before the manipulation. After completing the training or playing Tetris, students from both groups completed the same cross-section solid test and a new Crystallographic Forms Test (the Crystal) cross-section test.

Table 1. Training Condition

Experimental condition	Control condition
4 interactive animations Train two versions of object consecutively (e.g., ortho cone, followed by oblique cone) Object 1: orthogonal cone Object 2: oblique cone Object 3: orthogonal cube Object 4: oblique cube	Access to Tetris game (online game) This game aims to create order out of chaos and to provide intellectual sport with mental stimulation. The game requires players to strategically rotate, move, and drop a procession of Tetriminos that fall into the rectangular matrix at increasing speeds.
4 drawing trials (color images of Objects 1-4, printed on 8 x 11 paper)	
Sharp pencils with erasers	Sharp pencils with erasers
Drawing Packets	Tetris game competition score sheet

Participants: Participants were 36 undergraduate engineering students (M=14; F=22) who met a criterion for low spatial ability (rotation test score of 18 or less) and who were enrolled in an introduction to spatial visualization course at a large public university. Participants were assigned to an intervention group (7 males and 11 females) and a control group (7 males and 11 females). A Mann-Whitney U test showed no significant difference between the mean pre-test scores of the intervention (M = .35, SD = .12) and the control (M=.38, SD = .17) group.

Performance and transfer measures: The SBST [12] was used for both the pre- and post-training performance assessment. This test involves identifying the resulting cross-section when a solid object is cut with a cutting plane. The object in each test question is created from four fundamental objects (cone, cube, cylinder, prism and pyramid), where the object could be fundamental object itself; a compound object involving two of the fundamental shapes positioned relative to each other but

intersecting only at a surface; or an embedded object in which one of the objects is totally embedded within the other. In each test question the object is intersected by a cutting plane. For half of the questions the cutting plane is orthogonal to the object's primary axis (either horizontal or vertical); for the other half the cutting plane is oblique, positioned at a non-orthogonal angle to the primary axis of the object. Each question presents four possible resulting cross-sections from which to choose. As reported by the test developer, "Cronbach's Alpha computed across all items is .91 and for the major subscales of the test is: simple figures, $\alpha=.79$; joined figures, $\alpha=.80$; embedded figures, $\alpha=.73$; orthogonal figures, $\alpha=.84$; and oblique figures, $\alpha=.85$ " [12]. An example of the SBST is given in Figure 1.

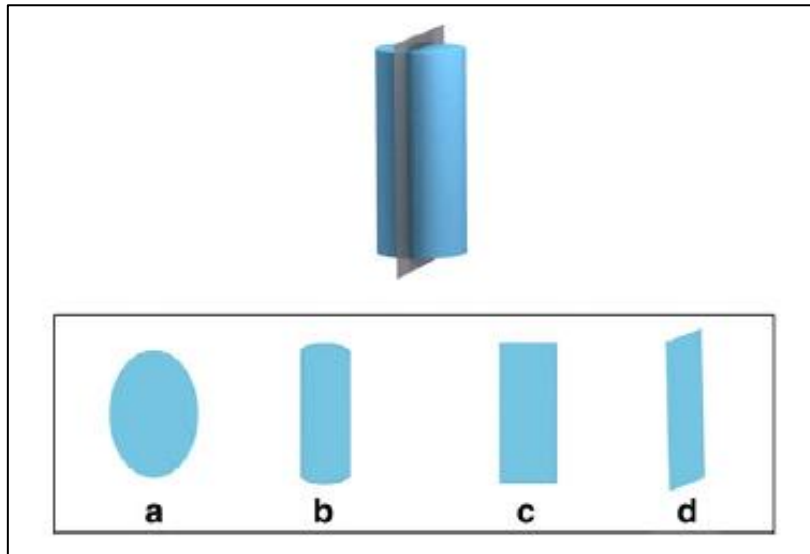


Fig. 1. An example of Santa Barbara Solid Test (SBST)

Following treatment and completion of the post-test, study participants also completed the Crystal Test [13], to measure the transferability of the learned cross-sectional skill to objects different from those used in the training. The objects in the Crystal Test are based on idealized crystalline shapes with a cutting plane. Like the SBST, the cutting plane may be orthogonal to the primary axes of the crystal structure or oblique to the primary axes. Figure 2 is an example of one of the 15 multiple choice questions. Each of the objects is symmetric front to back and shading is used to indicate depth. Three mutually perpendicular axes are shown for reference. The test has been used to assess spatial thinking skills that are required in mineralogy, structural geology and other geology courses.

Interactive training animation: Participants in the experimental group were asked to work through a series of four interactive animations. In the interactive animation an image of one of the fundamental shapes (cone, cube, cylinder, prism and pyramid) was displayed and a cutting plane is advanced through the object. As the cutting plane advances an image of the resulting instantaneous cross-section is displayed to the side of the object. The speed and direction of the advancement of the cutting plane is controlled by the participant using a computer mouse, allowing the participant to explore the development of the two-dimensional cross-section at a self-determined

pace. Participant were asked to sketch the expected cross-section and compare it to the actual cross-section as they advance the cutting plane.

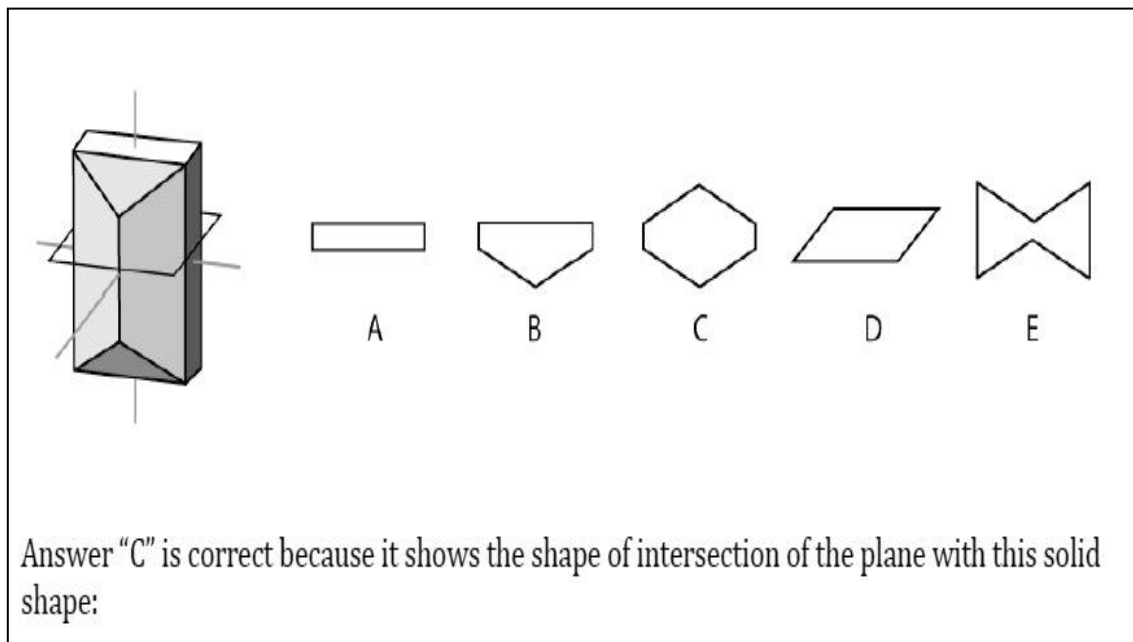


Fig. 2. A sample problem from the Crystallographic Forms Test

3 RESULTS

3.1 Performance on cross-section solid test trained, similar, and new figures

The 30 SBST test questions were classified into three categories (trained, similar, and new) for analysis of training and transfer. Four trained figures were orthogonal and oblique sections of the cone and the cube, identical to those used in the interactive animations. Similar figures were composed of two solids, at least one of which had been trained during the intervention. New figures were composed of two untrained solids.

Figure 3 shows pre-and post-test performance means and standard errors by object and condition. Given the unequal sample sizes by sex and a non-normal distribution of mean scores in the control condition, we used the non-parametric Mann-Whitney U test to assess group differences across the three categories of objects. At pre-test, there were no significant differences between the intervention and control groups for trained figures, similar figures or new figures (all p -values $>.30$). In contrast, participants who completed the animation training significantly outperformed the control at post-test on trained figures, $p<.004$, and on new figures, $p<.05$. There were no significant differences between the trained and control groups on similar figures.

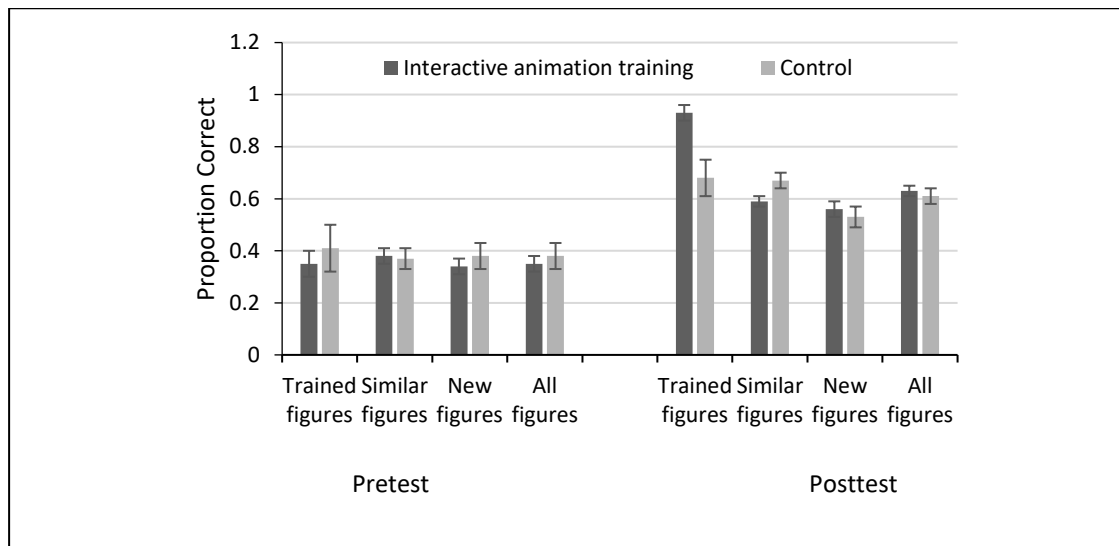


Fig. 3. Pre-and post-test performance means on SBST

There was a significant difference by sex in the pre-test scores of the experimental group. Males in this group had a mean score of .17, while females had a more reasonable score of .44. One plausible alternative explanation is that male participants did not put real effort into taking the pre-test.

3.2 Performance on transfer objects

Four of the 15 items on the Crystals test were selected to be used to measure transferability of the training to new objects. No significant difference in the scores on these four problems were observed for the two groups. One plausible explanation for the lack of significant difference can be that the objects in the four problems were considered very easy and too intuitive.

4 SUMMARY AND ACKNOWLEDGMENTS

While replicating previous studies, this experiment demonstrates the utility of using animation training and virtual objects in an introductory engineering class. In summary, our study findings reveal the following: First, there was a significant effect of the experimental condition on trained problems, with participants in the trained condition outperforming the control group. Second, we found a significant effect of the experimental condition on the new problems, with the trained condition again outperforming the control. Thirdly, there were significant differences between the two groups at pre-test, and no significant differences between groups at post-test.

While the small sample size is a recognized limitation, this proof-of-concept study demonstrates that the use of interactive animation training may add to the development and enhancement of spatial reasoning for students with recognized low spatial skills. Our next steps in this area of research include replicating the study results with a larger sample of the same population with equal numbers of male and female participants. We will consider offering an incentive appropriate for the experiment design to address the concern that some participants did not put serious effort into completing the pre-test. We will also use the results of the entire Crystals Test for measuring the ability to transfer learning from the training to new experiences.

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The Academic Perspective:

A study of academic's perceptions of the importance of professional skills in engineering programmes in Ireland

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Conference Key Areas: Engineering Skills, Educational and Organisational Development,

Keywords: Professional Skills, Phenomenography, Gender influences in Academia

INTRODUCTION

It has been argued that Industry 4.0 will revolutionalise the way we live, work and communicate with each other and engineers must develop appropriate professional skills to meet the challenges associated with an ever-increasing, energy-consuming population [1,2]. Much has been written in the last ten years about the need for reform in engineering education and in particular the need to prepare graduates to work on a global scale in diverse teams [3,4,5,6]. Engineering education research has responded by informing innovative teaching pedagogies but there is limited research investigating the human influence on engineering education; the academic's perspective. This paper presents the results of an online survey of engineering academics in Ireland (n=273). The survey represents Phase 1 of a phenomenographic study to explore academic conceptions of the importance of professional skills in engineering programmes. Whilst the principal aim of the survey was to identify participants for Phase 2 interviews, we also sought to answer the following research question;

- What factors influence an academic's consideration of the relative importance of specific professional skills?

The outcomes highlight aspects of an academic's life experience which may have an influence on their views on the importance of professional skills. In order to reform engineering education, we must not only look at new policies and procedures, nor only consider innovative teaching pedagogies, we must also consider how we can encourage academics of all backgrounds to engage in educational reform. To do that we must better understand the beliefs, perceptions and conceptions of academics

working with students every day. The results of this survey provide an initial insight into the perceptions held by academic staff, which will be explored further in the main phenomenographic study.

1. BACKGROUND

Engineering has always been central to society's progress. In the past, the work of engineers significantly improved the quality of life of large populations through advances in technology and new innovations by improving healthcare, housing, nutrition, education, transport and communication. Today, engineers need skills and competencies to work in multi-disciplinary teams, transcending international boundaries and dealing with globally complex issues in unfamiliar surroundings. Policymakers, economists, politicians and social scientists will also be key members of any team which aims to provoke societal change. Engineering graduates need to be prepared to engage with a diverse range of people and disciplines outside of the technical domain of engineering itself.

1.1 Skills Requirements

There have been several calls for reform in engineering education, in order that graduates are equipped with the relevant skills to meet future societal challenges [3,4,5,6]. Engineering education researchers have informed innovative pedagogical practices which will help develop those skills in students.

The outcomes provide a rich catalogue for engineering educators, of initiatives which can be implemented in engineering programmes to meet this aim. There is no doubt that the use of project driven, group-based pedagogies, community-based projects, work placement and other student-centred approaches have a place in developing relevant professional skills. There is also an increasing recognition of the importance of emulating engineering practice in the classroom [5,7,8] which may suggest there is value in employing engineering academics who have engineering practice experience, sometimes called 'Pracademics'.

1.2 Career Academics versus Practical Experience

The academics involved in such innovative pedagogies do not need to be convinced about the benefits to the students of these teaching and learning methods, nor the importance of developing professional skills in students. However, not all engineering academics have the same interest in engineering education. Some may be less inclined to implement innovative pedagogies in the classroom or even move away from traditional didactic teaching where learning is predominantly seen as the accumulation of knowledge and technical skills. Other academics may consider that the development of professional skills is at the expense of technical knowledge, when in fact they can be developed in synergy.

Many engineering academics value research over teaching, which is encouraged by the research orientated promotional policies of many Institutions [5,9,10]. Pilcher et al., [11] argues that academics who have significant practice experience can be better placed to advise on the professional skills that engineers need in the workplace, and are in a position to teach using real-life examples. However, recruitment policies which require a PhD as a minimum qualification can create a barrier to those industry practitioners considering a mid-career change [11]. Pilcher et al., [11] also attest that it is questionable whether someone with industry experience would attain employment ahead of what is termed the 'career academic' in UK universities, as a result of the emphasis on research output metrics associated with the Research Excellence

Framework. The Royal Academy of Engineering (RAE) foresee perhaps the inevitable decline in industry experienced academic staff “HE appointments are often driven by a need to improve the research profile of an institution and many academics are recruited on their research track record. The result is that fewer lecturers in UK universities will have significant industrial experience.” [9,10, p.21]. Glenn Miller, Dean of Olin College, attests that many engineering academics are not trained to teach professional skills since they were hired for technical expertise and not their professional skills [6]. He proposes that teaching professional skills is more complex and nuanced than teaching technical skills which can easily be defined and measured. Whilst there are calls for the employment of more academic staff with industry experience [11], there is little published research on the variation of conceptions of ‘career academics’ and ‘industry experienced academics’.

The reform of engineering education can only be successful when academic staff come to understand the value of integrating professional skills within the curriculum. This survey comprises the first step to ascertain conceptions of what professional skills are and the value placed upon them by engineering academics.

2. SURVEY DESIGN

An online survey was circulated to all academics teaching on engineering programmes in Ireland. A response rate of 34% was achieved and n=273 (29%) respondents answered all questions. Whilst the main purpose of the survey was to identify interview participants and therefore a representative sample was not required, we were unable to determine if there was a biased response as overall population data of engineering academics in Ireland was unavailable. The survey collected information on the following topics; gender, age, HEI employer, engineering, other and teaching qualifications, membership of professional bodies, extent of academic experience, role and number of teaching hours, extent of industry experience, role, involvement with graduate recruitment or initial training of graduates.

Respondents were asked to score the importance of a list of professional skills for today’s engineering graduates. The list of skills was created from a systematic literature review of recent engineering educational publications and research papers and comprised 17 ‘non technical’ skills with just one ‘technical’ skill option. The purpose of the survey was to attempt to show some correlations and relationships between different aspects of the response data

3. RESULTS AND DISCUSSION

3.1 Demographics

The majority of respondents were male 72% (n= 197) and only 8% of respondents indicated an age below 35 years old. Approximately half (49%) of all respondents had achieved a PhD/EdD qualification. There was a wide range of primary qualification types selected by respondents with 87% (n=268) having an engineering qualification of some type. Respondents who answered ‘Other’ (n=39) indicated primary qualifications in the following broad categories; Science and Mathematics, Architecture and Construction, Business / MBA or Economics and Arts and Sociology. Sixty-nine respondents (23%) highlighted that they had undertaken an educational qualification, such as a CPD course, Post Graduate Certificate, Diploma or Masters in Education.

Eighty-two percent of respondents held roles in industry, with 34 academic staff still working or consulting in industry as shown in *Fig. 1*. The authors acknowledge

however that there may currently be academics working in joint research projects with industry in a consultancy role and whilst this may have prompted a 'yes' to this question, it is not the equivalent to spending several years in full-time practice. Thus, the responses from this category of academic must be considered carefully.

Those who had industry experience were asked to select the most senior role undertaken as indicated in *Fig. 2*. Intuitively, the number of respondents who undertook project management, people management and senior management roles increased with length of time spent in industry. However, even 46% of those with less than 5 years' industry experience had opportunities for people and project management roles suggesting that they would have had direct exposure to new graduates and hence an understanding of their attributes and potential weaknesses.

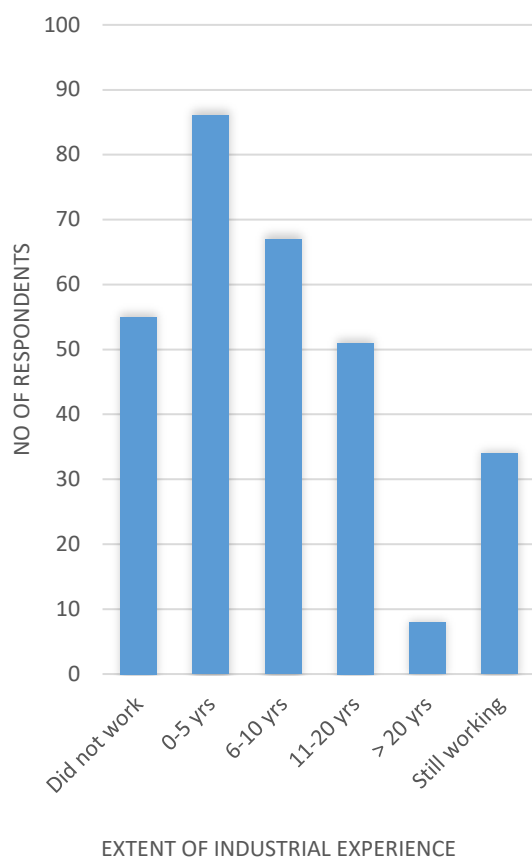


Fig. 1. No of respondents indicating length of industrial experience

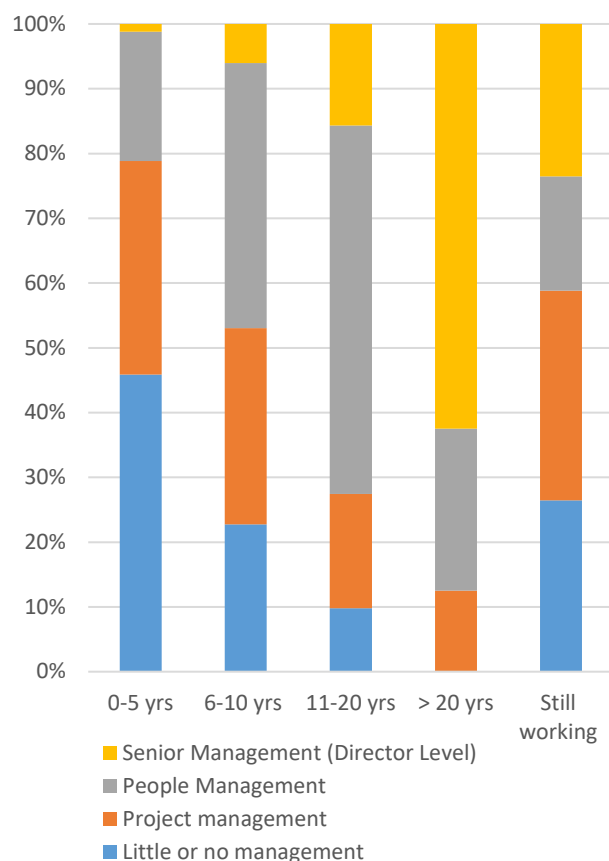


Fig. 2. Percentage of respondents in each category indicating most senior role in industry

3.2 Importance of specific skills

Participants were asked to comment on the importance of a list of skills for the engineering graduates of today. A sliding scale question was used with 'Not important' (scored as 0) to 'Essential' (scored as 4). The authors acknowledge that a ranked question may have yielded a more robust response and the question was originally trialled in that fashion. Feedback from the pilot surveys indicated that a ranked question with 17 options did not flow well within the overall survey and respondents were more likely to drop out of the survey at that point. Hence respondents were asked to score each skill individually.

It is accepted that technical skills are a critical aspect of an engineer's formation, however, this question sought to investigate if respondents would choose 'excellent

technical skills' as more important than the other professional skills. Hence, the question was phrased "*Assuming all engineering graduates have baseline technical skills, please indicate on a scale of 0-4, how important you think the following skills are for new engineering graduates of today?*". A summary of the skills in rank order of importance calculated by mean score and the number of respondents which scored '0 -Not important' for specific skills are shown in *Table 1*.

Table 1. Average scoring of skills and number of respondents who indicated 'Not Important'

Professional Skill	Mean score (<i>M</i>) out of 4	No of resps who scored '0' - not important
Problem Solving (visualise and present practical solutions)	3.7 (<i>SD</i> = .48)	0
Communication (written, oral, listening skills)	3.6 (<i>SD</i> = .64)	0
Critical Thinking (evaluate all aspects of problems and solutions)	3.6 (<i>SD</i> = .65)	0
Practical Focus (apply theory to real life problems)	3.5 (<i>SD</i> = .60)	0
Self Direction (initiative, independent work, continuous learning)	3.5 (<i>SD</i> = .66)	0
Teamwork & Collaboration Skills (working with diverse people)	3.5 (<i>SD</i> = .71)	0
Character and Interpersonal Skills (integrity, social skills, ethic)	3.3 (<i>SD</i> = .78)	2
Excellence in Technical Skills (excellent technical capability)	3.2 (<i>SD</i> = .74)	0
Project Management (time management, planning skills)	3.1 (<i>SD</i> = .73)	0
Health & Safety (within a specific industry)	3.0 (<i>SD</i> = .95)	0
Research Skills (conduct research on a project or product)	2.9 (<i>SD</i> = .89)	3
Risk Management (identify and reduce risk)	2.7 (<i>SD</i> = .89)	2
Leadership (responsibility, leading and directing teams)	2.6 (<i>SD</i> = .86)	4
Global Outlook (international and intercultural skills)	2.5 (<i>SD</i> = .92)	4
Business Acumen (financial and budgeting /cost awareness)	2.3 (<i>SD</i> = .90)	8
General Knowledge (current affairs, politics)	2.0 (<i>SD</i> = .91)	12
Foreign Language Skills (communicate in a second language)	1.5 (<i>SD</i> = .96)	46

There is minimal difference in the scoring of the first six skills; Problem Solving, Communication, Critical Thinking, Practical Focus, Self Direction and Teamwork and Collaboration Skills, which are typical of those highlighted most often in the literature review exercise.

There is clearly a low score attributed to the importance of foreign language skills, which reflects the fact that English is the main form of communication in Ireland. The survey did not collect information relating to the language skills of the respondents, which would have provided further insight into the level of internationality in academic staff on engineering programmes in Ireland.

3.3 Gender differences

Initially, the results were sorted by gender and although this was not an initial research theme, it highlighted a surprising result. *Table 2* shows the average scores for females, males and those who chose 'Other or Prefer not to say'.

Table 2. Average scores of respondents on the importance of specific skills

	Female Mean Score (n=60)	Male Mean Score (n=197)	Other/Prefer not to say Mean Score (n=16)	Difference between Female - Male mean score
Problem Solving	3.78	3.71	3.81	0.08
Communication	3.71	3.59	3.44	0.12
Critical Thinking	3.78	3.53	3.56	0.26
Practical Focus	3.69	3.50	3.44	0.19
Self-Direction	3.62	3.44	3.50	0.17
Teamwork & Collaboration Skills	3.71	3.41	3.25	0.30*
Character and Interpersonal Skills	3.60	3.27	2.93	0.33*
Excellence in Technical Skills	3.17	3.23	3.00	-0.07*
Project Management	3.22	3.07	3.06	0.14
Health & Safety	3.20	2.94	3.31	0.26
Research Skills	3.12	2.82	2.94	0.31
Risk Management	2.97	2.66	2.75	0.31
Leadership	2.82	2.56	2.38	0.26
Global Outlook	2.80	2.46	2.50	0.34
Business Acumen	2.42	2.31	2.06	0.10
General Knowledge	2.15	2.01	1.88	0.15
Foreign Language Skills	1.58	1.43	1.38	0.16

*Indicates cases in which a statistically significant correlation was observed with regard to gender.

Within this survey, in all but one professional skill, women were more likely to score the importance of professional skills more highly than men, i.e., they appeared to place more importance on each skill than men did. Only 'Excellence in technical skills' was scored as less important by women than men. Since excellence in technical skills could be considered the only technical skill presented within the survey, and all others are non-technical, this suggests that within this population, female academics place more importance on non-technical skills in engineering graduates than male academics.

Although this initial result suggested a gendered difference, a statistical test carried out on SPSS sought to clarify which factor was the highest determinant of scoring of each professional skill; Age, Gender and Length of Industrial Experience. There were no correlations observed with regard to length of industry experience. A significant correlation was observed between Age and the importance of Teamwork and Collaboration Skills, Pearson's $r(238) = .127$, $p = .05$. The results also indicated that whilst there was no significant correlation observed between the overall average score and gender, significant correlations were identified between; Gender and the importance of Character and Interpersonal Skills, Pearson's $r(235) = .144$, $p = .03$, Teamwork and Collaboration, $r(238) = .128$, $p = .05$ and Excellence in Technical Skills, $r(237) = .145$, $p = .03$. As this finding was based on only one question within the survey, it is difficult to draw a solid conclusion however, it suggests that there is value in a further study to investigate differences in gender profiles of academic staff and their attitudes or approaches to teaching non-technical skills.

3.4 Influence of Industry Experience in relation to the importance of skills

Table 3 shows the percentage of respondents who selected 'Essential' for specific skills in relation to their industry experience. Fig. 3 also shows the average score for

specific skills in relation to industry experience. Industry experience has been refined to show comparisons between those with none or up to 5 years experience, and those with more than 6 years experience, but excluding those still working in industry, which has been discounted due to potential ambiguity in the question.

Table 3. Percentage of respondents selecting 'Essential' for specific skills

Industry Experience	Practical Focus	Leadership	Problem Solving
Greater than 6 years experience (n=110)	68.2%	19.1%	57.3%
Less than 6 years experience (n=135)	52.6%	13.3%	42.2%

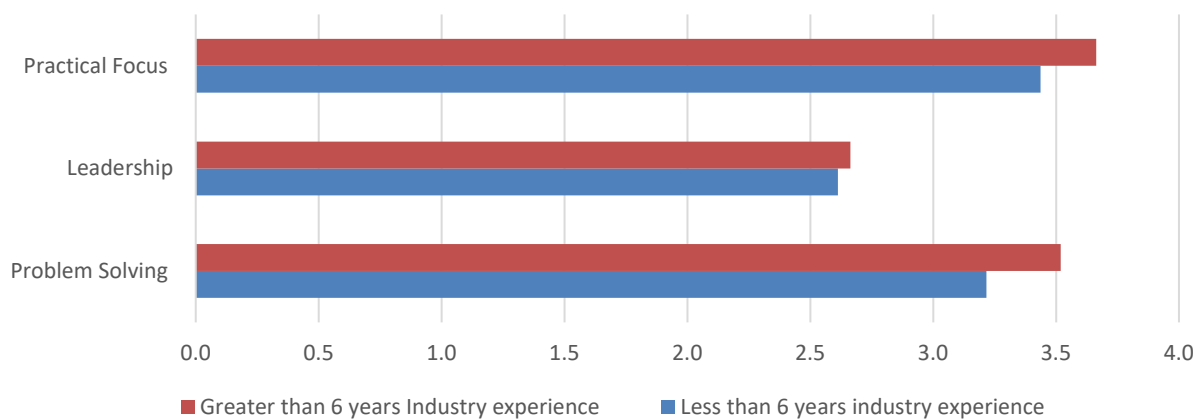


Fig. 3. Mean score of respondents with differing industry experience on specific skills where 0 = 'Not important' and 4= 'Essential'

3.5 Skills and Industry Experience

The results suggest that the importance placed on practical focus, leadership skills and problem solving may be linked to time spent in industry and this is an issue we intend to address further within the main phenomenographic interview sessions. Problem Solving is clearly an essential requirement for engineers and achieved the highest score in the overall survey. It is also highlighted here as showing the largest difference in score between those with little or no industry experience and those with more than 5 years experience.

4. CONCLUSIONS AND FURTHER WORK

The aim of this survey was to consider influences on an academic's opinion on the importance of specific professional skills in engineering graduates of today. The study showed that gender appears to have an influence not only on the importance of all professional skills, but particularly in relation to the importance of pure technical skills over non-technical skills. There is evidence to suggest that an academic's experience in industry also influences their judgements on the importance of professional skills and highlights the value of employing a diverse range of academic staff, including both career academics and those with industry experience, a proposal also put forward by Pilcher et al., [11].

The survey was administered to gather a range of views from academic staff in Ireland and to identify varied participants for a phenomenographic study. This work is ongoing. However, the results of the survey highlighted some interesting findings which will be investigated further in interviews. The authors would also welcome a comparative analysis of the same study of academics in another country.

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**The course structure dilemma.
Striving for engineering students' motivation and deep learning
in an ethics and history course**

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Conference Key Areas (3): Ethics in EE, Discipline-specific Teaching & Learning, Philosophy and Purpose of Engineering Education

Keywords(4): Deep Learning, Self Determination, Structure, Learning Environment.

INTRODUCTION

Engineers exert a decisive impact on the societal consequences of innovations when designing and implementing technologies. Engineering education prepares students for their future role by also offering them non-technical courses such as history or philosophy. Students – especially Bachelor's students – seem to consider these courses less important compared to the technical courses of their major and thus, engage with them as little as possible. This increases the risk of these courses not achieving their primary objective. It is therefore

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important to explore motivation and deep learning in ethics and history courses and how to improve these in engineering education.

1 CONTEXT OF THE STUDY

A medium-sized Dutch university offers its students four courses of five ECTS (European Credit Transfer and Accumulation System) each on the topic 'User, Society and Enterprise' ('USE') to address their future role as social responsible engineers. In the USE-sequence, Bachelor's students learn about the user, society, and enterprise aspects of technology and innovation. In the fourth academic quarter of their first year, all 2000+ students take the compulsory USE basic course providing an introduction to USE with ethics and history of technology. In their second or third year, students choose one USE course sequence from a list of sixteen, such as *Decisions Under Risk and Uncertainty* [1], *Patents and Design Rights and Standards* [2], or *Technological Entrepreneurship*.

The USE basic course is a complex course and has gone through continuous course redesign efforts during the five years of its existence. In 2015-2016, it was taught to 1864 engineering students of a diverse set of thirteen major programs, including Applied Mathematics, Electrical Engineering, Medical Sciences, Industrial Engineering and Sustainable Innovation. Lectures were provided in eight parallel streams in English or Dutch, each of which could accommodate about 250 students. For their assignment, students were given a choice of eight cases (e.g. *Sustainable Energy Technologies*, *Health Robotics* or *Self Driving Cars*). They worked in interdisciplinary groups of four students (from four different departments) on a case in which they used the ethics and history theories to improve an existing technology. Students worked on their assignment using a wiki platform, where they could see each other's ongoing work and gave feedback through this platform. Because of the organisational challenge of grading the large number of students efficiently within a very short time frame, the final exam was a multiple-choice examination. Students could prepare for the final multiple-choice exam with six multiple-choice on-line interim tests. The final grade was determined as follows: final multiple-choice exam counted 50%, assignment 40%, and interim tests 10%.

Analysis of the 2015-2016 version revealed that students showed low enjoyment of the course, reflected to a low overall evaluation score, in addition to self-reported low motivation for the course. An average workload had been strived for and been achieved, but the study time increased because students felt they had to write vast amounts of text (about one page per student per week). Analyses further showed that (1) students' perception of low competence was crucial for the assignment, (2) the course set-up should be simplified, (3) the course materials were crucial to students, (4) students from different majors and with different basic needs reacted very differently to the course set-up, so students' differences were important to take into account, and (5) learning approaches should be considered next to study time only.

This article shows how these conclusions were addressed in the redesign of the 2016-2017 version using theories for deep learning and motivation, its results, and what can be concluded from this redesign.

2 THEORETICAL BACKGROUNDS

2.1 Learning approaches

In order to improve students' learning, we focused in the 2016-2017 redesign on students' learning approaches, which describe their intentions when facing a task and the accompanying learning activities. Marton and Saljo [3] distinguish two approaches in students'

learning: a deep and a surface approach. Students with a deep approach to learning are intrinsically interested and try to understand what they study. A deep approach describes students who intend to understand the meaning of the text or task, who try to relate new information to prior knowledge, to structure ideas into comprehensible wholes, and to critically evaluate knowledge and conclusions they encounter. A surface approach describes students who use rote learning, memorizing and repeating the learning content and analysing learning tasks (dividing the learning content into smaller parts and performance of tasks in a more or less prescribed order) with primary objective to pass the test. Apart from the deep and surface approaches in learning, other researchers have identified strategic approaches to learning [4]. A strategic approach to learning describes students' motivation to achieve high grades with the use of organized study methods and efficient time management.

It is important to note that students' approaches to learning are not characteristics of the learner but of their relationship with the learning environment, including aspects like course content, activities and interaction with teachers. This means that a student can adapt their approaches to learning depending on the demands and opportunities of the learning environment. Teachers can change the way students approach learning by changing the way in which they teach their courses. The following factors encourage students' deep learning [5]:

- Relevance of the course: Perceived interest in and being challenged by the subject content.
- Relevance of the course to students' professional practice.
- Workload which is not perceived as excessive by students.
- Teaching behaviors that are associated with deep learning: structuring the course, providing materials, illustrating lectures, answering students' questions, giving feedback.
- Perceived supportiveness of the context: giving support and encouragement for student learning, making the goals and standards clear throughout the course.
- Students' autonomy to make choice within the course (choosing topic of assignment).
- Student involvement in their own learning, using strategies such as group work or negotiation of topics.
- Usefulness of the course book.
- Perceived assessment as assessing higher levels of cognitive processing. Students tend to employ deep approaches or deep learning strategies when they believe that this is the purpose of the assessment.
- Students' motivation; motivation influences the direction, intensity, persistence, and quality of the learning behaviors. Intrinsic motivation can encourage students to adopt a deep learning approach

2.2 Self-Determination Theory

Low students' intrinsic motivation was also suggested by the previous evaluation as a point of improvement and the literature suggests a clear and positive influence of motivation on deep learning (see e.g. [6]). In order to improve student motivation, we looked at the Self-Determination Theory (SDT). SDT divides motivation into several types [6] situated on an internalisation or self-determination continuum, ranging from amotivation, which is the state of lacking the intention to act, to intrinsic motivation which is the state of acting because of inherent interest, satisfaction and enjoyment. To give an example, amotivated students do not perform a given task and do not worry overly much about their learning outcomes. At the other

end of the continuum, according to SDT, an electronics student, who is intrinsically motivated just likes to build electronic devices and play around with them, because it is an inherently enjoyable task for him. Within this continuum we also find identified regulation, which reflects a conscious valuing of a goal, such that the action is considered as personally important and entails self-endorsement, self-knowledge and cognitive view of one's own functioning [7]. For example, a student in design might not be very interested in informatics in itself. However, if she identifies herself as becoming a good engineer, she acknowledges that informatics is nevertheless essential for her and she will therefore be driven to study informatics. SDT provided some insight on how to redesign a course in order to foster identified or intrinsic motivation to students by a) emphasizing the relevance of the course to students' interests, b) fostering students' sense of competence to succeed the course by providing clear guidance and c) fostering students' autonomy to make decisions and manage their learning.

3 INTERVENTION PROCEDURE

Based on the 2015-2016 analyses and the theories of learning approaches and motivation, the 2016-2017 redesign clearly divided the history and ethics part of the course. Each part consisted of separate lectures and three tutorials and had clear learning objectives throughout the course. There was a clear and one-to-one structure of lecture and assignment. The word count (of the reading materials and the assignment) was strongly reduced hoping students would not perceive this as excessive any more. In every part, the two first tutorials were devoted to guiding the students through the assignment and the last one was a feedback tutorial. The approach of the cases was retained. The redesign aimed to maintain student autonomy to make choices within the course and to preserve or increase the perceived relevance of the course to students' professional practice.

The two parts had different approaches, mostly in terms of the amount of guidance provided to students for the assignments in the first two tutorials and the type of feedback provided at the third tutorial. In the history part, an open approach was adopted aimed at higher levels of cognitive processing. *The open approach entailed less guidance through the assignment.* During tutorials, sources of policy documents and a description of how to scan these documents for relevant information was provided without providing detailed steps for the document analysis and the development of the assignment. The feedback was given orally during poster sessions, where students summarised their analysis until that moment. Poster session aimed to encourage discussion between different groups and between tutors and students for the more in-depth understanding of concepts. In general, in the history part students' were encouraged to be autonomous and self-directed in their learning. In the ethics part on the other hand, *structured approach was adopted, with emphasis in clarifying learning objectives and increasing students' perception of competence by guiding students and providing them with a structured methodology to do the assignment that was repeated in the lectures, in several elaborated examples in the book, in the study guide and in the tutorials.* A clear and very detailed rubric with 2200 words for six different steps was provided. Students gave written peer feedback online on the first draft of the assignment (using the rubric) and further discussed this orally in the last feedback session.

4 RESEARCH QUESTIONS

The research questions are as follows:

RQ1: Which approach (open or structured) gives the best results in terms of motivation, learning approaches, relevance and students' overall evaluation?

RQ2: Which course features contributed most significantly to students' learning approaches and what was the role of motivation?

5 METHODOLOGY

5.1 Questionnaire

Table 1. Variable names and items.

Name	Item
ClearGroup	It was clear what was expected in the individual part of the assignment.
Lectures	The lectures provided clear input for the assignment.
StudyGuide	The study guide was a help to know what I had to do in the assignment.
Activities	The activities in the tutorials helped me to make the assignment.
Sources	The sources provided were helpful to do the assignment.
Rubric	The rubric helped me to understand the assignment.
ClearDifficult	Even if the assignment was clear, I found it difficult to complete the assignment.
PeerFeedback	The tutorials provided me with peer feedback that I could use to improve my work.
GroupImprove	Working with my group members helped me to improve my parts of the assignment.

We administered an on-line student questionnaire right after the history and ethics part were finished. Each questionnaire contained nine items about the assignment (see Table 1) measured on a five-point Likert scale. The *overall evaluation* was measured on a 10-point Likert scale, *enjoyment* and *relevance* on a 5 point Likert scale. Deep learning was measured by a selection of Approaches and Study Skills Inventory for Students (ASSIST) [8]. Motivation was measured with a selection of items from the 'Self-regulation questionnaire – Academics' [9]. It measured three types of motivation (intrinsic, internalized regulation and amotivation) reduced to two Likert-type items per scale.

5.2 Participants and Data Analysis

The response rates were 15.3% and 15.4% for 300 and 303 respondents out of 1962 for the open and structured approach respectively. The learning approach factors have Cronbach's alphas from .54 to .64, motivation had a Cronbach's alpha of .87.

For answering the research question 1, the standard questions at item level between the two versions were compared with t-tests. For answering research question 2, we performed stepwise regression analyses for the deep, surface and strategic learning factors in both the open and the structured approach. All analyses were performed using SPSS.

6 RESULTS

6.1 Differences open and structured approach

Results showed that the open approach led to significantly more surface learning and significantly less strategic learning compared to the structured approach. However none of the approaches led to deep learning significantly above the average of 3 at the 5 point Likert scale.

Table 2. Paired Samples Statistics “Open approach” and “Structured approach” (per component). Mean difference ΔM , (significance of difference) and Cohen’s d . Overall score on a 1-10 Likert scale, all others on a 1-5 Likert scale. Items indicated with “i”.

	N	Open approach		Structured approach		$\Delta M(\text{sign})$	d
		M	SD	M	SD		
Overall evaluation ⁱ	160	4.94	1.87	6.39	1.49	-1.45***	-0.86
Relevance ⁱ	160	2.50	1.09	2.85	1.02	-0.35***	-0.36
Enjoyment ⁱ	160	2.24	1.04	2.91	0.97	-0.67***	-0.66
Autonomous Mot	160	1.98	0.81	2.26	0.83	-0.28***	-0.41
Amotivation	160	2.87	1.17	2.54	1.16	0.33***	0.31
Deep Learning	158	2.95	0.69	3.03	0.75	-0.08	-
Strategic Learning	158	3.28	0.70	3.46	0.65	-0.18**	-0.26
Surface Learning	158	3.21	0.81	2.84	0.72	0.37***	0.47

The structured approach also realised higher overall student evaluation, relevance, autonomous motivation compared to the open approach. This answers RQ1 that a structured approach gives better results in terms of motivation, learning approaches, relevance and students’ overall evaluation.

6.2 Hierarchical Multiple Regression

For the open approach, the hierarchical multiple regression revealed that at stage one, *Lectures*, *Sources* and *Activities* contributed significantly to the regression model, $F(13,285) = 4.305$, $p < .001$) and accounted for 16.4% of the variation in deep learning. Introducing the motivation variables explained an additional 10.4% of variation in deep learning and this change in R^2 was significant, $F(14,284) = 7.440$, $p < .001$. When motivation was added in step 2 of the model, the predictors of step 1 were not significant anymore. For the structured approach, *Lectures*, *Sources* and *GroupImprove* contributed significantly to the regression model, $F(13,267) = 7.772$, $p < .001$ and accounted for 27.5% of the variation in deep learning. Introducing the motivation variables explained an additional 10.8% of variation in deep learning and this change in R^2 was significant, $F(14,266) = 11.793$, $p < .001$. When motivation was added in step 2 of the model, *Sources* was not significant anymore but *Lectures* and *GroupImprove* remained significant predictors.

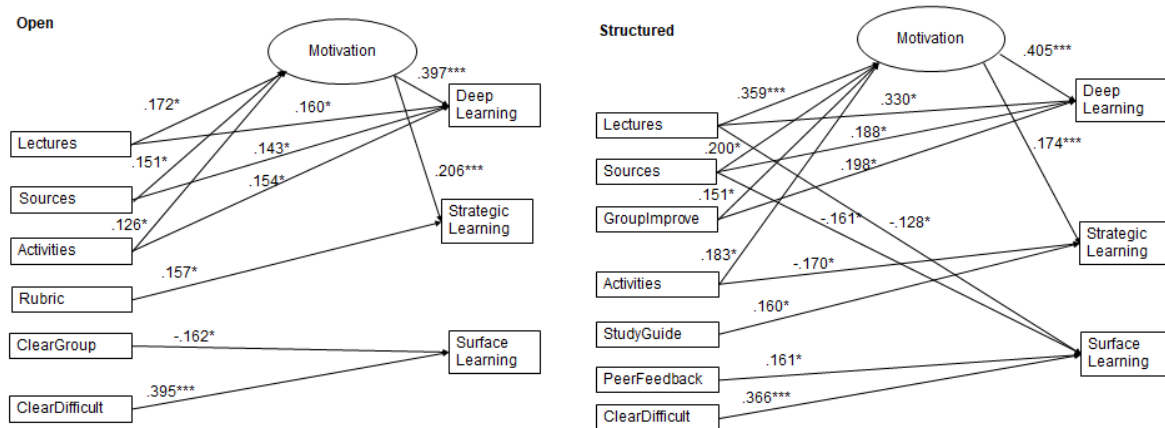


Fig. 1. Hierarchical Multiple Regression of deep-, strategic, and surface learning, with motivation as interim variable.

For strategic learning in the open approach, *Rubric* was the only significant predictor and contributed to the regression model $F(13,285) = 1.718$, $p < .05$ and accounted for 7.4% of the variation. Introducing the motivation variable explained an additional 2.8% of variation in strategic learning and this change in R^2 was significant, $F(14,284) = 2.274$, $p < .001$. In the structured approach, *StudyGuide* and *Activities* were significant predictors of strategic learning and contributed to the regression model $F(13,267) = 3.379$, $p < .001$ and accounted for 14.1% of the variation in strategic learning. Introducing the motivation variable explained an additional 2% of variation in strategic learning and this change in R^2 was significant, $F(14,266) = 3.565$, $p < .001$. The study guide and activities during tutorials remained significant predictors after the addition of motivation in step 2.

ClearGroup and *ClearDifficult* were predictors of surface learning, contributed to the regression model $F(13,285) = 6.875$, $p < .001$ and accounted for 23.9% of the variation in strategic learning for the open approach. Introducing the motivation variable did not contributed to the model as motivation was not predicting significantly surface learning. *ClearDifficult* and *PeerFeedback* were predictors of surface learning and contributed to the regression model $F(13,267) = 8.874$, $p < .001$ and accounted for 30.2% of the variation in surface learning for the structural approach. Introducing the motivation variable did not contributed to the model as motivation was not predicting significantly surface learning.

Deep, strategic, and surface learning play a similar role in predicting overall evaluation. Deep and Surface are most important predictors (see Table 4).

Table 3. Bêtas of stepwise regression analysis for the open and structured approach on deep, strategic, and surface learning

	Item	Open β	Structured β
Overall evaluation	Deep	.32***	.33***
	Strategic	.16**	.17**
	Surface	-.27***	-.24***
	R^2	.22	.26
	$F(3,296)$	28.99***	33.72***

7 DISCUSSION

7.1 The structure dilemma

Our analysis showed that the open approach led to higher surface learning. The strong predictive power of *ClearDifficult* in both approaches indicates that students missed guidance and had the feeling they failed to make sense of the assignment. Items addressing group support as *ClearGroup* and *PeerFeedback* added to this lack of control. Providing more options for control and competence will decrease students' surface learning. Surprisingly, *Motivation* is not a significant (negative) predictor for surface learning. SDT predicts either a negative influence of motivation or a positive of amotivation. One possible explanation could be that students' motivation level did not matter when they faced difficulties making sense of the assignment and decided to approach it in a superficial way.

In the structured approach students felt more they could make sense of the assignment. Not surprisingly, course aspects that helped to focus on achieving higher grades are important predictors such as *Rubric* or *StudyGuide*. *Motivation* plays a role here by *Lectures*, *Sources*, and *Activities*. It must be noted, however, that the overall predictive power for strategic learning is low and interpretations should be taken with caution.

Deep learning was not really addressed in either of the two approaches. Providing structure seems indispensable, but at the same time appears to trap students. Students are not familiar with history and ethics methodologies, they cling to the structure they are offered and cannot free themselves from this structure. A possible way to avoid the dilemma might be to connect to students' need for structure and their intrinsic motivation before they really start the assignment. The strong predictive power of motivation for deep learning suggests that it is very important [6]. The assignment and accompanying tutorials should start from students' life worlds with real life but not too complex cases. It may be beneficial to involve students' 'own' departmental staff to convince students about the relevance. *Lectures* that provide clear input for the assignment are a strong help for deep learning. Although it seems rather peculiar that lectures for 250 students could add to deep learning, students might expect both a motivational setting and good guidance for the translation of the theory to a relevant case. Next to lectures, *Sources* and *Activities* can add to deep learning.

Deep learning is an important predictor for students' overall course evaluation. This must be seen as a very positive result and a confirmation of SDT. Students want to be motivated for a course. Evaluating the overall course, their perception of deep learning plays a major role. Let this be an encouraging message for all teachers that sometimes feel disappointed in their search for more motivational history, ethics or other non-engineering courses in engineering education.

7.2 Further research

Our research has some weaknesses. Our learning approach and motivation factors consisted of a limited number of items and could be enlarged to achieve stronger factors. We did not report on student differences because of the limited scope of this article. Other research shows that these are very important and also here, many differences can be expected between different students. Further research could tackle these weaknesses.

Both the predicting independent variables and their beta's in the regression analysis show remarkable similarities for the open and structural case. Our research set-up provided us a

first confirmation of the replication of our analysis. However, it would be interesting to see whether this analysis shows different patterns in different contexts. It would also be interesting to see the proposed changes about lectures, cases and group work have an effect on motivation, deep learning and overall student evaluation.

8 ACKNOWLEDGMENTS

We thank all the students and teachers involved in the USE basic course for their useful comments and continuous willingness to improve the course. We thank the TU/e Education and Student Affairs for the data file support. We also thank Anthonie Meijers, Erik van der Vleuten, Eric van der Geer-Rutten-Rijswijk, Monika Roeling, Gerard van de Watering and two anonymous reviewers for their stimulating discussions and feedback.

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What children think about engineering: Children's perceptions of engineering following participation in an engineering education activity.

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Conference Key Areas: Attractiveness, Purpose of Engineering Education, Recruitment and Retention.

Keywords: Primary school, perceptions, qualitative methods, longitudinal study.

1 INTRODUCTION

Since the publication of the Roberts' Review in 2002 [1] there has been an increased focus on STEM (Science, Technology, Engineering, Mathematics) education in the UK, as summarised by Hoyle [2]. With the UK Government and Engineering Professional Bodies calling for increased STEM education focused at Secondary level and above [3], an industry around STEM education provision has emerged within the UK, leading to the ad-hoc provision of engineering education within compulsory education. The outcomes of this provision are now being questioned [2, 4]; evaluations of the current provision of engineering education are sparse [5] and have tended to

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focus on the 11+ age group, and inner city schools [6]. Recent literature has also suggested that children may be eliminating STEM careers during Primary school [7].

This paper presents part of a PhD study aimed at increasing our understanding of the outcomes of participation in an Engineering Education Activity (EEA) for Primary school children in rural schools. Thus helping to develop our understanding of the role that the current provision of engineering education plays at this age, an area that is relatively unexplored within the literature yet has significant consequences for the future of engineering [4].

2 METHODOLOGY

The current study posed the question:

How does participation in an Engineering Education Activity in Year 5 (age 9/10 in England) affect children's perceptions of engineering as a career at Year 7 (age 11/12 in England)?

In order to answer this question the study took a longitudinal, qualitative approach, utilising a case study methodology, drawing on grounded theory to inform the data collection and analysis process, as described by Broadbent [8].

Exploration of the children's perceptions of engineering and experience of participation in an EEA was obtained from the first person perspective, using exploratory observations and group interviews. Fieldwork was carried out with children from two schools over three school years, Year 5 to Year 7. This paper presents the findings relating to the perceptions of engineering held by the children following participation in an EEA at school.

The school ethics committee at Aston University granted ethical approval for this study and an ethical approach was maintained throughout the work, as discussed by Broadbent [8].

3 FIELDWORK

Data was collected between January 2016 and December 2017, from children at two rural Staffordshire schools (details of which are provided in *Table 1*), known in this work as Nant School and Phren School.

Table 1. Summary of information about the two research cases

	Nant School	Phren School
Type of school	Primary School Reception – Year 6 (age 4-11)	Middle School Year 5 – Year 8 (age 9-13)
Number of children enrolled (2016/17)	120	419
Number of participants	19 (12 males, 7 females) Predominantly White British with English as their first language.	29 (15 males, 14 females) Predominantly White British with English as their first language.

The EEA at Nant School formed part of the Design Technology curriculum taught at the school and was delivered by the class teacher. The activity took place in the Year 5 classroom over multiple lessons, two of which were observed as part of this research. The activity involved researching, designing, and building a simple moving toy.

The EEA at Phren School was an off-timetable, curriculum enrichment activity delivered by an external provider. The activity took place in the main hall of the school, the children participated in the activity in their tutor groups, and each session lasted between 45 minutes and 1 hour. The activity focused on the children building and testing a balloon powered car.

Exploratory observations were conducted in each case, observing the children participating in the EEA in order to inform the interviews and subsequent analysis of the data. Semi-structured, group interviews with the children were carried out three times during the research, once in Year 5 (0-1 months post EEA), once in Year 6 (6-12 months post EEA), and once in Year 7 (18-24 months post EEA). The findings from the interview data concerning the children's perceptions of engineering are presented in this paper.

4 FINDINGS

The interview data is presented in the dominant themes that emerged during the collection and initial stage of analysis. To illustrate the findings quotes are given; all are in italics and are accompanied by the gender, school year, and case of the child to whom the quote is attributed, given in parenthesis directly beneath the quote.

4.1 Perceptions of Engineering

The majority of the children interviewed in Year 5 held perceptions about engineering, with two dominant categories appearing in both cases. From Year 5 to Year 7, the children's perceptions of engineering were chiefly either product-focused (referring to specific artefacts the child associated with engineering) or process-focused (referring to specific practices the child associated with engineering).

It's like designing, it's not like, I don't think you do like the building it is just like designing, ideas and machinery.

(M, Year 5, Phren School)

Isn't it fixing things and is it a lot, don't you need to be really good at maths to do it?

(F, Year 7, Nant School)

Within the product-focused perceptions of engineering, transport was frequently cited as the artefact the children associated with engineering.

...for example you could engineer a car or a train or a plane.

(M, Year 5, Phren School)

Very few children appeared to hold perceptions divergent to these categories, however a small minority of children at each stage held perceptions of engineering in terms of the impact that engineering has on the world.

They help the world move on to like high tech stuff.

(M, Year 5, Nant School)

The majority of the children did not refer to the EEA without prompting when talking about engineering at any stage of the research, indicating that the perceptions they held about engineering formed prior to participation in the EEA. When this area was explored in the interviews the children spoke of a range of sources that informed them, with formal engineering education not appearing to factor in the formation of their perceptions about engineering.

4.2 Recall of activity

During each interview the children were asked to recall the EEA they had participated in, initially questions focused on the children's recall of the activity itself and then progressed to talking about the engineering involved in the activity.

Although many of the children had limited recollections of the activity in Year 6 and Year 7, the use of photographs taken during the EEA enabled the children to speak about their participation. Only a minority of the children referred to the activity as engineering without prompt questions introducing this area of discussion. When this did occur, the children largely stated that the activity was an engineering activity, or spoke about being told that the activity was engineering.

Yeah the toys one they said it was engineering...

(M, Year 6, Nant School)

It was a STEM activity.

(M, Year 7, Phren School)

When the interviewer used questions to explore these statements, many of the children were unable to expand on these assertions. However, once the topic was raised, children who had not identified the activity as engineering began to draw links between the EEA and engineering; some talked about the similarities and others the differences, with the responses focusing on the children's appraisal of the artefacts and processes involved in the EEA.

It's not like actually engineering, like a proper car or something like that.

(M, Year 5, Nant School)

Cos you were building it wasn't you, you were trying to find a way to build it.

(M, Year 7, Phren School)

A minority of children exhibited a different perspective and spoke about the engineering content of the activity in terms of whether they felt they had experienced

doing the work of an engineer when participating in the EEA, and the concept of *proper engineering* emerged within a number of the children's narratives.

It isn't like what you would do for engineering so you wouldn't actually know like what you would do for engineering, so that hasn't really helped because it isn't proper engineering.

(F, Year 6, Phren School)

Although the above quote indicates a lack of bearing on perceptions, a small minority of children during the Year 6 and Year 7 interviews spoke about areas where they felt participation in the EEA had influenced their perceptions. These changes focused on a number of different areas, the principal focus was a shift in the perceived difficulty of engineering, with children finding that the EEA was more challenging than they had thought it would be.

I thought "Oh it looks very easy" and you just put all the stuff together but it's actually really hard.

(F, Year 6, Nant School)

For a minority of the children, participation appeared to change perceptions around the processes involved in engineering. This occurred within both cases, however noticeably the change in perceptions for some children at Phren School, were limited to changes within their existing perception framework. This was observed where children expanded their ideas about engineering processes whilst the product they associated with engineering remained constant.

I didn't realise that they had to go through many stages to get it built, like planning and designing.

(F, Year 6, Nant School)

I used to think that engineering was just like they were people who just like went around and fixed cars, I didn't know that they actually made them, it made me think that they actually made them.

(M, Year 7, Phren School)

Whilst the majority of children identified no change in perceptions, or limited and minor alterations in their perceptions of engineering as described above, there were two notable exceptions. Firstly were the very small minority of children who identified the activity as their introduction to engineering and a nucleus of interest and knowledge acquisition; participation in the EEA appeared to provide some children with interest and the vocabulary they needed to find out more about engineering. For some however, this inspiration was seen to have dissipated by Year 7.

Since we learnt about this and this was called engineering we started watching more things on engineering because we thought it was cool...

(M, Year 6, Nant School)

In Year 5 it made me more interested [in engineering] and then through Year 6 I was still but I sort of am now, but not as much.

(M, Year 7, Phren School)

Secondly, a minority of the girls at Phren School spoke of their gendered-views of engineering ability being challenged by participation in the activity.

I think that I thought the boys were gonna be all really good at it but some, like the girls were good at it as well.

(F, Year 6, Phren School)

As the children did not explicitly gender engineering as a career, this finding suggests that for some children an implicit assumption about the engineering abilities of girls and boys may exist at a young age. Whilst these findings indicate that the EEA may inform perceptions for a small number of children in the year following participation, reflections by the children during the Year 7 interviews suggest that participation in the EEA during Year 5 did not inform the perceptions of engineering held by the majority of the children in either case in the long term.

Not really. It was kind of like, I've already done that kind of thing before.

(M, Year 7, Nant School)

I don't really think about it [engineering] and I've never really been like told what it is properly so I haven't really ever like thought about it because I don't really know what it is.

(F, Year 7, Phren School)

5 ANALYSIS AND DISCUSSION

The data from the Year 5 interviews illustrated that the children formed perceptions about engineering prior to engaging in formal engineering education. The data also highlighted the prominence of product-focused and process-focused perceptions held by children at this age, with an emphasis on transport and fixing. Although there is a limited volume of research in this area, these findings are found to be congruent with existing findings in the UK [9]. When examined in relation to the existing definitions of engineering provided by the profession (for example [10]) it can be seen that by focusing on a limited number of artefacts or processes, the children hold narrow views of engineering. This focus on specific roles within engineering, for example designing cars, results in the children holding inaccurate views of what engineering involves, as they miss the holistic definition of engineering as a creative, problem-solving profession that contributes to society [10].

The children's perceptions are seen to persist from Year 5 to Year 7, indicating that participation in an EEA in Year 5 does not result in children holding accurate perceptions of engineering, and that participation in an EEA in Year 5 does not significantly alter a child's existing perceptions of engineering. A notable exception to this was the concept of ability, where changes in perceived difficulty of engineering and gendered ability were visible for a minority of children; participation in the EEA

enabled some children to evaluate the challenging nature of engineering, and enabled some girls to see boys and girls as equally able. This indicates that attention needs to be paid to the structure of EEAs in order to capitalise on the potential that these activities have to inform children's perceptions regarding ability.

In order to understand the outcomes of participation in an EEA on the children's perceptions, analysis of how the children spoke about the engineering content they perceived the activity to contain was carried out. For the majority of the children, participation in the EEA did not appear to challenge their existing perceptions of engineering, resulting in the majority of children using their existing perceptions of engineering to inform their experience of the activity. This was observed as the children tended to use their perceived product or process lens to view the engineering involved in the EEA. This appeared to lead to the reinforcement of existing, narrow perceptions, for those children who could align the EEA to their perceptions of engineering, and the feeling that an experience of engineering had not been gained for those children whose perceptions differed from the content of EEA.

The outcome of this finding is significant, implying that for some children their existing perceptions went unaltered, with some dismissing the EEA as not engineering and therefore not using the experience to inform their perceptions regarding engineering. However, for some the inaccurate perceptions of engineering that were held prior to participation in the EEA may be reinforced by participation. This was seen in the case of Phren School more dominantly than Nant School, and concerned the focus of the EEA (building a balloon car). This finding indicates that the product of a 'design-and-build' EEA influences the outcomes of participation; although neither EEA appeared to challenge or improve the narrow perceptions held by the children, it is possible that having an EEA focused on an engineering artefact which children already associate with engineering, reinforces narrow perceptions.

It is argued that whilst EEAs during Primary school appear to have the potential to alter perceptions regarding gender and engineering ability, current provision appears to have little impact on the narrow perceptions of engineering as a field held by children; at best they appear to leave these perceptions unaltered, at worst they appear to reinforce them. The significance of the accuracy of the perceptions held by the children is illustrated when considering in context with the other findings of this research, which suggest that the children use their perceptions to create personal definitions of what "*proper engineering*" entails and that these are then used to evaluate subsequent interactions with engineering education.

The findings of this research suggest that in order to develop engineering education that equips future generations with accurate definitions of engineering, enabling them to make informed decisions regarding engineering careers, a deeper understanding of the formation of engineering perceptions is needed, as well as a critical evaluation of pedagogical approaches employed in EEAs. The aim of these enquiries should be to understand the role that other areas of society play in the formation of perceptions of engineering for young children, as well as ensuring that activities provide accurate portrayals of engineering that are internalised by the participating children.

6 CONCLUSION

In conclusion, this paper presents part of the findings from a PhD study exploring the outcomes of participation in an Engineering Education Activity for children during Primary school. The findings of this research indicate that although a minority of

children gain an increased awareness of engineering through participation in an EEA, participation in a one-off engineering education activity in Year 5 (age 9/10) does not significantly influence a child's perceptions of engineering over the following two years of education. This study finds that understanding the outcomes of participation in an EEA on the perceptions of engineering held by the children is complex; outcomes appear to be associated with a highly personal process involving comparisons between the activity itself and the child's own perception of engineering. The findings of this research indicate that the current provision of engineering education does not adequately understand, acknowledge, and challenge these existing perceptions. It is argued that without this forming part of an EEA, participation is unlikely to result in an accurate understanding of what engineering entails, with the worst case scenario being that participation reinforces narrow, stereotypical views of engineering. It is concluded that formal engineering education needs to progress from single 'design-and-make' challenges provided sporadically to children, and that without a change in this provision perceptions about engineering will not be challenged and improved to accurately reflect the engineering profession. This research provides an insight into a previously unexplored perspective of engineering education research, which challenges our present understanding of the efficacy of current models of engineering education provision in the UK.

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**Combining research and teaching in engineering.
Creating a pedagogical qualification programme on research-based learning
for early stage researchers**

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Conference Key Areas: Innovative Teaching and Learning Methods, Educational and Organisational Development, Others

Keywords: Research-Based Learning, Engineering, Pedagogical Qualification Programme, Evaluation

INTRODUCTION

It is of high importance for modern societies that universities of technology provide higher engineering education that enables students to solve new problems with solid expert knowledge, methodological skills and critical thinking. Thus, students should be enabled to develop extensive competencies at the university also by experiencing research and development on important questions. In doing so, research-based learning is supposed to be a promising educational practice of high impact [1]. It is connected with a long tradition, especially in Germany [2]. Integrating research into teaching follows disciplinary prerequisites [3]. Notably, academics play a key role in enabling a positive research experience for students. Across disciplines, Brew and Mantai [4] have already found that a lack of academic knowledge, skills and mindsets are barriers in implementing research-based learning, among other factors. This leads to a strong desire to implement a qualification programme for academics. In Germany, workshops on research-based learning are mostly offered with a one to a few days duration, tailored to interested, often experienced academics. In contrast, little attention is given to what could be achieved with a more complex qualification programme on research-based learning for early stage researchers in higher engineering education. This article highlights how participants respond to a one-year programme consisting of workshops, teaching projects and a final presentation. It is questioned how they react to the programme, how they reflect their learning, whether they intend to integrate research-based learning in their teaching and why they do so.

1 MATERIAL AND METHODS

1.1 Initiating staff development on research-based learning

There are several ways to develop students' research skills [4]. Enriching teaching and learning in single courses by integrating research seems to be promising, but nevertheless pedagogically challenging. This is even more the case if early stage researchers having mostly little experience in research and teaching, strive to competently integrate research into their courses, which also have to complement their professors' lectures. To overcome these difficulties, the executive committee of a University of Technology in Germany assigned its centre for teaching and learning (CLL) in 2015 to create a compulsory in-house qualification programme on research-based learning for early stage researchers. The ongoing overall aim of this pedagogical qualification programme is to:

- introduce participants to research-based learning, and
- facilitate integration of research results, methods or processes in their courses.

1.2 Providing a complex qualification programme on research-based learning

The qualification programme on research-based learning aims to qualify participants to teach according to modern pedagogical principles, to design research-based learning scenarios and to inspire communication within a network of early stage researchers across departments. In the training, *research-based learning* is used for

course inventory and development in a wider sense as a pedagogical framework according to Rueß, Gess, and Deicke [5] which is based on the model by Healey [3]. However, in a narrow sense *research-based learning* is also used to mark a possible course development perspective i.e. as a teaching format enabling students to experience the whole research cycle, ranging from formulating their own research questions to producing interesting findings for others according to Huber [2]. Benefits from a double connection of integrating research into teaching as well as researching on teaching were expected. Thus, in the first cohort of the programme, research-based learning was combined with *classroom action research*, according to Mettetal [6], which can be seen as a pragmatic approach of *scholarship of teaching and learning* (e.g. Wankat et al. [7] for engineering). However, this approach was changed in the following cohorts, resulting in a different focus (basic pedagogics instead of classroom action research), products (writing abstracts instead of reports) and effort (60 hours instead of 110 hours compulsory). Currently, the one-year programme starts twice a year and consists of a series of workshops, a teaching project and a final presentation. Supervision is realised throughout the year by experts on research-based learning. Participants concentrate on research-based learning along with teaching and learning approaches, course design, teaching methods, digital tools, assessment techniques, and evaluation approaches. Participants, mostly in teams of two, apply their pedagogical knowledge in a teaching project, wherein they design and implement classroom activities in one of their own courses, mostly within the programme period. With respect to the underlying pedagogical problems that occur in exercises, seminars, laboratory courses or problem-based learning courses, the project objectives vary e.g. from increasing students' research interest, autonomy, activity or practical experience. Thus, the corresponding classroom activities also vary a lot. The teaching projects are discussed in a final event on campus with poster presentations along with reports or abstracts and are partly published on the homepage of the CLL [8].

1.3 Evaluating the participants' perspective on the qualification programme

To evaluate this qualification programme on the individual level, the perspective of the participants was gathered, i.e. cohorts 1 to 4 with altogether 77 participants conducting 46 projects. The evaluation was designed according to Kirkpatrick's *four-level model of evaluating training programmes* [9]. The research questions focused on the three individual levels of the model, asking how participants assess their reaction, learning, and behaviour after completing the training. It was also of interest to gain a deeper understanding of the participants' perception. Data was collected using a mixed-method approach. To begin with, quantitative online surveys were conducted. Using a 5-point Likert scale, participants were asked to:

- value the qualification programme (level 1: reaction),
- assess their knowledge and skills in respect of general principles used for classroom instruction, research-based learning, classroom action research, dissemination and value the combination of research and teaching (level 2: learning),

- indicate their future intention towards course development, research-based learning, classroom action research and dissemination (level 3: behaviour).

Furthermore, semi-structured interviews were conducted with 13 participants. These were selected according to a specific criteria catalogue resulting in a wide variation of interviewees. The interviews addressed the three levels and several additional aspects of the relationship between research and teaching. The data was analysed using descriptive statistics and thematic investigations. Surveys and interviews indicated barriers and potentials for implementing research-based learning at this university. These were categorized, quite similar to Brew and Mantai [4], here as (1) culture, (2) structures, (3) resources, (4) academic qualification and (5) academics' views on student qualification.

2 RESULTS AND INTERPRETATION

2.1 Reaction after participation in the training programme

Participants' evaluation of the qualification programme in respect to their reaction, learning, and behaviour is summarised in Table 1.

Table 1. Evaluation of the qualification programme on research-based learning.

level	#	item	n	mean	sd
reaction	1	I find a structured pedagogical qualification important in the first year as research assistant.	38	2,1	1,0
	2	I find it valuable for me that I participated in a programme for pedagogical qualification in STEM.	37	2,8	1,3
learning	3	I am able to explain principles of good teaching and learning.	40	1,9	0,6
	4	I am able to select various pedagogical methods for research-based learning for my course.	38	2,2	1,0
	5	I am able to select methods to systematically collect data with respect to my problems in teaching.	40	2,2	1,0
	6	I am able to implement at least two principles of good teaching and learning in my own course.	40	1,9	0,7
	7	I am able to apply different teaching methods for research-based learning in my course.	37	2,7	1,1
	8	I am able to develop an appropriate research design to investigate problems in my teaching.	39	2,3	0,7
	9	I was able to present my teaching project at the final event well.	36	1,8	1,0
	10	I think it is important to see research and teaching as a unity.	38	1,9	0,9
	11	I think it is important to integrate research in my own teaching.	38	2,5	1,1
behaviour	12	I am motivated to continuously develop my teaching.	38	1,6	0,8
	13	I am planning to design my teaching according to research-based learning in the future.	38	3,1	1,0
	14	I envisage integration of course analyses according to classroom action research into my daily teaching routine in the future.	36	3,4	1,1
	15	I am interested in publicly presenting and discussing questions and approaches on the development of my teaching.	38	3,9	1,1
	16	I would write about course analyses or innovations in a similar format in the future.	37	3,8	1,0
#3-5: relate to knowledge, #6-9: indicate to skills, #10-11: mention attitude, n: number of persons taking part in the survey, mean: arithmetic mean of answers of cohort 1 to 4 with respect to the specific item on a 5-point Likert scale (1: totally agree and 5: totally disagree), sd: standard deviation					

First of all, it was found that on average participants consider a structured pedagogical qualification as important (#1). In respect to the interviews, this suggests that on average participants accepted the training programme. This can indicate to a desire to enhance their own pedagogical competence and to solve prevalent problems in teaching and learning. However, participants' satisfaction might be diminished, since the training was compulsory. However, interviews in cohort 3 and 4 indicate that this aspect of the programme might not be a dominant issue for participants.

Interestingly, participants find participating in the programme only moderately valuable (#2). Here, a high variability in responses was detected. Four aspects evolve in the interviews: Firstly, the institutionally demanded focus on research-based learning, might have affected the direct usability for some participants, setting aside the need for a basic pedagogical qualification. Secondly, the effort spent on the programme, while other tasks are important and often urgent, might have lowered the acceptance of the programme for some participants. Thirdly, the prominent focus of research could have reduced the relevance of teaching for some, and thus of a training programme focusing on integrating both. Finally, future career prospects seemed to influence how participants acknowledge such a pedagogical qualification. It seems that participants see a lower need for teaching qualification if they seek a non-academic career after their PhD studies.

2.2 Learning after participation in the qualification programme

Participants consider themselves as well qualified in respect to basic pedagogical knowledge and skills (#3, #6). Remarkably, the standard deviation is low which indicates that participants assess their competencies in core areas quite similar.

Furthermore, participants estimate their knowledge regarding the advanced format of research-based learning as good (#4) and their skills as moderate (#7). Interestingly, the standard deviation is relatively high. This is probably due to varying possibilities to experiment with research-based learning within the programme period. Secondly, interviews indicate the participants' need for more experience in research in order to combine research and teaching. Questions regarding participants' attitude are answered differently. Although participants see research and teaching as a unity (#10), they rate the importance of integrating research into their own teaching as moderate (#11).

Moreover, participants feel competent to gather data for analysing problems in teaching (#5) and applying those using an appropriate research design (#8). Considering that participants dealt basically with quantitative data and open questions from surveys, they could have probably knotted this topic to their prior knowledge and skills. Finally, participants rate their presentation skills as quite good (#9). This is probably due to the participants' prior experience in presenting during the workshops.

2.3 Behaviour after participation in the qualification programme

Participants report a quite high motivation to further developing their teaching and learning, with low variation (#12). This suggests a high and broad fundamental interest in teaching innovation. Remarkably, participants seem to have only moderate interest in designing future courses in regard to research-based learning (#13). This is addressed in Chapter 3.1. Additionally, they indicate to have moderate intentions to routinely integrate classroom action research (#14). Interestingly, interviews show that participants made their decision on conducting classroom action research based on pragmatic reasoning. The cost-benefit relation and supervisors' support seem of importance here, besides intrinsic motivational aspects, affecting their teaching engagement in an already busy daily routine. Finally, participants state low interest in further dialogue on teaching innovations (#15) and analyses (#16). It is assumed that low intentions relate to the presumed efforts in regard of dissemination. Also, this kind of communication might not be the prior focus of departments and might thus be rewarded lower than research publications.

3 DISCUSSION

3.1 Detecting barriers and identifying potentials for implementing research-based learning

To find out more about the participants' low interest in implementing research-based learning, it is necessary to explore the presumed constraints. Participants indicate obstacles in all five categories, i.e. (1) culture, (2) structures, (3) resources, (4) academic qualification and (5) academics' views on student qualification. In regard to culture, participants report that research and teaching are 'two different ball games', i.e. two separate academic tasks. Furthermore, teaching focusing on content and basic knowledge is seen as very important in engineering study programmes, whereas the integration of research results, methods or processes is seen to be of secondary importance. As to structures, a perceived high responsibility for students' success and, at the same time, low pedagogical autonomy, which is implicated by the traditional structure of lectures and accompanying courses, were experienced as impeding. Limited resources, such as low numbers of staff for supervision, limited time for guiding through a complete research cycle, no appropriate facilities, and large classes are also crucial. With the emphasis on academic qualification, when participants target a career in industry, they focus on research in their academic practice which results in a perceived low relevance of research-based learning. In addition, low interest of some professors affects the participants as well. Participants also see research-based learning predominantly suitable for higher semesters. In regard to the academics' view on student qualification, participants report a lack of basic knowledge and low student motivation as hindering aspects.

Consequently, participants suggest several facilitating aspects in all categories to implement research-based learning. To begin with, they recommend showcasing a broad variation of good practices. Secondly, they propose concentrating on small courses and certain course types, such as laboratory courses and seminars. Other

aspects include updating syllabuses regularly, making use of state-of-the-art research in departments, allowing more time for studying or reducing content, integrating obligatory courses on scientific methods and research into the curriculum, and revising teaching approaches on the level of modules, rather than on single sessions. Thirdly, participants suggest to actually making use of already available support for course innovations and available facilities. Fourthly, they highlight the need for qualified supervision of students' research. This requires open minded professors in regard to teaching innovations, and professors encouraging staff training as well as drawing professors' attention to the benefits of research-based learning. Finally, they suggest motivating students with additional credits and product-orientation.

3.2 Proposing an improved qualification programme on research-based learning

An improved qualification programme, which considers the participants' personal satisfaction and their qualification towards research-based learning, is a prerequisite to enable an appropriate implementation of research-based learning.

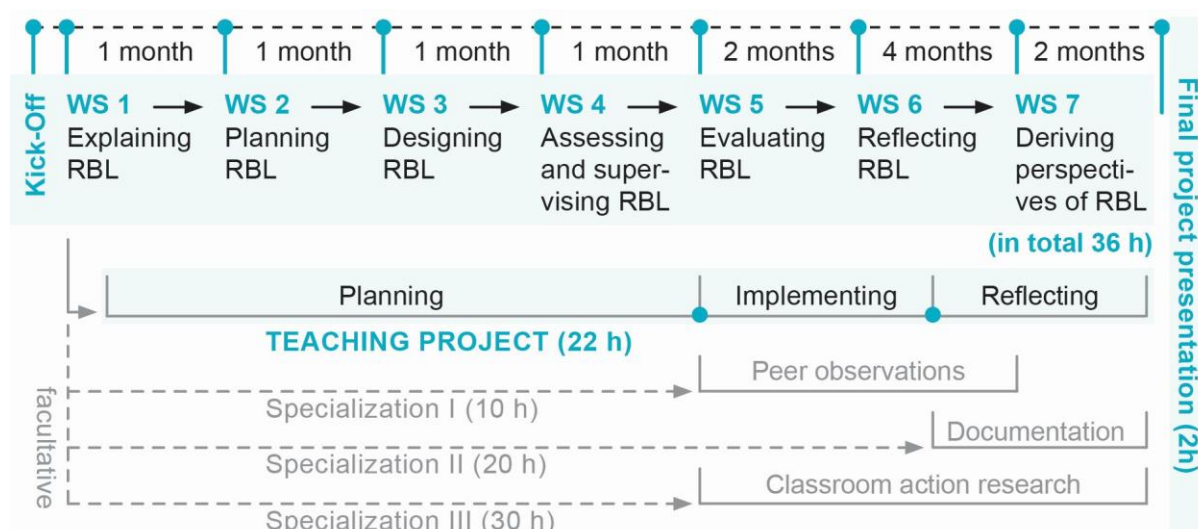


Figure 1. Improved qualification programme on research-based learning (RBL).

The recent qualification programme (see Fig. 1) integrates general principles in qualifying for research-based learning within 60 hours, finalized with a poster and an abstract. The emphasis is on deriving personal benefits for participants' career, reflecting own perceptions, as well as experiencing and testing a set of teaching methods and digital tools for research-based learning. This improved programme integrates professors and supervisors, spreading good in-house practices, and supporting networking on campus in respect to research-based learning. Additionally, interested participants can enhance their competencies during the training period by selecting specializations, for instance, peer observations, classroom action research, or documentation. More programme insights are provided by the CLL [8].

4 SUMMARY AND OUTLOOK

This study presents a qualification programme on research-based learning for early stage researchers and its perception. In conclusion, the foremost aim of the programme, that is introducing research-based learning, has been reached in an acceptingly manner. Still, attempts for enhancement on the three individual levels reaction, learning, and behaviour have been recently realized by an improved qualification programme and will be evaluated soon. However, implementing research-based learning clearly faces substantial obstacles in regard to disciplinary and institutional characteristics, among others. As a consequence, this requires additional in-depth investigations of the results on the institutional level, and identification of the profound barriers and potentials for research-based learning experienced by various university stakeholders. Adjusting those findings with prerequisites of higher engineering education could help to overcome barriers cooperatively. To do so, recommendations by participants can serve as a first source to take actions. To summarise, qualifying early stage researchers proved to be a promising approach to integrate research into teaching and learning as part of a comprehensive institutional strategy towards modern higher engineering education.

ACKNOWLEDGEMENTS

We gratefully thank all early career assistants and their supervisors for their efforts and inspiring ideas in respect to the qualification programme. We express our great gratitude to the persons taking part in surveys and interviews. This project was partly funded by the Federal Ministry of Education and Research of Germany.

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Student retention and dropout in a PBL environment

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Conference Key Areas: Recruitment and Retention

Keywords: Student retention, student dropout, problem-based learning

INTRODUCTION

Student retention is an issue that gathers increasing attention within the engineering education community. This is mainly due to the increasing need for engineers, paired with untenable dropout rates of 50%-60% in engineering programmes at many universities all over the world (1-3).

Until recently, Aalborg University (AAU) had avoided this development, even compared with other Danish universities (4). The common sense logic had been that Aalborg University adheres to a problem-based learning (PBL) approach, which inherently combats dropout. A very recent largescale English investigation about retention and dropout states that this is more than common sense logic:

'High-quality, student-centred learning and teaching is at the heart of improving the retention and success of all students. Academic programmes that have higher rates of retention and success make use of group-based learning and teaching, and varied learning opportunities, including real-world learning and work placements' (5).

Lately, however, we have started to see some AAU dropout rates at 30% and several research projects have been initiated to investigate this apparent paradox. As our initial studies also have shown, retention and dropout are phenomena with a complex causality of a practical, academic, pedagogical and social nature (4,6). A particular area of interest is, however, the extent to which our pedagogical PBL model has an impact on these new trends and whether it should be modified. As an important step in this area, this paper evaluates existing literature to research state-of-the-art methods of addressing retention, dropout and PBL learning environments.

1. RESEARCH DESIGN

1.1. Research question

This paper aims to investigate the phenomena of student retention and dropout in a problem-based learning (PBL) environment by means of a literature review. Because most dropout takes place within the first year of college (5), we will limit our focus to first-year students. Consequently, the research question guiding the literature review is as follows:

What are the dynamics at play between a problem-based learning environment in engineering education on the one hand and first-year student retention and dropout on the other?

After defining the core concepts employed in this paper, we will go through the methodology behind the literature review, after which we will present the results of the review and discuss the implications for further research within the area of retention/dropout and PBL.

1.2. Theoretical core concepts defined

In this section, we define our two main concepts and the relationship between them. We also define a few related concepts, because either we use them in our search string and the analyses, or they were important in some of the studies we analysed.

Following Kolmos (7) a problem-based learning environment refers to an innovative learning approach on a curriculum level that combines specific cognitive, collaborative and content-related strategies. Cognitively the learning is both problem- and project-based and situated in a specific context. Collaboratively the learning takes place in participant-directed teams. In terms of content, the learning is interdisciplinary, exemplary and emphasises theory as well as practice, including research methodologies. It aims to model real-world situations and guide the learners to develop interdisciplinary, deep-content learning within an exemplary discipline area, as well as foster problem-solving and collaborative skills. As such, it is a huge leap away from traditional college teaching and puts new qualitative and quantitative learning demands on both students and faculty. PBL activities or approaches can also be a pedagogical learning strategy employed at a workshop or course, in which case it normally refers to problem- or team-based activities. Active learning activities or approaches are learning strategies that in this context refer more generally to 'any activity in which every student must think, create or solve a problem (3). It can also be applied on any level – workshop, course or curriculum – and does not necessarily entail problem- or team-based activities.

Retention is defined as the likelihood of a student remaining in university (8) and can be attributed to a number of factors beyond their academic ability when they enter their first year. *Dropout* is defined as the likelihood of a student leaving university (ibid). Two other important concepts appearing in the literature review are *engagement* and *persistence* (9). *Engagement* is defined as the time and effort students devote to a learning a task. *Effort* here is understood as affective, cognitive and metacognitive

mobilisation. *Persistence*, on the other hand, is the conscious choice one makes to carry on with an activity despite the obstacles or difficulties one may encounter. Even if engagement and persistence do not equal retention and dropout, the two pairs are strongly correlated. *Dynamics at play* is the relationship between the two main concepts. Below we analyse the kinds of relationships that the literature generally imagines between retention and dropout on one hand, and a problem-based learning environment on the other.

1.3. Methodology

To carry out the literature search we first concentrated on the search string's specific words. We aimed to find literature within the engineering education field concerning retention and dropout for first-year students. Each area of interest was scrutinised for relevant synonyms. Two people participated in this endeavour, including one librarian. We came up with the following words for each search:

- Engineer – STEM – sciences – natural sciences
- PBL – problem based – problem-based – project based – project-based – student-centered – active learning
- Drop out – dropout – attrition – retention – retain – holding power – withdraw – persistence
- Student – freshman – freshmen – undergrad – bachelor

The search string ended up looking like this: (engineer* OR STEM OR sciences OR 'natural science') AND (student* OR freshman OR freshmen OR undergrad* OR bachelor*) AND (PBL OR 'problem based' OR 'problem-based' OR 'project based' OR 'project-based' OR 'student-centered' OR 'active learning') AND ('drop out' OR dropout* OR attrition OR retention OR retain OR 'holding power' OR withdraw* OR persistence). Thus, we wanted literature that combined the four areas of interest. We carried out the search in four databases central to education: Educational Resources Information Center (ERIC), PsycARTICLES / PsycINFO, Academic Search Premier and Web of Science. We looked only for peer-reviewed articles and there were no restrictions concerning the date of the papers. However, we did restrict the search to include only papers that had the search words in the title or the abstract. We carried out the search in November 2016. When we retrieved the data, every abstract was read through twice. The first reading was done to get an initial understanding of the literature at hand and determine what kinds of categories were operational. After the second reading, the researchers determined whether each paper had been placed in the proper category. Finally, we scrutinised papers of particular interest and analysed them in relation to the research question.

2. FINDINGS

2.1. Articles retrieved

An overview of the article output is shown in Table 1. In total, 87 papers were retrieved in the search, the oldest from 2000. Most of them we found via ERIC. Leaving out repeating papers, Academic Search Premier yielded another 30; PsycARTICLES / PsycINFO yielded three and Web of Science provided a single paper. Most of the 87 articles – 48 articles to be specific – did not cover the subject of student retention and dropout. They dealt with the quality and retention of the knowledge that students would

acquire from different learning strategies. At most, they mentioned student retention and dropout in a sentence or two. Consequently, we left them out. Twenty articles covered issues not related to student retention in college. Issues like student retention and dropout in high school, how teachers and management related to the issue of retention or how student retention would look in a non-engineering discipline.

Another seven articles dealt with the theme of retention and dropout during the first year of college within engineering education. However, they dealt with the subject on a course level, rather than a programme level. The authors usually had an exclusive focus on a specific course (e.g. a math course), trying to determine whether active learning or problem-based learning would make the specific course more forthcoming and digestible for the students so that they would not fail the course. Only 12 articles addressed student retention on an overall programme level, while at the same time considering the merits of active learning in general (6 studies) or PBL (6 studies). Out of these 12 articles, we could not find a full paper for one active learning programme, and had to dismiss it. Nine articles were positive toward active learning/PBL learning strategies. Active learning and PBL learning strategies were seen strictly as part of the solution for retention and dropout issues. Only two articles, both by the same Canadian main author, investigated how PBL curricula might also increase persistence and lower engagement of engineering students during the first year of college. In the following section we will go through the 11 articles on a programme level more thoroughly.

Table 1. Overview of articles retrieved in the literature search

	Eric	'Academic'	'PsycINFO'	Web of Science	Total no. articles by category
Knowledge Quality/ Retention Active L strategy	15	11			26
Knowledge Quality/ Retention PBL strategy	14	8			22
Retention Act L Strategy Course Level	3				3
Retention PBL strategy Course level	3	1			4
Retention Active L strategy Programme Level	5	1			6
Retention PBL strategy Programme level	3	2		1	6
Other	10	7	3		20
Total no. articles	53	30	3	1	87 in total

2.2. An active learning strategy in service of retention

Retention was the focal point for this category of papers. It dealt with the question of what active learning strategies can do for retention on a programme level, while also looking at other, more general, retention factors like financial issues. All five papers stemmed from American contexts and all of them celebrated active learning strategies as a tool to secure retention. The specific arguments and the weighing of them differed, though, as did their definitions of active learning. Table 2 gives an overview of the different types of active learning employed and the context of retention. Four papers (1,2,10,11) reported results of a changed curriculum in which active learning played a larger role. One paper (3) went through a conceptual model for improving persistence of college students in STEM based on a literature review. Even if all papers acknowledged that the character of the single student played a role in retention, they all shared a conviction that institutional characteristics and initiatives are important. Xu (1) underlined that STEM areas are inherently challenging, demanding an institutional focus on a good learning environment such as smaller class sizes and in-class interaction with instructors.

Table 2 Overview of active learning activities, the relationship between active learning and retention and core beliefs about retention in general for each study

	Type of Active Learning	Relation between Active Learning and Retention	Understanding of Retention in general
(1)	Interesting learning <ul style="list-style-type: none"> • Student-centred teaching practice • Authentic research activities 	Active Learning → Retention by default	Challenging nature of STEM demands good learning environment
(2)	Engineering learning communities <ul style="list-style-type: none"> • Cohort courses • Activating L technics • Peer study groups • Mentor/Tutor 	Active learning → Sense of community → Retention	Chilliness of climate, financial issues and poor math skills are core challenges
(10)	Team-based learning <ul style="list-style-type: none"> • Administrative groups • 'Flipped classroom' with application 	Active learning → Active and accountable science students → Retention	Collaborative instructional strategies lead to retention and other learning outcomes
(3)	Any activity in which a student must think, create or solve	Active learning → Identification as scientists, better understanding → Retention	Early research experience, Active Learning and learning communities provide persistence
(11)	Student learning communities <ul style="list-style-type: none"> • Cohort courses • Activating L technics • Peer study groups • Mentor/Tutor 	Active learning → Sense of belonging, self-confidence and improved learning → Retention	Collaborative structures provide academic and social support

Articles (10) and (3) took the academic focus a little further, insisting that a scientific identity is a basic requirement for retention, underlining the need for methods like early research experiences and active-learning strategies resembling what a scientist does. Articles (2) and (11) emphasised sense of community and belonging as important factors in retention, urging experimentation with different kinds of student learning communities.

2.3. A PBL learning strategy in service of retention

In the four papers about retention and problem-based learning strategies, retention was a major concern for which varying degrees of PBL strategies provided an excellent solution. Two stemmed from American contexts, one from Canada and one from South Africa. (12) looked at the employability of a PBL strategy on a course level, whereas the others looked at some initiatives that involved broader parts of the curriculum. For these three studies (13-15) PBL learning environments were also interesting because they yielded other positive results, such as improvements in the students' communicative, critical and professional skills. No findings pointed in the direction of PBL learning environments having negative impacts on retention. In general, little was said about potential challenges of PBL learning environments – this was limited to challenges and costs of implementation or group dynamics.

Table 3 Type of PBL, relationship between PBL and retention and understanding of retention in general for each study

	Type of PBL	Relation between PBL and Retention	Understanding of Retention in general
(12)	Change Chem initiative <ul style="list-style-type: none"> • Small design projects as part of courses • Authentic prob. descriptions • Teamwork 	Promising relation: Increased learning and identity with engineering Some dysfunctional team issues	Building engineering identity, sup. social interdependence and achievement will attract women and minorities, fit workforce demands and secure retention
(13)	GDW initiative <ul style="list-style-type: none"> • Interdisciplinary project module • Real world game design 	PBL → Increased motivation, disciplinary and communicative skills, increased quality, group dynamics and retention	Retention is one issue that can be addressed by the introduction of PBL
(14)	Integrated PBL <ul style="list-style-type: none"> • Problem-based curriculum • Collaborative teaching strategies 	PBL → Collaborative, critical and prof. skills building, earlier maturity, self-directedness and retention	Curricula changes, faculty education and introduction of PBL is the solution to retention issues
(15)	PBL ala Maastricht <ul style="list-style-type: none"> • Integrated • Problem-based • Seven jump 	PBL → Impact the learning style of at-risk students and thus improve retention	At-risk students in South Africa do benefit from a PBL strategy in terms of retention

2.4. A PBL learning environment in terms of engagement and persistence

Only two papers intimately dealt with challenges of a PBL learning environment that may have potentially affected retention and dropout. The papers were written by the same team of researchers who were associated with the Centre for Research in Higher Education at the Université de Sherbrooke in Canada. Université de Sherbrooke is a university that has had PBL learning environments within medicine since the late 1980s, and in their engineering education since around 2000.

(9) and (16) presented a predictive conceptual model of the factors that influenced the engagement and persistence of students within an innovative PBL curriculum, similar to the Aalborg model. The papers also presented the results of a questionnaire study and an interview study, carried out in medicine and two engineering programmes, to gain insight and test the model.

According to Bedard et al. (9,16), the engagement and persistence of a student in a PBL learning environment can be predicted based on four factors: the student's *self-efficacy*, *stress level*, *level of competence in new cognitive tools* and their *theories and beliefs about knowledge*. Following Bandura, Bedard et al. (9) defined self-efficacy as the notion that the more one thinks they are effective, the more they will persist. Stress was defined as the particular relationship between individuals and their environment, when the latter exceeds the resources available to the individual. New cognitive tools – demanded by a new learning environment – included knowledge articulation and reflexive thinking. The student's theories and beliefs about knowledge were important in a curriculum that introduces 'contextualisation of knowledge' as one of its main characteristics. Reaching the level of relativism (contextual lenses) as opposed to subjectivism (personal truth) and dualism (right or wrong) will make a difference for the student's engagement and persistence.

What is interesting about this research is that the best predictor of a student's engagement and persistence was the support that reduced stress. If a student found this support high, the engagement and persistence of that same student was equally high. In fact, the stress factor was singled out as the factor that explained most of the variance found in the research, especially related to engagement. Self-efficacy, which is usually singled out as important, played a minor role. An overview of the arguments and suggested activities are given in Table 4.

As can be seen from Table 4, initiatives that helped the students overcome the stress of a new, demanding learning environment positively affected engagement and persistence. Stress levels were higher in the first year due to the new learning environment and the lack of appropriate learning strategies. Bedard et al. (16) emphasised that different types of curriculum resulted in different factors carrying the most weight. For example, computer science did not see stress-related issues at the top as other programmes did. Instead, one of the new cognitive tools, knowledge attrition, carried the most weight. Bedard et al. pointed to the fact that within computer science, it is vital to understand and articulate abstract mathematical knowledge, and the tutors placed great emphasis on this, which could both be reasons for this specific outcome.

Table 4 Relationship between PBL and engagement/persistence and activities that affect engagement and persistence positively in a PBL learning environment

	Type of PBL	Relation between PBL and engagement and persistence	Activities that affect engagement and persistence positively
(9) and (16)	Innovative PBL curriculum	<p>Engagement and persistence in PBL curriculum can be predicted based on four factors:</p> <ul style="list-style-type: none"> • Self-efficacy • Stress • New cognitive tools • Theories and beliefs about knowledge <p>The support measures that reduce stress is the better predictor of engagement and persistence</p> <p>Collaborative work is effective in reducing stress, however conflicts are stressful</p> <p>Disciplinary fields influence which factors carry the day</p>	<p>Knowledge production in a real life problem context</p> <p>Enough time to project work</p> <p>Support from peers, faculty and mentors</p> <p>Stable learning environments with tutors</p> <p>Scaffolding measures for managing time and organising learning practices</p> <p>Clear objectives and expectations of the curriculum</p> <p>Collaborative spirit rather than competition</p> <p>Evaluation process coherent with PBL learning mode</p>

3. DISCUSSION OF FINDINGS AND IMPLICATIONS FOR ENGINEERING EDUCATION

The literature review shows that very few studies overall have dealt with the dynamics at play between PBL learning environments within engineering education and college student retention and dropout rates. This is the most basic and telling finding – not a lot is known within this area.

Of the studies that dealt with the issue, the majority experienced the dynamics at play to be purely positive. PBL and active learning were seen as part of a solution to a problem that is increasingly present in the world of engineering education. There seems to be very little inquiry into the question of whether a PBL learning environment could be anything but positive in terms of retention and dropout. Active learning and PBL strategies enhance scientific identity, improve learning quality and resemble what scientists and workplaces do. They provide peer support and nourish a sense of community and belonging, factors that support retention and diminish dropout, as we also saw with the introductory quotation. This is vital in a STEM context, where the disciplines seem to be inherently challenging and the demand for workforce is rising.

How can we then explain the contradictory situation at AAU? Why have retention rates changed?

What the Canadian findings seem to teach us is that while innovative curricula, like PBL, improves retention for the reasons stated above, and in particular by reducing students' stress, too much of a new thing might also trigger stress. PBL often necessitates that students develop more autonomy, responsibility and new learning strategies, as well as self-awareness about the value of these student-centred

activities. This has been the case at AAU for a long time, though. What the Canadian study also shows is that some factors positively enhance engagement and persistence. Among these include: enough time for project work; support from peers, faculty, and mentors; clear objectives and expectations of the curriculum; a collaborative spirit rather than a competitive one and an evaluation process coherent with the PBL learning mode.

Some of the inquiries that we have already used (4,6) with students at AAU suggest that they feel more stressed in general. Among other things, they lack enough time to do their project work and believe course activities take up a lot of energy. Speculatively, there has seemingly been a general increase in course activity at AAU, an increased competitive spirit and the evaluation process has definitely been under heavy pressure to become much more individualised. It is, however, outside this paper's scope to speculate further regarding the underlying reasons. Regardless of what makes the AAU students more stressed, this literature review advises us to strike a balance, where overcoming the stress of a new learning environment is possible, while at the same time harvesting the many benefits of PBL learning environments.

The research into these areas is far from sufficient and more research will be necessary. Based on this literature review, in an AAU context, issues that stand out include: new ICT-driven generations of students entering university. To what extent do these new generations of students alter the fit of the existing pedagogical PBL model? Economic pressure and pressure from faculty toward more traditional knowledge training imply a more diluted PBL learning environment. Do we then ultimately put students in a clamp by asking them to honour both traditional and innovative learning pedagogies – adding to a stressful environment? These and other questions will be addressed in our research projects concerning retention and dropout in the coming years within the area of engineering education.

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Identification and preliminary review of doctoral theses in engineering education that have used phenomenological methods

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Conference Key Areas: philosophy and purpose of engineering education, other

Keywords: phenomenology, systematic review, literature review, engineering students, research methods

1 INTRODUCTION

This paper presents the design, data collection process, and preliminary findings of an exploratory study that will lead to a more systematic review of phenomenological research in the realm of education regarding engineering and other STEM subjects (i.e., science, technology, engineering and mathematics). This paper identifies doctoral theses and dissertations that have used the method to produce findings. The term “thesis” is used throughout to connote both “thesis” and “dissertation”. The term “phenomenology” is used to mean a research methodology for understanding and describing human experience—by analyzing, interpreting, and synthesizing personal accounts of a phenomenon. Accounts are typically collected via in-depth interviews. Moreover, phenomenology seeks to identify core,

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shared aspects of the experience, or its overall essence. Phenomenologists often assess the texture (what happened while experiencing the phenomenon) and structure (the various ways the phenomenon was experienced by participants). This study represents a work-in-progress and is guided by recommendations for conducting systematic reviews that have been published by recognized scholars in engineering education [1], [2].

The study reported here focuses on a foundational body of gray literature, so that researchers and engineering educators can better understand and make use of this particular knowledge base. Findings of the study are intended for use by education researchers, phenomenological researchers, third-level engineering educators, higher education administrators/managers, and policy makers. Research questions driving the overall study are: *What patterns emerge via systematic review of phenomenological doctoral theses? What demographic groups and range of topics have been explored?*

Work completed to date suggests phenomenological methodologies that phenomenology is being used as a research method more and more frequently in engineering education research (EER), but although they may inform earlier studies, they have been explicitly called out as the formal research methodology only recently in EER. Databases recommended specifically for use in systematic reviews in engineering education [1] provide access to 33 theses, with most of these originating in Higher Education Institutions (HEIs) in the United States. This number is not far behind the number of scholarly journal articles (49) and conference papers (50) identified using the same databases and search constraints.

2 FOCUS OF SYSTEMATIC REVIEW

At the outset of this study, multiple databases were mined to identify publications where “phenomenology” and “engineering education” or “engineering students” or “STEM students” appear in the title, keywords, or abstract. Three types of documents were mined: (1) peer-reviewed journal articles; (2) conference papers; and (3) doctoral-level theses that have been approved by a recognized HEI. The first group is considered the highest form of “scholarly literature” whereas the second and third groups are described as “gray literature” [1]. Gray literature also includes government documents, reports, books, websites, and the like [1]. In emerging fields, publications typically appear in gray literature before they make their way into scholarly journals [3].

Table 1. Yield of database search

Search “phenomenology”	& “engineering education”	& “engineering students”	& “STEM students”	Total
ProQuest (journal articles)	40	Adds 1	Adds 2	43
Scopus (journal articles)	6	Adds 0	Adds 0	06
Scopus (conference papers)	16	Adds 4	Adds 0	20
ProQuest (conference papers)	23	Adds 2	Adds 5	30
ProQuest (theses)	17	Adds 1	Adds 1	19
Open Access (theses)	6	Adds 0	Adds 8	14

A basic search using *Google Scholar* identified 2750 sources associated with the terms “phenomenology” and “engineering education”, 1910 associated with “phenomenology” and “engineering students”, and 218 associated with “phenomenology” and “STEM students”. A similar search of *Taylor and Francis Online* identified a similarly large number of results

(1561, 1540, and 1670 respectively). To limit the search to items that have been more thoroughly vetted, it was advantageous to specify terms under the “advanced search” options that many databases provide. Results, however, varied widely from one database to the next, with regard to accuracy and applicability. Subsequent searches for this study set the search parameters to identify only instances where the three terms appeared in the title, abstract, or keywords. Although searches using such parameters will identify many relevant sources, they will not identify documents that do not tag these particular terms up front.

3 METHODOLOGY AND DESCRIPTION OF MATERIAL STUDIED

This study used multiple databases to locate basic information on relevant journal articles, conference papers, theses and dissertations. For all these, the researchers collected bibliographic information and full-length abstracts. For the theses, they collected a full set of full-length texts as well. The best databases to use depend upon one’s research subject and intent [1]. This study included searches of: the general databases *JSTOR* and *Scopus*; the journal databases *Science Direct* and *ProQuest*; and thesis databases *ProQuest* and *Open Access Theses and Dissertations*. Across these databases, using the terms “phenomenology” and “engineering education” yielded many more results than the other two sets of terms, but the addition of terms “engineering students” and “STEM students” added value to the study by identifying a few texts not found using the primary terms.

4 RESULTS

With regard to journal articles, *Scopus* and *ProQuest* yielded the most plentiful and useful results. Surprisingly, there was no overlap in the results gathered using *Scopus* and *ProQuest*; none of the references located using one appeared in the other. Using *Scopus* and *ProQuest* identified a total of 49 peer-reviewed scholarly journal articles. Publications not relevant to this investigation were excluded manually (e.g., those using phenomenography rather than phenomenology). Phenomenology focuses on pre-reflective, raw experience and identifying shared that summarize the essence of the experience, whereas phenomenography focuses on different categories of conceptualization and is thus post-reflective; these two methods are quite different.

Two additional databases were searched without yielding useful journal results. Although *JSTOR* identified some relevant resources, it did not add any items beyond those already identified using *Scopus* and *ProQuest*. *Science Direct* did not identify any relevant results. Since *Scopus* and *ProQuest* provided good access to vetted conference papers, we harvest basic data about these as well, for use in future analyses.

In keeping with expert recommendations [1], thesis searches were conducted using *ProQuest* and *Open Access Theses and Dissertations* (shown in boldface in Table 1), with a yield of 33 relevant theses. All results identified by *ProQuest* came from HEIs in the United States and were published between the years 2009 and 2016. *ProQuest* was established in Michigan in 1938, and this helps suggest in the US, phenomenology is now emerging in EER. Initial searches using *Open Access* were unsuccessful, so follow-up searches were conducted manually. Since tightly controlled searches yielded no results, searches were run without “ ” surrounding search terms, yielding identification of 109 theses. Those focused on phenomenology in education (rather in than technical, physics-related terms) were harvested from the list manually. Only 14 fit the requirements of this study. Of these, 6 matched the primary terms of phenomenology and engineering education. Eight more had to do with

STEM more broadly, including two from Architecture and Built Environment. *Open Access* provided greater diversity in dates (2003-2017) and origin (with 5 written outside the USA). This implies manual cultivation of other database searches could increase yield (Table 1).

Table 2. ProQuest Demographic and Institutional Information of Researchers

Author's Name	Year	Lev.	Sex	Institution	School/Area
Benedict-Augustine	2010	EdD	F	Univ. of Pennsylvania	Higher Educ. Management
DeRamus-Suazo	2012	PhD	F	Capella University	School of Education
Ecklund	2013	PhD	M	Colorado State Univ.	School of Education
Frillman	2011	PhD	F	Purdue University	School of Engineering Educ.
Luo	2014	PhD	F	Purdue University	School of Engineering Educ.
Masterman	2014	PhD	F	Boston College	Department of Educ. Leadership & Higher Educ.
McDonald	2016	PhD	F	University of Utah	Department of Educational Leadership and Policy
McNeill	2013	EdD	M	Northcentral Univ.	School of Education
Mena	2010	PhD	F	Purdue University	School of Engineering Educ.
Parker	2013	PhD	F	UNC Charlotte	Curriculum and Instruction
Richards	2009	PhD	M	Purdue University	School of Engineering Educ.
Spaulding	2013	EdD	M	Fielding Graduate University	Somatics, Phenomenology, & Communicative Leadership
Strutz	2012	PhD	F	Purdue University	School of Engineering Educ.
Sun	2012	PhD	F	Purdue University	School of Engineering Educ.
Torres Ayala	2012	PhD	F	University of South Florida	Curriculum and Instruction, College of Education
Troesch	2015	PhD	F	Michigan Tech. Univ.	Rhetoric, Theory and Culture
Verdan	2012	PhD	F	Clemson University	Chemistry
White	2014	PhD	F	Capella University	School of Engineering Educ.
Zhu	2013	PhD	F	Purdue University	School of Engineering Educ.

This section tabulates results as recommended by [2]. Tables facilitate comparison of results between *ProQuest* (Table 2) and *Open Access* (Table 3). These two tables identify each author's name, year of graduation, degree earned, gender or sex (as identified using name recognition, university website, and LinkedIn profiles), HEI granting the degree, and the School or academic area named in the title page of the thesis.

Table 3. Open Access Demographic and Institutional Information of Researchers

Author	Year	Level	Sex	Institution	School/Area
Alkhadrawi	2015	PhD	F	University of Toledo	Curriculum and Instruction
Darrow	2012	PhD	F	Iowa State University	Education (Educ. Leadership)
Foulcher	2017	PhD	M	Univ. of Newcastle	School of Architecture & Built Env.
Gardner	2017	PhD	F	Syracuse University	Teaching and Leadership
Heroux	2012	PhD	F	Loyola Univ. Chicago	Education
Howard	2003	PhD	M	Pennsylvania State Univ.	Workforce Educ. & Development
Mabovula	2002	MEd	F	Rhodes University	Education
Marais	2014	M	F	University of South Africa	Master of Commerce (industrial and

					organisational psychology)
McCann	2013	PhD	F	University of Oklahoma	Instructional Leadership & Academic Curriculum
Pan	2014	PhD	F	University of Maryland	Education Policy and Leadership
Subryan	2017	PhD	F	University of Derby	Education
Thackeray	2016	EdD	F	Northeastern University	School of Education
Troesch	2015	PhD	F	Michigan Tech. University	Department of Humanities
Tuapawa	2017	PhD	F	University of Newcastle	School of Architecture & Built Env.

Table 4 facilitates comparison of the engineering subjects studied (which are underlined). Sample demographics, sample size, and research method often do not appear in the title.

Table 4. Comparison of Titles and Topics

ProQuest	Open Access
Benedict-Augustine, A. (2010). <i>The impact of international internships on undergraduate college students' career development.</i>	Alkhadrawi, A. A. (2015). <i>Gender differences in <u>math and science choices and preferences.</u></i>
DeRamus-Suazo, N. (2012). <i>The influence of college choice on the success, ethnic identity, and professional sense of belonging of African American engineers.</i>	Darrow, M. E. (2012). <i>Engineering transfer student leavers: Voices from the sidelines of the engineering playing field.</i>
Ecklund, A. P. (2013). <i>Male engineers: An interpretive phenomenological analysis of the experiences of <u>persistence</u> in higher education.</i>	Foulcher, N. C. (2017). <i>The tale of two schools: Design technology, digital mediation and aesthetic dispositions within <u>architectural design education.</u></i>
Frillman, S. A. (2011). <i>A hermeneutic phenomenological study of the experiences of female African American undergraduate engineering students at a predominantly white and an historically black institution.</i>	Gardner, M. (2017). <i>Understanding integrated STEM science instruction through the experiences of teachers and students.</i>
Luo, Y. (2014). <i>Use of Web 2.0 technologies: A virtual ethnographic and phenomenological study of first-year engineering students' experiences.</i>	Heroux, K. H. (2012). <i>How do secondary science teachers understand and implement <u>technological design</u> in their classrooms?</i>
Masterman, A. K. (2014). <i>Women's doctoral student <u>experiences and degree progress</u> in education versus engineering.</i>	Howard, C. A. (2003). <i>From engineer to manager: A qualitative study of experiences, challenges, and individual transitions for <u>engineering managers</u> in aerospace companies.</i>
McDonald, L. K. (2016). <i>"You have no life other than that, so you better like what you're doing": A <u>feminist phenomenology</u> of women in undergraduate engineering majors.</i>	Mabovula, N. (2002). <i>A phenomenological investigation of a female leader's perceptions and <u>experience of discrimination</u> in the work place.</i>
McNeill, D. G. (2013). <i>Industry driven electronic communication <u>competencies</u> for an associate electronics degree: A phenomenological study.</i>	Marais, M.-H. (2014). <i><u>Retention and engagement</u> of generation Y engineers: A hermeneutic phenomenological inquiry.</i>
Mena, I. B. (2010). <i>Socialization experiences resulting from engineering teaching assistantships at Purdue University.</i>	McCann, F. (2013). <i>Engineers' self-perceptions and a strategy for fostering authentic images of engineers and scientists among elementary school students.</i>
Parker, A. D. (2013). <i>Family matters: <u>Familial support and science identity formation</u> for African American female STEM majors.</i>	Pan, Y. (2014). <i>Transcendence of time and space: The lived experiences of Chinese <u>international graduate students</u> in the United States.</i>
Richards, G. P. (2009). <i>Relating engineering technology students' <u>experiences in electromagnetics</u> with <u>performance in communications</u> coursework: A mixed-methods</i>	Subryan, S. (2017). <i>Exploring secondary school science teacher professional identity: Can it be influenced and reshaped by experiences of professional development programmes?</i>

study.	
Spaulding, R. J. (2013). <i>An alternative expert knowledge transfer model: A case study of an indigenous storytelling approach.</i>	Thackeray, S. L. (2016). <i>Overcoming the toxic influence of subtle messaging: Utah women who persist in STEM.</i>
Strutz, M. L. (2012). <i>Influences on low-SES first-generation students' decision to pursue engineering.</i>	Troesch, V. (2015). <i>What is it to be an ethical engineer? A phenomenological approach to engineering ethics pedagogy.</i>
Sun, Y. (2012). <i>Investigating the learning to teach process: Pedagogy, innovation adoption, expertise development, and technology integration.</i>	Tuapawa, K. (2017). <i>An interpretation of key stakeholders' experiences using educational online technologies in blended tertiary environments: A phenomenological study.</i>
Torres Ayala, A. T. (2012). <i>Future engineering professors' conceptions of learning and teaching engineering.</i>	Other relevant theses
Verdan, A. M. (2012). <i>Finding a new continent versus mapping all the rivers: Recognition, ownership, and the scientific epistemological development of practicing scientists and engineers.</i>	Chari, D. (2014). <i>What is nanoscience?'-A hermeneutic phenomenological study of nanoscience researchers' experiences.</i> (PhD, Dublin Institute of Technology).
White, S. M. (2014). <i>The experiences of women engineers who have completed one to five years of professional engineering employment: A phenomenological study.</i>	Charity-Leeke, P. C. (2012). <i>Women in engineering: A phenomenological analysis of sociocultural contextual meaning of gender roles.</i> (PhD, Cleveland State University).
Zhu, J. (2013). <i>Personal epistemological development of Chinese engineering doctoral students in U.S. institutions: An application of Perry's theory.</i>	Kuzmak, N. (2010). <i>Women engineers: Stories of persistence.</i> (PhD, Capella University).
	Somerville-Midgette, K. N. (2015). <i>An engineering journey: A transcendental phenomenological study of African-American female engineers' persistence.</i> (EdD, Liberty University).

5 DIRECTION OF UPCOMING RESEARCH

Using a system such as this can facilitate comparison. Although analysis is in very early stages, Tables 5 and 6 suggest directions for future work. Table 5 suggests one format, with presentation of focused data.

Table 5. Tabulation of Focused Data

Author	Sample Demographic	#	Focus of Study
Benedict-Augustine	Undergrads & support professionals in business, engineering, liberal arts	20	Impact of international internships on undergraduates' career development
DeRamus-Suazo	African-American engineers	8	Influence of college choice (HBCU vs. PWI) on sense of success, ethnic identity, professional belonging
Ecklund	Male engineering undergrads	12	Experiences of persistence in higher education
Frillman	Female African American engineering undergrads	19	Experiences at demographically different HEIs (one HBCU and one PWI)
Masterman	Female doctoral students (10 in the field of Education and 11 in Engineering).	21	Doctoral education culture in Education and Engineering and how these cultures influence women's student experiences and their degree progress
McDonald	Female engineering undergrads	7	How participants made meaning of challenging major, being one of a few women, and seeking fulfillment

The format used in Table 6 provides more detailed information, including sample group (size and demographic characteristics), framework and/or focus, and primary findings.

Table 6. Tabulation of More Detailed Data

Source	Framework or Focus	Major Findings
Sample Number and Criteria		
DeRamus-Suazo, N. (2012). The influence of college choice on the success, ethnic identity, and professional sense of belonging of African American engineers.	Two foci: (1) How college choice influenced success, ethnic identity, sense of belonging, and (2) if participants “favorably viewed their choice of HBCUs versus PWIs” after experiencing practice.	Whether from an HBCU or PWI, participants felt achievement and competence to succeed. Most would choose their HEI again and said it supported their professional aspirations. Sense of belonging and a supportive network (of peers and faculty) influenced participants’ outlook. Several described conviction to become an engineer despite challenges faced at HEI and in workforce.
8 African-American eng. grads. from Historically Black College/ Univ. (HBCU) or Predominately White Institution (PWI) in USA		
Ecklund, A. P. (2013). Male engineers: An interpretive phenomenological analysis of the experiences of persistence in higher education.	Used interpretative phenomenological analysis (IPA) with Tinto’s theory of persistence. Focused on HEI experiences to build upon findings of Kuzmak (2010).	Preparation before university was important to persistence, as were having/building a strong network of support, and “being grounded in academic skills and characteristics” (Ecklund, 2013, p. iii). Discussions of persistence involved both intrinsic and extrinsic motivations.
12 male undergrads in one private university in Texas in mechanical, electrical, or computer engineering		
Luo, Y. (2014). Use of web 2.0 technologies: A virtual ethnographic and phenomenological study of first-year engineering students’ experiences.	Methods to study use of Web 2.0 technologies: (1) virtual ethnographic inquiry regarding its use in daily life, and (2) phenomenology regarding its use in (a) formal and (b) informal learning communities.	Web 2.0 tools were important in facilitating the interaction among first-year engineering students in multiple communities, including informal engineering-related communities, online communities for first-year engineering students at Purdue, and for communities
15 first-year engineering students at Purdue Univ. (Indiana, USA)		
Parker, A. D. (2013). Family matters: Familial support and science identity formation for African American female STEM majors.	Using critical race feminism to investigate how family and science identity influence “persistence in STEM while considering the duality of African American women’s status in society.”	Families and science identity formation influenced STEM experiences of participants. Five themes were identified: (1) independence, (2) support, (3) pressure to succeed, (4) adaptations, and (5) race and gender.
10 female African-American STEM undergrads from public HEIs in North Carolina (1 PWI, 1 HBCU)		
McNeill, D. G. (2013). Industry driven electronic communication competencies for an associate electronics degree: A phenomenological study.	Qualitative phenomenological study using “a modified van Kaam method” and perspectives of curricular improvement	This study identified 12 competencies an applied ETE curriculum should develop in graduates. Results indicated most graduates of applied ETE associate programs lack adequate computer related skills and comprehension of ECTE systems.
11 applied electronic technology and/or engineering (ETE) professionals		
Mena, I. B. (2010). Socialization experiences resulting from engineering teaching assistantships at Purdue Univ.	What socialization experiences engineering doctoral students report going through as a result of being engineering TAs	Participants characterized socialization experiences related to: training, interacting various groups, undertaking responsibilities, balancing teaching and research, and developing skills. Experiences varied on multiple factors.
28 engineering doctoral students who worked as teaching assistants		

6 DISCUSSION

Despite being “gray literature”, doctoral theses proved to be essential resources in assessing the use of phenomenology in EER. The exploratory results were greatly limited by the search terms and databases used. Searches using two of the best-known thesis databases, *ProQuest* and *Open Access Theses and Dissertations*, failed to identify theses the authors had previously studied and found relevant to the topic. These databases appear to have strong US and English-language bias, with research from other locations and other languages not well represented. Future searches could include European-specific databases and other databases recommended by [1], such as *Academic Search Complete*, *Wiley*, and the *Directory of Open Access Journals* and education-specific databases *ERIC* and *Education Full Text (EBSCO)*.

Current search terms may be too limited. Researchers may have used terms such as “engineering pedagogy”, “engineering didactics”, or “engineering learning” which in Europe are seen as synonymous with “engineering education”. “STEM” is a fairly new term, not common in the past. Identification of phenomenological work proves difficult. Upon closer analysis it may be found that some of the studies located are more phenomenographical than phenomenological. Some researchers may have been inspired by phenomenology but have used some other specialized terms. Researchers inspired by phenomenology may not have prioritized the methodology in their front descriptors; they might not have listed the word in the title, keywords, or abstract even when they used it in a study. Snowball sampling [1] would be necessary for conducting a comprehensive review, if one were aiming to identify all relevant publications with relevant findings pertaining to the specified terms.

Nevertheless, this exploratory study has identified HEIs, mostly in the US, generating phenomenological EER at the doctoral level as well as the range of dates (2003-2017, increasing steadily in recent years), and favoured topics of phenomenological EER enquiry (frequently race and gender, but sometimes the experience of a particular technology or pedagogical approach). A big lesson is that persistence is required in systematic reviews.

ACKNOWLEDGMENTS

This project has been supported by the Centre for Engineering Education at University College London and the European Union’s H2020-MSCA-IF-2016 program under the project title “Designing Engineers: Harnessing the Power of Design Projects to Spur Cognitive and Epistemological Development of STEM Students”.

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Gender Difference in University Students' Engineering Creative in Taiwan

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Conference Key Areas: Gender and Diversity, Teaching Creativity & Innovation

Keywords: Engineering Education, Creativity, Gender Difference

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INTRODUCTION

Creativity is a fundamental element of engineering [5]. Creativity is concerned with the generation of effective, novel solutions to problems, while engineering, and engineering education have a similar goal, focused on technological solutions [9]. In recent years, creativity has become one of the most important issues in engineering education in Taiwan. Many trans-disciplinary projects in Taiwan have focused on the subject and hundreds of web pages display information on how to be more creative and achieve innovation in engineering. Studying university students' creativity is very critical for acquiring in-depth understanding of engineering education for educators and researchers who take great interest in education- or engineering-related fields.

It has been emphasized that more females should be able to contribute to society in the engineering field [11]. Abraham [1] proposed that gender is an important affecting factor to creativity. As Kang and Yune [11] indicated that studying gender differences of creativity in engineering is important and practical in providing educational materials or teaching interventions for both male and female university students in the engineering field. Therefore, the main purpose of this study was to analyze engineering university students' creativity by examining a sample of students in Taiwan. In addition, this study is to investigate the relationship between students' gender and engineering creativity.

PERSPECTIVES

Since Guilford [10] proposed the definitions of creativity in 1950, the issue of creativity research had been scrutinized by researchers. Then Torrance [20] applied Guilford's creativity theory to draw a framework for creative thinking processes that consists of four aspects: fluency, flexibility, originality, and elaboration. Fluency refers to the production of a great number of ideas or alternate solutions to a problem. Flexibility refers to the production of ideas that show a variety of possibilities or realms of thought. Originality involves the production of ideas that are unique or unusual. Elaboration is the process of enhancing ideas by providing more detail. Recently, Charyton [4] contended that engineers not only need to address esthetics like artists, but also to solve problems, prevent potential problems, and address utility within the constraints and parameters that have been designated. These aspects of creativity have been described as "functional creativity," [7] which means that products designed by engineers typically serve a functional and useful purpose. Building on this, problem finding offers another avenue for increasing creative production [13]. Problem solving skills are often found in and commonly associated with art, yet are also necessary in science and engineering. However, these attributes have not been specifically measured traditionally nor in engineering creativity. Such attributes need to be assessed and further developed by appropriate educational intervention activities [7]. Mainly adopting the definition of

creativity by Torrance [20] and covering the dimension proposed by Cropley and Cropley [7], this study led to the development of a framework of an instrument for measuring students' engineering creativity, which contained five dimensions: fluency, flexibility, originality, elaboration, and usefulness.

Abraham [1] proposed that gender is an important factor. Since researchers began to focus on gender differences in creativity, no simple conclusion has been drawn from the empirical evidence on this issue. For example, some studies considered that there were no gender differences in creativity [12] [16] [19], while some studies reported that females tended to score higher than their male counterparts in creativity [2] [17] [14]. Some other studies indicated some opposite results with males scoring higher than females [6] [15]. The conflicting outcomes could be results of tests being conducted in different cultural contexts. On the other hand, most studies of creativity tended to focus on general creativity, not creativity narrowing to that revolving around engineering, especially with gender factor completely overlooked. Therefore, this study was intended to explore the gender differences in engineering creativity in Taiwan.

METHODS

3.1 Measures methods. The instrument used in this study was "The Engineering Creativity Scale (ECS), developed by authors to measure university students' engineering creativity. The ECS consisted of two sub-tests: "Design of generating sound" and "Design a car" which were derived and revised from Charyton's [4] and Yeh's [21] studies with minor changes according to the Mandarin usage and local culture. The "Design of generating sound" was designated to ask participants to draw two designs (Design 1 and Design 2) based on two 3-dimension images. The participants were asked to describe each of their two designs by answering the following questions: "What is your design?", "What are the materials of your designs", "What are the problems solved with your designs", and "Who will be users of your designs". The second subtest, "Design a car", required participants to draw a car with their imagination and design. Subsequently, the participants were asked to describe the features and specifics of the car they designed and used pens to draw their designed products on the ECS. The amount of test time was 30 minutes: 10 minutes for Design of generating sound, and 20 minutes for Design a car.

The coefficients of internal consistency reliability of the ECS were between .12-.90, $p < .001$. The coefficients of test/re-test reliability were between .32-.50, $p < .05$. The coefficients of inter-rater reliability were between .47-.97, $p < .001$. The coefficients of parallel-forms reliability were between .30-.50, $p < .01$.

Regarding the validity of the ECS, six university professors in engineering or psychology were asked to determine the content validity of the ECS by rigorously and

thoroughly reviewing the item content of the ECS. And the ECS was modified based on these experts' suggestions and comments. In addition, the coefficients of criterion-related validity were applied and were ranged from .25-.55, $p < .05$.

3.1 Data resource. This ECS was given in a group administration to assess university students' creativity in engineering. A sample of 104 university students who studied in the engineering field from 3 (2 public and 1 private) universities in Taiwan was invited to participate in this research voluntarily, from April to November 2017. As shown in Table 1, the sample included 59(55.7%) males and 47(44.3%) females, and consisted of 12(11.3%) freshman, 26(24.5%) sophomore, 51(48.1%) junior and 17 (16.0%) senior students.

Table 1 The distributions of samples in this study

	Male		Female		TOTAL	
	<i>N</i>	%	<i>N</i>	%	<i>N</i>	%
School type						
Public	40	37.7	30	28.3	70	66.0
Private	19	17.9	17	16.0	36	34.0
TOTAL	59	55.7	47	44.3	106	100
Grade						
Freshman	5	4.7	7	6.6	12	11.3
Sophomore	16	15.1	10	9.4	26	24.5
Junior	29	27.4	22	20.8	51	48.1
Senior	9	8.5	8	7.5	17	16.1
TOTAL	59	55.7	47	44.3	106	100

3.3 Analytic strategy. The following procedural steps were used to score each participant's answer. The Design of generating sound consisted of four dimensions: fluency, flexibility, originality, and usefulness. Fluency was computed by the number of ideas on the sketch, description, materials, problems solved, and potential users. Flexibility was calculated by the number of different categories, types, or classifications of responses. Originality was scored by a 11-point scale (0 = dull, 1 = commonplace, 2 = somewhat interesting, 3 = interesting, 4 = very interesting, 5 = insightful, 6 = unique and different, 7 = exceptional, 8 = innovative, 9 = valuable and beneficial to the field, and 10 = genius). Usefulness was scored with a 5-point scale (0 = not useful, 1 = somewhat useful, 2 = moderately useful, 3 = very useful, and 4 = indispensable). At first, Design 1 and Design 2 were scored separately, and then scores of Design 1 and Design 2 were summed up for each dimension, respectively.

“Design a car” included four dimensions: fluency, flexibility, originality, and elaboration. The fluency score was given simply by counting all the valid responses given by the participants. The flexibility score was given by counting the numbers of categories of students’ answers on the car features. The originality score was developed from a tabulation of the frequency of all the responses obtained. Frequencies and percentages of each response were computed. Among all answers, 2 points were given to a special answer for the originality score when the probability of this answer was smaller than 5%. One point was given to an answer of which the probability was between 5% and 10%. The elaboration was obtained by counting the numbers of car specifics given by participants. The total score of “Design of generating sound” for each participant was computed by summing up his/ her T scores of fluency, flexibility, originality, and usefulness. The total score of “Design a car” was computed by adding up the T scores of fluency, flexibility, originality, and elaboration. The combined scores of engineering creativity for each participant were computed by averaging scores of these two subtests’ scores.

Moreover, in order to explore the relationship between students’ gender and creativity, the independent *t* test was employed to test the significant difference between male and female in each of five dimensions and the total score of the ECS.

RESULTS

The results of this study, shown in Table 2, have some interesting findings. (1) The range of the means of five dimensions from males is 50.27 to 55.19 (T Score), from high to low: Usefulness, Fluency, Flexibility, Originality, and Elaboration, and the total score is 52.04. (2) The range of the means of five dimensions from females is 48.03 – 50.67 (T Score), from high to low: Usefulness, Flexibility, Fluency, Elaboration, and Originality, and the total score is 48.94. (3) Male students score significantly higher than female students in Fluency ($t(104) = 2.75, p < .01$), Originality ($t(104) = 2.27, p < .05$), Usefulness ($t(104) = 2.26, p < .05$) and the total score ($t(104) = 2.69, p < .01$). Nevertheless, there is no significant gender difference in scores of Flexibility and Elaboration.

Table2 The summary of university students’ gender and engineering creativity

Dimension	Male (<i>n</i> =59)		Female (<i>n</i> =47)		<i>t</i>
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	
Fluency	52.32	6.48	48.82	6.53	2.75**
Flexibility	51.98	6.25	49.52	7.84	1.80
Originality	51.05	7.48	48.03	5.86	2.27*
Elaboration	50.27	9.48	48.06	8.55	1.25
Usefulness	55.19	12.13	50.67	8.38	2.26*

Total	52.04	5.85	48.94	5.99	2.69**
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* $p < .05$ ** $p < .01$

DISCUSSION

Results above present some interesting and noteworthy findings. Firstly, both male and female participants score highest in Usefulness among the five dimensions of engineering creativity. The participants' responses to the test corresponded positively to Charyton's [4] point that problem solving or the utility of product should be designated or described in the product designing process.

Secondly, male participants score significantly higher than female participants in Fluency, Originality, Usefulness and the total score. The results of this study differ from previous studies, such as those conducted by Bender, Nibbelink, Towner-Thyrum, & Vredenburg [2], in which females scored significantly higher than males. However, the results of this study partially support Kang & Yune's [11] finding that Korean female engineering students had lower scores on both the integrated creativity and engineering creativity tests than male students. Does this imply that Asian's culture and learning environment are more supportive for male than for female students in their creativity development in the engineering field? It is cortical for the faculty can promote female students to practice creativity thinking skills by giving more opportunities to promote females' engineering creativity. It is crucial for the teachers in the engineering field to take student gender, culture, and teaching strategies together into consideration when creating and maintaining a supportive and friendly learning environment for their female students.

Thirdly, gender plays an essential role in engineering creativity and it may have some interaction with other variables [2]. Chang [3] stressed that individual's creativity could be influenced by some variables, such as social environment, motivation, or cultural context. This study suggests that future research could explore the interaction effect on students' engineering creativity by their gender and other personal variables such as academic background or learning experiences.

Finally, this study was conducted with a small sample from three universities in Taiwan. Further research is also needed to determine whether the results obtained here generalize to students in engineering in other Asian societies.

ACKNOWLEDGMENT

The author would like to thank the two SEFI anonymous reviewers, who made helpful comments on an earlier draft of this paper. This research was supported by research grant (MOST 105-2511-S-259 -013) from Ministry of Science and Technology in Taiwan.

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The Effect of Integrating Creative Problem-Solving Process in an “Industry 4.0” Course on College Students’ Creativity

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Conference Key Areas: Curriculum Development, Innovation as the context for Engineering Education, Innovative Teaching and Learning Methods

Keywords: Industry 4.0, Creative Thinking Strategy, Creative Problem-Solving, Creativity

INTRODUCTION

Industry 4.0 may hold the key to any adaptation to the changing nature of the current state of industries with its potentials to generate, conceptualize, design, and materialize essential ideas surrounding this process. As a high-tech and innovative strategy for the physical production of goods [1], Industry 4.0 is a concept about how to further digitalize the entire value chain of production in the 21st century [2]. Bearing far-reaching influence on the intricate connection that follows among people, objects, and the surrounding systems [2], Industry 4.0 has been widely referred to as the fourth industrial revolution [1]. As the world economy rapidly evolves towards an era of "industry 4.0," an ever-increasing number of studies [3] have focused on effective cultivation of creativity and problem-solving skills among students of higher education. This present study presents an integrated teaching strategy, using four creative strategies: Brainstorming, Six Thinking Hats, SCAMPER, and Bug-List-Technique as well as six stages of creative problem-solving process, to explore relevant implications on teaching and learning about project-based courses in Industry 4.0.

1 LITERATURE REVIEW

1.1 Creativity

Creativity drives people to come up with original ideas for potentially workable solutions to problems [5]. It is no longer treated merely as a source of tangible solutions to existing problems; rather, it has transcended and become a set of strategies for a flexible mind set up for all contingencies in an ever changing and increasingly complex world [6, 7]. Recognized as a sequence of thoughts as well as actions for novel and adaptive production [8, 9, 10], this creative process can stimulate problem-solving skills or be mobilized in combination with the said skills towards the development of new products. The emerging prominence of such creative process also propelled Kiesel and Wolpers [11] to list creativity and problem solving as two, out of a total of five, key competences for employees.

1.2 Creative Problem Solving

Knowing the necessity for students to have creative thinking and problem-solving skills upon entering the workplace [12], university program researchers [13, 14, 15] have launched courses on creative problem solving for students such as engineering majors searching for marketable and desirable attributes that meet business demands. Field research [16] featuring job profiles of Information Technology also enlisted

creativity and problem-solving skills as qualifications for Industry 4.0 jobs. Problem solving ability also receives surging popularity from businesses and industries within the field of physical production, the job requirement of which include having been constantly on the change and in which work settings have become increasingly complex and digitized [17]. However, Basadur, Tagaar, and Pringle [18] suggested that creative trainings attempting to achieve further than its framework of thinking are what actually induce new ideas or solutions and truly permeates students' personal creativity. An increasing number of barriers has emerged as research efforts continue to explore such undertaking. As indicated by previous research [19, 20, 21], one of the most common barriers teachers encounter when engaging in such courses is lack of new skills to carry out creative pedagogical approach since few explicit guidelines are available for incorporating creativity into the curriculum and for providing assessment on the impact and effectiveness of their teaching. One possible solution to this challenge was proposed by Titus [22] who invented a 6-stage creative problem solving process as a way to help student develop different phases of creativity. This process inspired the present research to develop a similar creative problem solving (CPS) process as an instructional resource for trainings in creativity among engineering majors.

2 RESEARCH PURPOSE AND QUESTIONS

The purpose of the present research is to explore the influence of the CPS process on creativity among college students when it is used in teaching. This study aims to achieve a successful design of a holistic CPS process, one that is transferable for use in a one-semester course on mechanical engineering. The study also aims to benefit future engineers, who will be solving problems once they go into the workforce of Industry 4.0, which means that creative skills such as identifying potential attributes related to a targeted problem and pinning down probable solutions are crucial.

3 METHOD

3.1 Instructional contexts

Developed by researchers and university instructors in Taiwan, the "Industry 4.0" project-based course is the target of the present research, which employed a 6-staged CPS process and integrated an array of creative thinking strategies such as "Brainstorming", "Six thinking hats", "SCAMPER", and "Bug-List-Technique". Students of this course were required to develop plans, based on the aforementioned creative instructional strategies, for their physical projects related to "industry 4.0" in one of the following six topics: Internet of Things (IoT), big data and cloud computing, cyber-physical systems, embedded systems, sensors, and mechatronics.

3.2 Participants

The research was carried out in the fall semester of 2017 in an “Industry 4.0” project-based course, which featured different trends of learning industry 4.0 as well as their application. The course lasted 18 weeks and included 48 participants (42 male and 6 female), who were assigned to 12 groups according to their chosen topics of the project. Most students in this course majored in mechanical engineering.

3.3 Procedure

Six stages of the CPS process were introduced to the students in sequence across a total of 3 sessions, each of which lasted 3 hours. All of the 3 sessions required students to work the newly learned knowledge at the newly introduced stage into their project. Creative teaching strategies such as Brainstorming, Six Thinking Hats, SCAMPER, and Bug-List-Technique were taught during the course. Each group of students had to complete a worksheet at each stage.

In Huang’s study [23], innovative thinking, which includes cross-categories, multiple-direction, reverse, and originality thinking, and adaptive thinking, which includes mono-category and enriching thinking, are the two constructs for measuring students’ level of divergent and convergent thinking. A subsequent evidence-based evaluation, Revolutionary Drawing, offers a new testing tool, which was adopted in the present study for identifying improvement in students’ level of creativity.

4 RESULTS

A total of forty-eight cases were available for quantitative analysis. Table 1 shows the result of paired sample t-test, which used students’ total scores from the pre and post tests to evaluate their potential progress in creativity. Results indicate a significant improvement ($t=-7.23$, $p<0.001$).

Table 1. The Pair Sample T-test between Pre & Post Total Scores of Creativity Test

	Mean	N	SD	<i>t</i>	<i>p</i>
Total scores(pre)	100.02	48	41.10	-7.23***	0.000
Total scores(post)	167.10	48	63.22		

*** $p<0.001$

Table 2 displays the descriptive statistics of students’ scores in innovative creativity as well as adaptive creativity. Paired sample t-test was adopted both in the analysis of students’ innovative and adaptive creativity. Whereas significant difference ($t=-7.063$, $p<0.001$) was found on innovative creativity, there was no significant difference ($t=-1.864$, $p>0.05$) on adaptive creativity. These findings suggested that students made improvements in terms of innovative creativity but not quite as much in terms of adaptive creativity.

Table 2. The Pair Sample T-test between Pre & Post Innovative Creativity and Adaptive Creativity

	Mean	N	SD	<i>t</i>	<i>p</i>
Innovative Creativity(pre)	98.25	48	40.76	-7.063***	0.000
Innovative Creativity(post)	164.15	48	63.22		
Adaptive Creativity(pre)	1.77	48	2.44	-1.864	0.069
Adaptive Creativity(post)	2.96	48	3.52		

*** $p < 0.001$

Innovative and adaptive creativity are the two constructs of creativity, and innovative creativity includes four types of thinking, cross category thinking, multiple-direction thinking, reverse thinking, and originality, while adaptive creativity includes mono-category thinking and enriching thinking. Paired sample t-test was adopted to analyze how students' creative thinking changed and how the six types of thinking are related to one another through the course. As indicated in Table 3, significant differences were found in terms of innovative creativity, including cross-category thinking ($t = -7.51$, $p < 0.001$), multiple-direction thinking ($t = -2.49$, $p < 0.05$), reverse thinking ($t = -3.23$, $p < 0.01$), and originality ($t = -5.88$, $p < 0.001$). However, no difference was found regarding adaptive thinking, which includes mono-category thinking ($t = 0.00$, $p > 0.05$) and enriching thinking ($t = -0.94$, $p > 0.05$).

Table 3. The Paired Sample T-test between 6 types of thinking

	Mean	N	SD	<i>t</i>	<i>p</i>
Cross category(pre)	50.00	48	18.33	-7.51***	0.000
Cross category(post)	82.50	48	27.56		
Mono-category(pre)	0.83	48	1.42	0.00	0.092
Mono-category(post)	1.63	48	2.82		
Enriching thinking(pre)	0.94	48	1.92	-0.94	0.354
Enriching thinking(post)	1.33	48	2.09		
Multiple direction thinking(pre)	6.25	48	5.79	-2.49*	0.016
Multiple direction thinking(post)	9.31	48	8.53		
Reverse thinking(pre)	4.81	48	5.80	-3.23**	0.002
Reverse thinking(post)	9.63	48	10.07		
Originality thinking(pre)	37.50	48	18.39	-5.88***	0.000
Originality thinking(post)	62.71	48	29.08		
Total scores(pre)	100.02	48	41.10	-7.23***	0.000
Total scores(post)	167.10	48	63.22		

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

5 DISCUSSION

In the present study, CPS process, which includes problem identification, problem

delineation, information gathering, idea generation, idea evaluation and refinement, and idea implementation, was integrated into an “Industry 4.0” project-based course for researchers to investigate how different types of creativity affect students’ creative performance. Pretest-posttest Revolutionary Drawing was implemented as a tool to evaluate students’ progress in creativity through their participation in the CPS process.

A significant improvement in creativity was found in students’ test results, implying that the application of CPS process had a positive influence on students’ creativity. Results also indicated that different types of divergent thinking are closely associated with one another in their making of innovative creativity. It is also indicated that innovative creativity had a significant impact on students’ total score of creativity. These research findings imply that the CPS process is effective. Students learned to put their imagination into work as groups and were able to generate diverse solutions by thinking out of the box. When interviewed, many students gave credit to the CPS stages, which, they described, “helped them think more systematically.” One student said, for example, “the structure of this course helped me organize many ideas.” Nevertheless, when asked, “which one do you find more difficult, diverging ideas or converging ideas?”, most interviewees chose the latter. One student said, “converging ideas is challenging because we had no means of evaluating the feasibility of ideas generated among ourselves.” Another said, “converging ideas is rather difficult since we often had a hard time separating valuable ideas from bad ones.” We believe that these responses correspond to the non-significant results regarding mono-category thinking and enriching thinking, which are both aspects of adaptive creativity.

6 CONCLUSIONS

The purpose of the present study is twofold. First, it explores the influence of the CPS process on creativity among engineering majors in a project-based course on Industry 4.0. In addition, the present research integrated a problem-based learning approach and thematic practice targeted at college students, aiming to enhance creativity through team cooperation. Significant improvement in divergent thinking was found in a paired sample t-test analysis using Revolutionary Drawing. However, no significant improvement was found in students’ convergent thinking. Results indicate that this course design favored students’ innovative creativity over adaptive creativity.

For future research, we suggest more varied CPS methodologies to be employed to extend choices and varieties available for as many aspects of creativity as possible in order to be applied in more diverse programs and course designs in college.

7 ACKNOWLEDGMENTS

This research was supported by a Grant from the Ministry of Science and Technology, Taiwan (MOST 104-2511-S-011-007-MY3).

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**Has the engineering school trained you to innovate?
Higher apprenticeship students' progressive innovation skills development.**

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Conference Key Areas: Engineering Skills

Keywords: Engineering skills, Innovation, Students' perception

INTRODUCTION

Globalization has progressively given a new definition to competitiveness. Due to their market expansion, companies have to cope with an increasing number of competitors. Innovation and opening up of the market to novelties are, thus, of outmost importance, and companies must cope with it. Innovation has also become a new standard for differentiation since it is the only process through which a company can propose something new. The (exact) same reasoning applies to engineering schools, since they are now open to foreign students and still consider visibility as a key element for a successful recruitment. Both students and professors now have the possibility to choose amongst all the schools in the world where they want to study or teach.

Top French engineering schools, 'grandes écoles', have trained the elite for the highest ranks in the society since the 17th century [1]. Until 1837, the engineers were former students of state schools: Military Engineering, Artillery, Arsenal, Mines Bridges and Roads were considered as the most successful innovators. However, even if engineer's skills are considered as the main investment to develop a successful innovation strategy [2], these high-end profiles often use their competencies in managerial positions and barely spend a few years with scientific-engineering occupation in technical fields. Using and taking innovation into account

for business purposes thus replaced the vision of innovation as a sole application of science with a new vision of innovation as a way to enhance competitiveness. This observation still stands today: “per capita, the number of start-ups launched in France is three times less than in the United States and for the number of patents registered with the World Intellectual Property Organization, two times less.” [3:p9]

In view of these observations, innovation in French engineering school becomes increasingly significant. As the very concept of innovation appears when technique is not taught as a reproduction of the world anymore but becomes a conception of the world [4], a technical thought emerges. The stake is now to train engineers able to link technique, business and innovation. Hence, apprenticeship students, benefitting from both academic technical inputs and business relationship with a real mission to carry on in their companies, need to be targeted. Over the past twenty years, lots of efforts have been made to improve apprenticeship training in engineering schools and, at the same time, the profession of engineer has evolved [5].

The objective of our study is to bring a better understanding of engineering apprentices' perception of their innovation skills. Therefore, we will try to answer the following questions:

- Do students consider they have been delivered an appropriate training to face the innovation challenges they will meet in their companies?
- What skills do they value as the most important for innovation purposes; and are they the best taught within their schools?
- To what extent does the otherness of the apprentices contribute to their training in innovation?

To answer these questions, we would like to explore the training of French higher engineering apprentice students, and particularly their innovation training program. A first part will deal with the bibliography study to help us understand the context. After that the methodology of study will be detailed, paving the way for the results. Eventually, the most interesting findings will be analyzed and compared to expectations and to the survey that was launched last year. The final section also showcases perspectives brought by this study, while still pointing the limitations out.

1 THEORETICAL BACKGROUND

Increasing competition from different companies in the industrial sector pushes them to require their engineers to innovate, so as to stay constantly ahead of others. Thus, to prepare future engineers to be as effective as possible when they join the workforce, engineering schools need to adapt their teachings [6]: subjects that were not taught in such courses before now take an important place in the curriculum (communication, teamworking ability or intercultural thinking for instance). Thanks to those multidisciplinary teachings, students will be prepared for all kinds of situations they may encounter in their future careers. Passow [7] highlighted that these soft skills are perceived as the most important competencies – before science – by the graduate engineering students.

As innovation is a large subject and is exploited by many researchers, lots of definitions exist. Among those, we can note the Oslo Manual that is the most frequently used definition, which describes innovation as "the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations" [8:p46]. Innovation does not only involve the creation of innovative objects, such as smartphones or cars, but is also about social relations, marketing or communication. According to students, the interest is not to

be exclusively technical engineers but also to bring added value to the company. These multidisciplinary and ability to innovate enable students to climb easier on the hierarchical ladder, to obtain an ever-greater influence within the company and, above all, to gain an understanding of their ever-changing surrounding environment.

To companies, recruiting innovative engineers is crucial. According to Leiponen [9] (2005), “there are statistically significant complementarities between technical skills and innovation”. Indeed, Walton demonstrated in 2003 [10] that more than three quarters of managers regard creativity and innovation as vital for a company. These managers will thus choose innovative people to constitute their teams. Borrás and Edquist [11] (2015) also highlighted the fact that “organizations need to tap into external competencies in order to be able to reach its own innovation targets”. Freeman and Soete [12] (1997) went further, concluding: “not to innovate is to die”.

In this list of skills needed for innovation, Toner [13] observed that business, information technology and marketing are amongst the ones often observed in the innovating firms. There has already been some profound interest leading studies about the skills required for innovation; and even if our study does not aim at completing these, it is however important to emphasize that problem-solving abilities, multiple approach attitude, flexibility and responsibility, which have been identified as keys, are now always soft-skills.

Higher engineering schools are at the forefront of innovation trainings, due to the technical subjects they teach and due to the capacity they have to evolve and to propose more complete trainings, incorporating to incorporate soft skills. Nevertheless, they cannot be held solely responsible for the backwardness in innovation training [1]. Before joining engineering schools, most French students have attended preparatory classes that are in reality a two years high-level scientific course. On the one hand, these classes do give students true scientific capabilities but, on the other hand, they limit the time students spend working on projects, whether they are master's thesis or innovative student' contests [14]. At the same time, French engineers activities are not always technical. The Engineering Council (2010) [15] highlighted that approximately half of the British or German engineers are working in research or design, and only one third in France. If Munjal & Kundu (2017) [2] explained the historical reason, the fact remains that the training part dedicated to research activities in France is really smaller than in other countries. A good illustration of that phenomenon is that 15 % of US master's students pursue their studies with a PhD, while only 4 % of the French do the same.

However, the apprentices may step apart from other students, as most of them did not receive the same previous background: a majority comes from technical degrees – which are in France much more practical – and thus has already worked on real projects for most of them. In this framework, apprentice engineer training should take advantage of the different levers offered by the otherness that its students developed. It would then fully benefit from the different capabilities of this student category. This can also benefit to “regular” students in mixed classes. [16]

2 APPLIED METHODOLOGY

Our research is based on both our literature review and our previous research study, and aims to complete the findings of last year study. Thus, our work is in the continuity of our previous study [17] and used the same sequential exploratory research design. In the framework of this first exploratory study, experimented engineers of various fields were interviewed to define which the most relevant innovation skills are. Then, those different skills were confronted to students'

perception through an online survey, aiming to determine whether or not students agree on this selection, and if they feel adequately trained to innovate.

A new online survey achieved the 2018 data collection. The same 2017 qualitative study results have been used to design this quantitative multiple-choice form in order to keep a similar sample of proposed answers. However, the survey differentiates the status of the respondents to focus on the apprentices. Some filter-questions have also been used to sort people out according to how long they did study in engineering school (first, second, or third year students) and how many years of experience (<1, 1-3, 3-5, >5) they do have. Such questions were also employed to sort out respondents according to the previous background they had before joining their respective schools (university, technical degree, or work in a company). Another difference with the previous study is that the survey has been widely broadcasted, enabling students of ten different engineering schools to express themselves. The common points between those ten engineering schools are:

- They have a higher engineering apprenticeship curricula,
- They do care about innovation as they met the opinion pollster at a student conference on this topic (pollster just presented the research at that time, and surveys have been sent online afterwards),
- Teachers accepted to forward the survey to their students.

The first set of questions aimed at knowing how apprentices engineering students perceive the 18 skills considered as important to innovate, while the second one helped us to draw up a list of their feedbacks regarding their trainings: do they think their school trained them well to innovate? Those two sets of questions were both needed to compare our answers with last years' results to underline that they are consistent. The need was also to check if there are still some contrasts, related to the sample disparity: apprentices sample vs students sample (students sample incorporate both apprentices (~20%) and "regular" (~80%) students).

Once we collected apprentices' opinion on their skills and their training, the last set of questions has been used to question them about how they would modify their courses to be better prepared to innovate. Let's remind that these students already have a professional mission, and that most of them are in contact with innovation within their companies. The propositions that have been incorporated in the form were those discussed and developed by a team of nine engineering apprentices of our school. They are a reflection of what those students already tried (e.g.: courses, project, entrepreneurial curriculum, business seminars) both at school and outside, and what they knew as already existing in others engineering or business schools.

The heterogeneity of our sample lies in the fact that questioned students are coming from various fields of study (e.g.: mechanics, electronics, biology, computer sciences, telecommunication, finance ...) or are specialized in different areas (as diverse as naval architecture, food science, or embedded systems for example), and in the ten schools sounded out. Respondents were asked to answer using a five-point Likert scale, so that analysis is rigorous and easy. We post-processed 144 different answers from 10 schools.

3 RESULTS

The results of our online survey show that students are aware of the importance of innovation in their future engineering profession. This is in accordance with the qualitative survey carried out by [Author1] (2017) [17], which indicated that confirmed engineers unanimously expressed the capital function of innovation to be a good contemporary engineer.

In order to understand how apprenticeship students perceive innovation, we asked the participants in our survey to assess the importance of 18 innovation skills on a 5-point Likert scale (0 being "not important" and 5 being "indispensable"). The results of this question clearly show that the most important skills for innovation are objective outlook (4.38/5), open-mindedness (4.33/5), and creativity (4.19/5).

We asked students to evaluate how their engineering schools prepare students for these same innovation skills. The comparison of the results for the two questions is illustrated in Figure 1.

Our results indicate that higher apprenticeship students consider that their engineering schools mainly prepare them to work as a team (3.86/5), multidisciplinary (3.75/5) and knowledge (3.71/5). These skills are indispensable in the technical engineering profession but are not vital to become innovative. It can be noticed that the three competencies cited previously as the most important in innovation are respectively valued at 3.01/5, 3.16/5 and 2.45/5. The difference between the required and real training level is the most important for these skills (Table 1). It has therefore to be noted that engineering schools are not focusing on the development of innovation skills but rather on the development of technical skills and knowledge, which will enable their student to become an efficient engineer on the technical level.

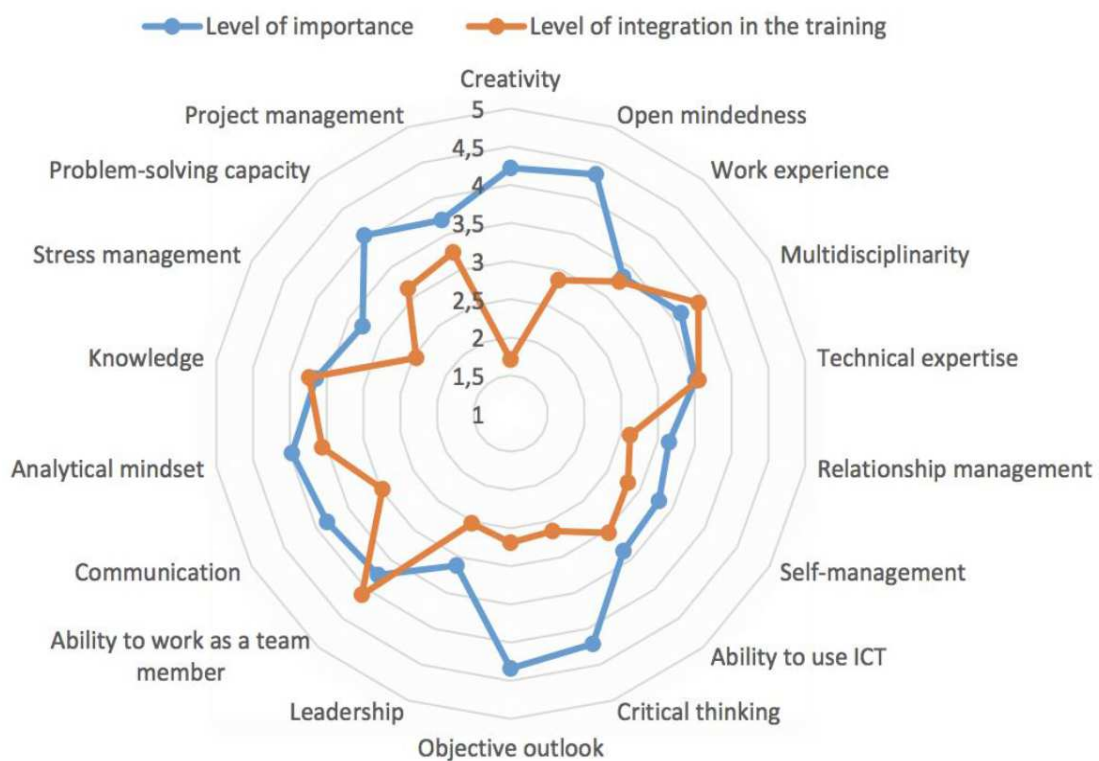


Fig. 1. "Level of importance vs. Level of integration" for innovation skills

Table 1. Marks and difference for each skill

Skill	Skill for innovation /5	Skill taught at school /5	Difference
Creativity	4.19	2.45	1.74
Open mindedness	4.33	3.16	1.17
Work experience	3.13	3.40	-0.27
Multidisciplinarity	3.53	3.75	-0.22
Technical expertise	3.29	3.54	-0.25
Relationship management	2.82	2.98	-0.16
Self-management	3.18	2.65	0.53
Ability to use ICT	3.41	3.71	-0.30

Critical thinking	4.08	3.11	0.97
Objective outlook	4.38	3.01	1.37
Leadership	2.75	2.40	0.35
Ability to work as a team member	3.75	3.86	-0.11
Communication	3.78	3.30	0.48
Analytical mindset	3.73	3.48	0.25
Knowledge	3.22	3.71	-0.49
Stress management	2.93	2.10	0.83
Problem-solving capacity	4.03	3.47	0.56
Project management	3.68	3.55	0.13

We then asked all participating students to evaluate their engineering schools' trainings according to how they prepare them for innovation. We split answers into three groups corresponding to the three years of the engineering apprenticeship cycle. Plus, we compared the results of the three school years in order to see if there was an evolution of the students' feelings towards their preparation for innovation. Results show that upon arrival in the first year of engineering school, students feel rather prepared to innovate (3.42/5). These are more students' expectations than a true feedback on training. On the contrary, at the end of the training cycle, in third year, students feel much less prepared for innovation (2.23/5) and highlight the fact that innovation is not a priority for engineering schools. Second-year students, in the midst of their training, evaluate this criterion at 3.01/5, which reveals a gradual declination as the training progresses. It is therefore possible to see that the engineering schools do not meet the innovation expectations of the various students integrating the three-years-course.

Finally, we asked the apprenticeship students if their academic or professional experience was the best way to develop innovation skills. Almost 60% of respondents answered that the combination of academic training and work experience is the ideal way to train for innovation. Interestingly, 38% of the students believe that professional experience is sufficient to develop this capacity, and only 2% believe that academic training is sufficient. The apprenticeship students show clearly, thanks to their experience, that the academic training only is not sufficient and that the curriculum they carry out, combining work and studies, is the ideal way to develop strong innovation skills.

The results we present in this paper should be discussed and compared to others, both from our previous study and from the literature. Thereby, apprentices' words about the needs of academic and professional experiences in their course are not a surprise. It has already been highlighted [18] that apprentices (who are shifting between a company and a school on a few weeks regular basis) improve their skills faster compared to "regular" students. This is especially right when it comes to responsibility and autonomy, two competencies that need to be mastered before being able to turn to innovation in an organization.

Also, what students feel, regarding their lack of preparation to innovate, was already known. Last year survey [17] clearly showed that 49.7% of the 2017 sample "do not feel sufficiently well-trained to innovate". What is more surprising, and this is the value of our study, can be found in the evolution of this feeling throughout the school curriculum. Indeed, we do not just confirm the previous results, but we also feature that engineering schools may fail in their duty since apprentices feel less prepared when leaving school. Before jumping to conclusion, let us remind that students still feel well prepared about their technical skills and that it confirms last year's finding about the quality of the engineering technical education. Thus, it could be said that the sensitivity of apprentices also evolves through their training on innovation topics,

and that students may gain awareness regarding a potential lack of competencies during their training.

4 CONCLUSION

To conclude, we can relate one more time that innovation skills are today needed for companies, in order to keep their position in the globalized markets. Companies are aware of this, and it seems that students also perceive that innovation skills are quite important in their training. However, this study shows that higher apprentices engineers perceive themselves as not (fully) ready to innovate. It looks like they hold their schools responsible for that, as they concentrate mainly on the development of technical knowledge and not sufficiently on the development of innovation skills and competencies. Moreover, students' expectations at the beginning of their training regarding courses and skills to be developed are not met, based on the feedback given by final year students.

A first comparison with last year study results highlights that there is no systematic discrepancy between hard and soft skills, and that students feel at ease in different competencies in those two domains, even if they also express a lack of confidence in other competencies. The balance takes place in other places, and the competencies for which a lack of training has been noticed are specifically the ones involving innovation; creativity ahead.

Our research also suggests that the best innovation training would be a mix between academic courses and professional experiences. Hence the apprenticeship appears to be the better formula to gain innovative skills, and even more when engineering schools seems unable to reach students expectations. The results of our survey suggest that the link between schools and companies should be reinforced to ensure a higher level on innovation capacity for higher-engineering students.

It should yet be noted that this study only concerns apprenticeship students from ten schools, and only partially reflects the reality of the whole country and of this type of training. However, this survey reveals the shortcomings in learning innovation in engineering schools.

To push the research further, we would like to add to last years and this year's comparative students' responses the view of their teachers, and particularly those implicated in the courses training. Are they aware of their students' feeling about their lack of preparation for innovation? Do they know that students would benefit from closer links to companies? Is there possible to improve higher engineering apprentices training? This study, combined with last year findings could give us a better understanding and a clearer view on how to develop engineering training, while always reducing the gap between reality and requirements.

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Wanted: super(wo)man - A study to define professional roles for future engineers by distinctive professional competences.

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Conference Key Areas: Engineering Skills, Career Guidance, University–Business Cooperation

Keywords: professional roles, professional competences, engineering skills, labour market, employability

INTRODUCTION

Excellent communication skills, work independently, a big team player, fluent in English ... This is just a selection of professional competences mentioned in vacancies addressed to young engineers. Unless they are super(wo)man, it is impossible for engineering students to acquire a mastery level in all professional skills [1].

Different types of jobs are associated with different demands. The professional role is relevant for explaining the importance of competences [2]. For example, some competences are more relevant for an engineer working in maintenance than for one working with customer relations. Students who can identify their strengths, become more specialized and more confident in a professional role, will increase their employability [2–4].

Cech et al. (2011) identify two dimensions of professional role confidence [3]. (1) Expertise confidence refers to the confidence students have in a set of competences required in a kind of profession. (2) Career-fit confidence encompasses the confidence that a professional role will suit the students' particular interests, needs and values. Where career fit is more about students' alignment with a certain profession, the expertise fit is about students' assessment of their own abilities and competences.

Both dimensions are addressed in the PREFER project (Professional Roles and Employability for Future EngineerRs). This European project aims to reduce the skills mismatch in the field of engineering by increasing students' awareness of their strengths, weaknesses and interests by offering them opportunities to actively explore the different engineering roles [5]. Not only do we want to provide students a better understanding of what it is to be an engineer, we also want to provide students a better understanding of what kind of engineer they want to be.

Hence, the aim is to design a validated Professional Roles Framework for Future Engineers. The framework consists of three roles, independent of domain or sector and described by typical professional competences [5].

This paper focuses on the performed research about the key competences per role. In a two hour round table discussion, 12 expert panels of engineers and HR managers reflected on the key competences of the three roles. The result is a list of competences per role that picture the specific competences industry and business organizations require from young engineers to be successful in that professional role.

1 PROFESSIONAL ROLES FOR FUTURE ENGINEERS

1.1 Professional competences

Many studies focus on the essential professional competences in the field of engineering, but it is often presumed that all engineering careers require the same balance of technical and professional skills [6]. However, some studies demonstrate that different engineering roles require different skill sets. Brunhaver et al. (2013) asked alumni to rate the importance of a set of 20 professional competences in their job. Results indicate that for example problem solving and analytical skills were deemed equally important in all engineering sub-occupations, but communication was less important in some and more in others [6]. Male et al. (2011) identified competences were inter-related and their importance varied across job tasks and work contexts. They question the assumption that professional competences are the same for all jobs [7].

1.2 Professional roles

A Professional Roles Framework for young engineers was designed with three roles, based on the value disciplines of Treacy & Wiersema [8]: operational excellence (engineers who focus on process optimization), product leadership (engineers who focus on radical innovation) and customer intimacy (engineers who focus on tailored solutions). Previous research by Hofland (2015) and De Norre (2016) tested whether the model was recognized by the different stakeholders (industry and higher education). More specifically, 92% of the HR representatives and engineers that filled in the questionnaire of Hofland (N=122) confirmed they recognized these roles within their company [9]. De Norre mapped the roles to the learning outcomes of the KU Leuven Faculty of Engineering Technology and investigated how the roles could be implemented in the curriculum. Students were able to indicate a preference for one of these roles [4].

1.3 Competency profiles

Based on the previous research, the professional roles will be optimized by developing competency profiles for each role. A competency profile pictures the essential and typical professional competences required in a particular role.

The raised research question in this paper is the following:

“Which professional competences do engineering students need to possess in order to be successful in one of the professional roles?”

2 METHOD

A **modified Delphi method** was used to develop competency profiles. The Delphi method is widely used across numerous disciplines as a method to seek expert opinion in an iterative structured manner [10]. The methodology was chosen for its potential to simultaneously explore similarities and differences of opinions.

The Delphi technique is a consensus development technique with the following characteristics: anonymity, iteration and controlled feedback [11]. We modified this technique to a mixed method that combines a collection of quantitative data with the qualitative methodology of a group discussion in a face-to-face round table setting.

2.1 Participants of the expert panels

Experts were identified as engineers and HR managers or recruiters with expertise in hiring engineers. Both parties can make a good estimate of the required competences for a certain role.

We set up 12 expert panels. 11 panels were organised in companies from different sectors: construction, nuclear & energy, telecommunication, automotive, 3D printing in manufacturing and biomedical technology, automation, (micro-) electronics & IT, chemical and nutrition. A 12th mixed panel was organized with experts from different sectors and from companies with different sizes (start-up, SME, large company, independent entrepreneur).

During a preliminary meeting that took place before the expert panel, we presented the research project to our liaison in the company. The liaison selected the experts within his or her company according to the following criteria:

1. 6 to 8 engineers from different professional roles, preferably of different age and experience;
2. 1 or 2 recruiters or HR managers with expertise in hiring engineers;
3. male and female experts.

Eight participants (min. 6, max. 10) are considered a good panel size to provide enough input for the discussion and encourage a good group conversation [12].

Expert	Female	Male	Total
Engineer	8	61	69
Engineer with HR expertise	0	3	3
HR	8	7	15
Total	16	71	87

Table 1. Participants of the 12 expert panels

2.2 Panel structure

The expert panels were led by the researcher-observer and the moderator. The moderator, an expert in talent management and HR screening tools, led the actual expert panel without bias (Figure 1, phase 2 and 3). The next paragraphs will describe the different steps of the panel.

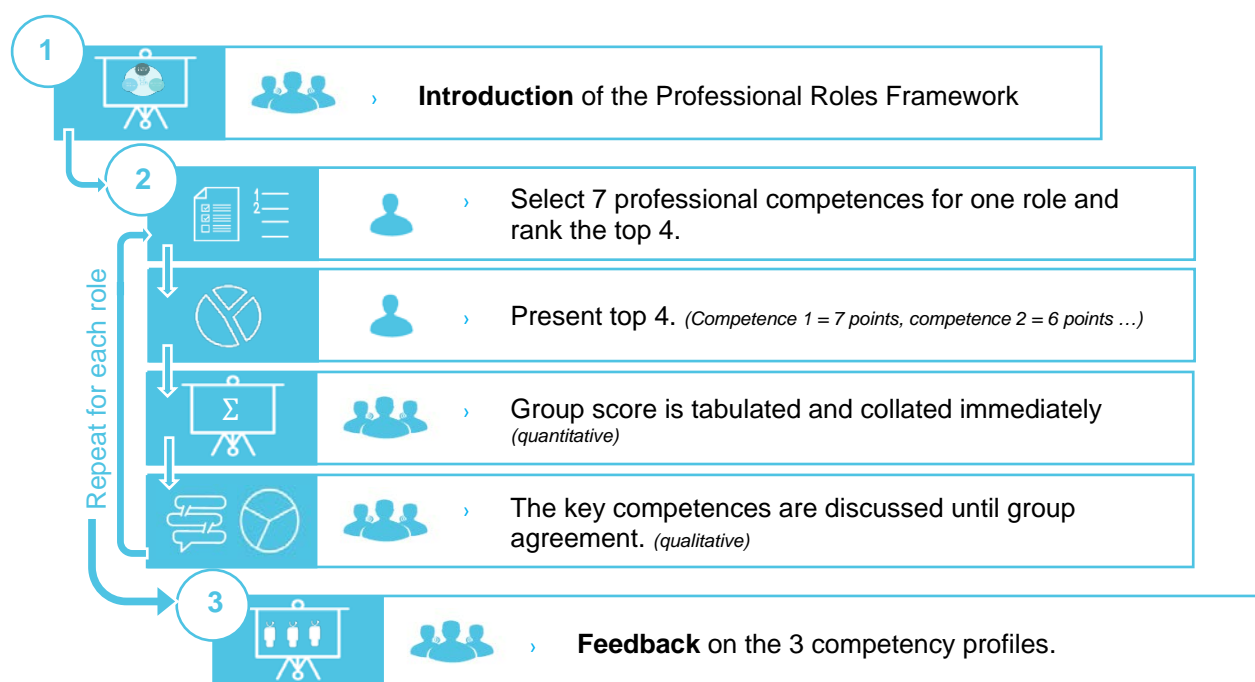


Figure 1. Different steps of an expert panel

2.3 Phase 1 : introduction of the professional roles

The researcher explained the model to the experts using the overview of the different roles in table 2. Competences were not mentioned to define the roles. The participants were allowed to give feedback to the model or ask questions to clarify the roles.

	OPERATIONAL EXCELLENCE	PRODUCT LEADERSHIP	CUSTOMER INTIMACY
	PROCESS OPTIMIZATION	RADICAL INNOVATION	TAILORED SOLUTIONS
CORE PROCESSES	<ul style="list-style-type: none"> Focus on increasing efficiency & reliability Cost, logistics & resource efficiency Quality assurance: high reliability Sustainable maintenance Subcomponent analysis & priorities Standardization & flow optimization: process (re-)design ... 	<ul style="list-style-type: none"> Focus on new cutting edge products or processes Research: high level of specialised knowledge Fast development Commercial exploitation Market exploration (internal + external market) Superior branding ... 	<ul style="list-style-type: none"> Focus on customer satisfaction Individual customer needs analysis Client-centred customized solutions Client acquisition & establishing long-term client relations Integration and implementation in client systems Follow-up support service & training ...

Table 2. Three roles for young engineers, defined by core processes

2.4 Phase 2 : Individual assessment & group discussion

Principles and guidelines

The moderator explained the principles and guidelines to the experts:

- One exercise consists of 2 rounds: (1) individual assessment and (2) group discussion
- The exercise is finalized when the experts reach consensus about the competency profile or decide that no consensus can be reached.
- Consensus is reached when the experts agree on 6 to 10 competences that define the role.
- The exercise will be repeated for each of the three roles, with a final feedback moment at the end (phase 3).

Selecting competences individually

The participants received an extensive list of 64 professional competences, based on the Big Eight Competences, described by Bartram (2005) as a model of performance in the workplace. The framework is often used to develop diagnostics tests in recruitment [13]. The competence list is available on request.

The experts selected individually seven competences that seemed to be the most crucial ones for each particular role. Afterwards, they were asked to rank them from most important to least important.

Feedback on individual outcomes

The experts presented the top four of the selected competences in order of importance. No discussion was allowed to avoid that participants would feel limited to express their opinion. The competences were tabulated and scored simultaneously by the researcher. Competence 1 got seven points, competence 2 got six points etc. When all the experts had presented their top 4 competences, the researcher could easily calculate the final group score.

Group discussion

The group score was presented to the panel. The moderator indicated certain particularities, e.g. a clearly defined top 3 or a less distinctive top 5. The top 5 (or more in the case of equally scored competences) was highlighted and presented as the key competences that picture the role. Based on this information, the group discussion started. Experts could add competences that were mentioned but did (not) make it to the top or decide a competence was ranked too high. They also had the opportunity to add competences that were not mentioned in the individual outcomes.

The group score fed the discussion. The scores will not be used for further analysis as the ranking changed through the group discussion. The discussion ended when consensus was reached on six to ten competences or when the panel decided they could not reach consensus.

2.5 Phase 3 : feedback on group outcomes

When phase 2 was repeated for the three roles, the competency profiles were presented again to the panel. The experts had the opportunity to confirm the consensus or to make adjustments after comparing the three profiles.

3 RESULTS

All the panels reached **consensus** on the competency profiles. As the panels were organised in-company, the company culture and strategy might have facilitated the consent between the experts. The mixed panel also reached consensus, but the experts had to argue more profound and illustrate with more examples why a competence was more or less relevant.

One panel managed to describe the roles by five competences. The other panels pictured the roles by six to ten competences (**average eight competences per role**). After a few panels, clear patterns appeared in the competency profiles. The point of data saturation was reached in the 12th panel: no new elements were added in the group discussions that were not mentioned in one of the previous panels.

The competency profile of the operational excellence role seemed the most difficult to construct. In all panels, the individual outcomes resulted in a longer list of essential competences than the lists of product leadership or customer intimacy. The top scores were less distinct (see also table 3) and the discussion was more intense. Nonetheless, the experts recognised the importance of this role and declined to advice a redefinition of the role or to scale the framework with a fourth role. The more extensive outcome is

likely typical for the role of operational excellence, which can include various functions, tasks and responsibilities.

Although the competence list provided a brief and comprehensive definition per competence, the experts identified **similar competences** (competences labelled differently but with a comparable meaning): networking & relation building and stress tolerance & stress resistance. We combined these competences in the final data analysis.

The outcomes of the twelve expert panels resulted in a collection of:

- 29 competences associated with operational excellence
- 28 competences associated with product leadership
- 22 competences associated with customer intimacy

Out of the 64 initial competences, a list of 41 competences was drawn when combining the outcomes of the three roles. Fifteen **competences overlapped** in the three roles: clear communication, client focus, coping with criticism, creativity, focus on results, initiative, negotiation, networking & relation building, perseverance, persuasiveness, planning & organisation, realism, solution oriented, stress resistance and team spirit / team player. A few competences overlapped only in two roles, for example responsibility appeared to be even more important for engineers in the role of operational excellence and customer intimacy.

When we limit the competences to those mentioned in at least four panels, the roles can be defined by eight to nine competences (table 3).

OPERATIONAL EXCELLENCE		PRODUCT LEADERSHIP		CUSTOMER INITMACY	
Competence	N	Competence	N	Competence	N
Positive critical attitude	10	Creativity	12	Client focus	12
Solution-oriented	10	Innovation	12	Networking & relation building	11
Focus on results	6	Client focus	7	Clear communication	10
Planning and organisation	6	Initiative	7	Negotiation	9
Clear communication	5	Out of the box thinking	7	Capacity for empathy	8
Initiative	5	Persuasiveness	6	Focus on results	8
Creativity	4	Vision	6	Solution-oriented	7
Networking & relation building	4	Conceptualisation	5	Stress resistance	5
		Perseverance	5		

*Table 3. Competency profiles per role based on the outcomes of 12 expert panels.
(N = number of panels that mentioned the competence)*

Also in the limited competency list, we observed overlapping competences, mainly between operational excellence and customer intimacy (4 overlapping). During the group discussion, experts **nuanced the overlapping competences**. For example, client focus: an engineer in the role of product leadership must be aware of the prospect client markets for new innovative technologies, while an engineer in the role of customer intimacy must be able to attune his or her actions to the needs and wishes of a particular client.

A **mixed meta panel** will be organised to consolidate the results of the 12 panels by an all-decisive exercise. This panel will address the possible influence of company culture to the panel consensus and the nuances made in overlapping competences. The meta panel with experts from different sectors, SME's and large companies will be organised according to the same criteria as described in 2.2. The final outcomes will be the subject of another paper (in progress) in which the focus will also be on the practicability of the final framework.

4 CONCLUSION

Higher education programmes are expected to prepare students for future professional work experience. Students are expected to learn how to become effective professionals, ready to handle the demands associated with his or her job shortly after graduation to improve their employability [2]. Therefore, it is interesting to know what key competences are required for a fresh engineer entering the labour market [7].

This research identified different professional competences for professional roles for future engineers. Via a modified Delphi method, 12 expert panels mapped competences to the three professional roles that were described in the Professional Roles Framework: operational excellence, product leadership and customer intimacy.

This resulted in three competency profiles made up of eight to nine key professional competences. Some competences are overlapping, for example 'focus on results' and 'networking & relation building' seems to be crucial competences in both operational excellence and customer intimacy. A mixed meta-panel with experts from different sectors, SME's and large companies will be organised to validate the outcomes of the 12 expert panels. The outcome will be a competency profile per role consisting out of six to eight competences.

In essence, the competency profiles give a clear picture of the essential competences that are required to be successful in a particular role and allow us to finetune the Professional Roles Framework for Future Engineers.

5 DISCUSSION

Male et al. (2011) recommend that engineering educators design their **programmes** with an understanding that diverse programmes and diverse graduates are desirable because different jobs place different importance on the professional engineering competencies [7]. Such programmes can help students to develop a realistic understanding of engineering work and the different competencies required by different engineer roles [6].

The Professional Roles Framework for Future Engineers is a valuable instrument to adjust the curriculum in this regard. The competency profiles with an aspiration to career perspectives can be easily implemented in existing curricula, when framing activities with industry, working on specific competences etc., but also extracurricular, for example extra activities including career guidance.

In future work of the PREFER project, the competency profiles will be used to develop a tool for students to help them reflect on their strengths and weaknesses and their future professional role(s). The outcomes of this research will be used to further investigate how acquaintance with the professional roles will increase students' professional awareness and align their expectations with the work field.

A nice edge effect of these expert panels is that the participants were triggered to reflect on the **company's recruitment policy**. Almost all the experts asked to receive the final outcomes. One company decided after the panel to revise their vacancies and make them more specific according to the competency profiles. These companies are no longer looking for super(wo)man. They prefer an engineer that fits the job.

6 ACKNOWLEDGMENTS

This work was supported by Erasmus+ programme of the European Union (grant agreement 575778-EPP-1-2016-1-BE-EPPKA2-KA) and is part of the PREFER project. The authors would like to thank BDO Human Capital for their support in moderating the expert panels and the experts for their time and effort during the panels.

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Quality of Multiple Choice Questions in a Numerical and Statistical Methods Course

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Conference Key Areas: Discipline-specific Teaching & Learning; Quality Assurance and Accreditation; another topic relevant to the conference but not listed above

Keywords: Item Response Theory, Multiple Choice Questions, Numerical and Statistical Methods

INTRODUCTION

The quality control of written examination is very important in the teaching and learning process of any course. In educational assessment contexts, Item Response Theory (IRT) has been applied to measure the quality of a test in areas of knowledge like medicine, psychology, and social sciences, and its interest has been growing in other topics as well. Based on statistical models for the probability of an individual answering a question correctly, IRT can be addressed to measure examiners' ability in an assessment test and to estimate difficulty and discrimination levels of each item in the test. In this work, IRT is applied to Numerical and

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Statistical Methods course to measure the quality of tests based on Multiple Choice Questions (MCQ).

The present study focuses on three school years, namely 2015, 2016 and 2017, more specifically on the 1st semester of the 2nd year of the degree course. It has involved more than 300 students in each year, and it points out questions (also called items) from some chapters of the program that were evaluated through MCQ. Emphasis is given on the range of item difficulty and item discrimination parameters, estimated by IRT methodology, for each question in those exams. We show where each partial exam explores ability levels: at a passing point or at more demanding levels.

After the application of IRT to each test, which was composed of eight questions, we got 48 item difficulty and item discrimination parameters. The application of standard boxplots shows few atypical responses from students in terms of extremal values of difficulty and discrimination, which corresponds to MCQ that deserve further attention.

We have concluded that the vast majority of questions are well posed considering that they are designed to focus on the cut-off point (passing/not passing). A proposed reflection, about the learned benefits from 'good' outliers and possible causes for those 'bad' items, suggests future improvements to classes, study materials and exams.

1 GENERAL

1.1 Context

Numerical and Statistical Methods is a curricular unit with those components isolated from each other and it makes part of the curricula of several engineering courses since its creation in 2004. Each component is examined in two folds with equal weights: using Open Questions and Multiple Choice Questions (MCQ), where only one out of four choices is correct. In 2014 we started using automatic digital scan correction of MCQ answer sheets [1] and in the years that followed, that were 2015, 2016 and 2017, we used exactly the same scheme for exam moments: the first three chapters of the numerical component (Errors, Interpolation and Numerical Integration) and the first two chapters of statistics (Exploratory Analysis and Distributions) were evaluated using MCQ.

Inspired by the question 'Do you evaluate your examinations in your courses?,' posed in a seminar [2], the quality of MCQ used to individual evaluation during those three mentioned years was investigated. It must be noted that the course has had a stable teaching staff and the same curricula during the study period.

We have been collecting data from the application of Item Response Theory (IRT), since we have started using an automatic correction method of MCQ. IRT model has a long tradition in social and psychology sciences, in what the analysis of personal traits is concerned, as well as in medicine courses to evaluate the quality of exams (e.g., [3]),. It has also been applied to engineering and other sciences (e.g., [4]), so this method is a widely used instrument for the study of the exams quality (e.g., [5]).

1.2 Item Response Theory Summary

In our context, an item (each posed MCQ) has a binary value as result - if it is correct it is valued 1 and if it is incorrect or ignored it is valued 0. A powerful feature of IRT in characterizing each item (question) is the so called latent traits [6]. They are called "latent" due to the fact that they are not directly observed. In IRT, the probability of an individual with ability $z \in \mathbf{R}$ to

respond correctly to each question can be estimated using regression models with one, two or three latent traits. In order to evaluate latent qualities of each MCQ, we propose a model with two latent traits: the difficulty and discrimination parameters by MCQ. Objectively speaking, the probability of an individual with ability z to respond correctly to MCQ (i), with difficulty (β_{0i}) and discrimination (β_{1i}), is estimated by a logistic function defined by

$$p(i, z) = \frac{1}{1 + \exp(-\beta_{1i}(z - \beta_{0i}))}, \quad i = \text{item}, z = \text{ability}.$$

The curve of this function is the Item Characteristic Curve (ICC) and an example is given in Fig. 1. For a given ability, we get the probability of choosing a correct answer to a given item (in this case, three curves for questions about the Poisson distribution, Normal distribution and Bayes rule).

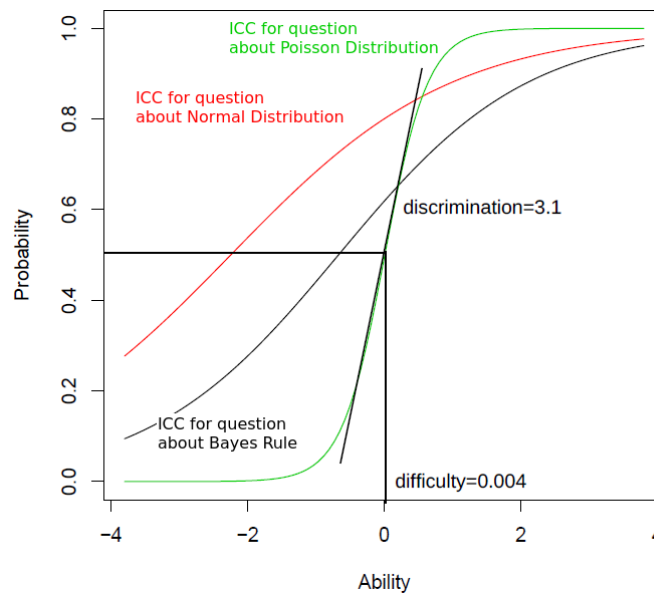


Fig. 1. Item Characteristic Curves (ICC)

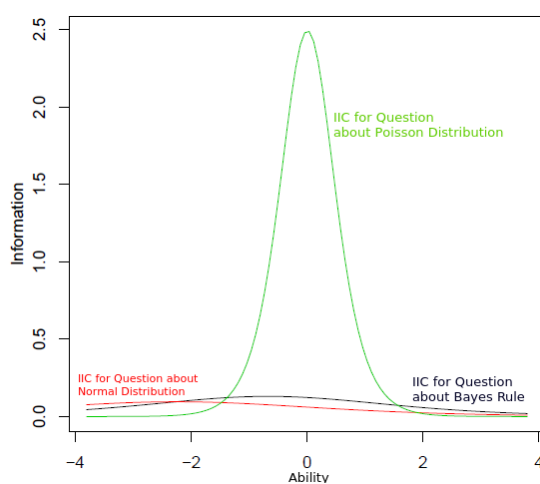


Fig. 2a. Item Information Curves (IIC)

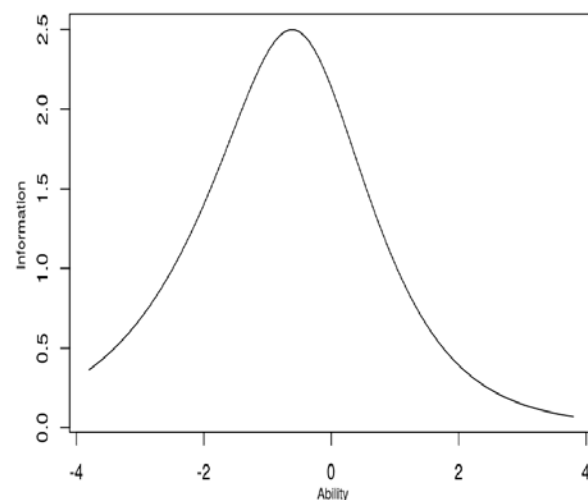


Fig. 2b. Test Information Function for 'Statistics/2015'

In the example above, the curve for the named 'Poisson' question, Fig. 1, has difficulty level $\beta_{0i} = 0.004$ and discrimination level $\beta_{1i} = 3.1$ (here i is the named 'Poisson' question). The difficulty parameter is described as the necessary ability to have 50% probability to answer correctly (median ability). The discrimination parameter is the slope of the curve at this point and it is intended to determine how well an item differentiates the performance of respondents. If a respondent presented lower ability to answer an item, we expect lower probability to answer correctly, and when a respondent presented higher ability to respond correctly, then we expect greater probability that his answer is correct.

Another informative curve is provided by the graphic of the Item Information Function, which is defined by a normalized version of the derivative $\frac{\partial p(i,z)}{\partial z}$. This curve gives a visual perspective on where an item is more discriminative for a given ability level (z). For instance, in Fig. 2a, the question about Poisson distribution is discriminating much more, among the range of ability levels, than the other two questions.

The sum of all Item Information Functions, over all items in a test, defines the Test Information Function (TIF). From its curve (an example in Fig. 2b), one can see if a test gives more information about the requirement for the passing grade ability or if it focuses on higher ability levels. An application of this curve, which is described in the next section, shows different ranges of ability being discriminated.

1.3 Application

We will start by mentioning the oscillatory behaviour of the required ability at each exam. The study was done by plotting a Test Information Function (see above), for each of the six tests in the three years under study. *Table 1* shows the ability unitary length intervals, for each examination, in which the curve has its peak of information (see in Fig. 2b that the unitary interval occurs in $[-1,0]$). These six intervals show an oscillatory pattern to differentiate ability. In 2015, the first test contained questions that showed that less ability was needed to answer correctly compared to the second test of the same semester. The same phenomenon happened in 2016, but with less magnitude. In 2017, there was an effort to evaluate ability to a more central level. However, the decision to use hard questions has produced a test in which the peak of information distances 3 units of ability from the first test in 2015. Questions in the second test matched the capacity to discriminate ability of the first test in 2015. We recall that these MCQ tests are only 50% of the student grade and, yet, no study has been done for the Open Questions.

Table 1. Most Informative Ability Intervals

2015		2016		2017	
Numerics	Statistics	Numerics	Statistics	Numerics	Statistics
(-2,-1)	(-1,0)	(-1.5,-0.5)	(-1,0)	(+1,+2)	(-2,-1)

1.4 Study of the Boxplot Outliers

Next, based on the IRT method, we have studied some Multiple Choice Questions (MCQ) that called our attention and are related to the previously presented oscillatory effect in ability demanding. As described in the introduction, we have studied the difficulty and discrimination parameters. IRT has been applied to six tests, containing eight MCQ each. We have made two standard boxplots for the 48 MCQ, one for each parameter. What follows is the study of

questions characterized by values of difficulty or discrimination that are outliers in one, or both, of the boxplots.

The boxplot describing the difficulty has values ranging from -4.7 to 404.4, where the standard values are from -3 to 3. There are six outliers' cases and, when removing them, we obtain the histogram of the difficulty parameter, characterizing 42 MCQ, in Fig. 3. We can conclude, for the course under study, that MCQ have typical values for the difficulty parameter in a IRT analysis. Half of the MCQ has been rated within the difficult level from -1.5 to -0.5.

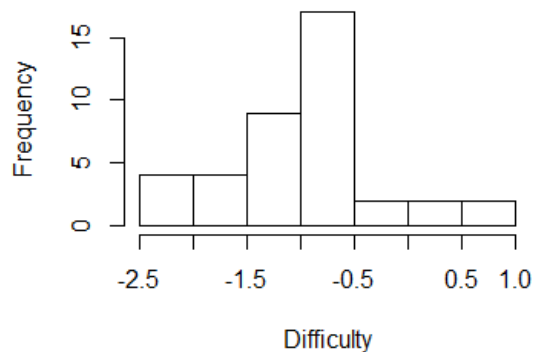


Fig. 3. Histogram of difficulty level estimates, after removing six outliers

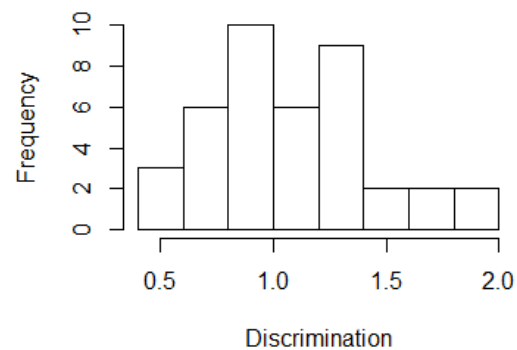


Fig. 4. Histogram of discrimination level estimates, after removing three outliers

In the case of the discrimination parameter, only three outliers have been observed for the 48 questions. After removing the outliers, the histogram in Fig. 4 shows good values for discrimination in the majority of the questions.

Next, we will present questions that cause the atypical behaviour. Although the correct answer is always identified as the first option, the questions and the options within each question were both mixed by the software (see [1]) in all the six exams.

1.5 Questions with small value of difficulty parameter

Three 'easy' questions were rated with difficulties -4.473 and -2.805, in the numerical part (years 2015 and 2017), and -2.845 in the statistical part (year 2016). The two numerical questions are about Lagrangian interpolation with three points and a standard trapezoidal integration. This simple type of questions is presented and practiced in several moments in classes. Therefore, we believe this is the reason for the required lower difficulty levels.

The next atypical question is a statistics question; see Fig. 5. A student, using only a bird-eye look and, without ability in statistics, easily and intuitively chooses the first two options as targets. At this time, it's easy to fulfil the task because the correct option is very close, in form, to the formula in the question's text. This possible reasoning, outside knowledge about statistics, combined with students that know how to solve it, turn this question into an 'easy' one.

Question [Pbb2] Let A and B be two events such that $P(A) > P(B)$ and $P(A \cap B) \neq 0$. Then

- ☒ $P(A|B) > P(B|A)$.
☐ $P(A|B) < P(B|A)$.
☐ $P(A) = 0$.
☐ (None of the other three options is correct.)

Fig. 5. Question 'Pbb2' with difficulty= -2.845 and discrimination= 0.840

1.6 Questions with higher value of difficulty parameter

Question in Fig. 6 is almost a standard question in the Numerical and Statistical Methods course, with one exception: the problem description has the expression $f^{(4)}(x) \in [-5, 2]$. Usually, an upper bound of $|f^{(4)}(x)|$ is obtained using a calculator to draw a plot of a given fourth derivative function. This slight change in the question's text caused a more demanding ability to answer this question correctly. The discrimination parameter indicates a good separation between ability levels, which means that even small changes in questions can transform a well-practiced problem into a more difficult one.

Question [Cap2Q2] Consider a function $f \in C^4([-4, 4])$ and p_3 the cubic polynomial that interpolates f at the nodes $\{-4, -2, 2, 4\}$. Assuming that $f^{(4)}(x) \in [-5, 2]$, $\forall x \in [-4, 4]$, an upper bound for the error $|f(0) - p_3(0)|$ is

- ☒ $\frac{40}{3}$.
☐ $\frac{16}{3}$.
☐ $\frac{8}{3}$.
☐ (None of the other three options is correct.)

Fig. 6. Question 'Cap2Q2' with difficulty=0.718 and discrimination=1.651

Question in Fig. 7 is about the Runge phenomenon in numerics. This theme is usually presented in expository classes only, and students rarely practice the concept. We can conjecture that the high ability required to answer correctly is due to the tendency of students to read less theoretical materials. The discrimination parameter is small, revealing that the concept is not well understood, even by students with higher abilities.

Question [Cap2Q1b] Let p_n be the interpolating polynomial of a function f on an interpolation support with $n + 1$ equally spaced points in the interval $[a, b]$. Under these conditions,

- ☒ there are functions f for which the distance between f and p_n increases as the number of points in the support increases.
☐ for any function f , the distance between f and p_n decreases as the number of points in the support decreases.
☐ for any function f , the distance between f and p_n decreases as the number of points in the support increases.
☐ (None of the other three options is correct.)

Fig. 7 Question 'Cap2Q1b' with difficulty=1.934 and discrimination=0.606

The next problematic situation arises from the definition of Lagrange interpolation: the interpolated polynomial crosses each given point in the support. We believe that almost all students know the formal definition. However, the question's text and its options lead people

to the wrong answer. The discrimination parameter is even smaller when compared to the previous question, certifying that this situation was not well understood by the vast majority of students.

Question [Cap2Q3] Consider an interpolation support for a given function f with 11 equally spaced nodes between -5 and 5 , and the respective 11 nodal values. Let p_n be the Newton's divided-difference polynomial of maximum degree in this support. Under these conditions,

- ☒ $f(2) - p_n(2) = 0$.
- ☐ it is not possible to use a linear spline because the number of nodes is odd.
- ☐ p_n is the polynomial that always provides the smallest interpolation error in this support.
- ☐ (None of the other three options is correct.)

Fig. 8 Question 'Cap2Q3' with difficulty=13.35 and discrimination=0.158

Our last question under study, which is linked to statistics, has difficulty of 404.4 and almost none discrimination. This has surprised the authors of the question since it had been inspired in a question presented in the course's textbook (though it had only been practiced once in classes). Possible causes for the high value of difficulty in this question are the phenomenon of repeated observations in a sample and the mixture of definitions in a same question. Also, the simplified definition of median, as the value that divides the ordered sample into two halves, does not always help thinking about the possibility of repeated observations in a sample. A study about this issue has been done in [7].

Question [ED] In a recent environmental study, 200 samples of water were collected from a swamp and the nutrient concentration was recorded. It was concluded that: percentile of order 25 = $0.4\text{gr}/\text{cm}^3$ and 3^o quartile = mean = $0.5\text{gr}/\text{cm}^3$. Under these conditions,

- ☒ the percentage of observations greater than or equal to the mean is not less than 25%.
- ☐ the median of the data will necessarily be a value greater than 0.4 and less 0.5.
- ☐ if samples with atypical levels of nutrient concentration are observed in the boxplot, they will correspond to samples with concentration levels above 0.55.
- ☐ the length of the polygon in the center of the boxplot is equal to 0.5.

Fig 9. Question 'ED' with difficulty=404.4 and discrimination=0.004

2 SUMMARY AND ACKNOWLEDGMENTS

The use of Multiple Choice Questions (MCQ) in written tests, supported by the digital scan and automatic correction, has been evaluated using the application of Item Response Theory methodology. A simple detection of outliers using boxplots of difficulty and discrimination values shows few cases from the 48 questions that required investigation. In overall, the six partial exams contained appropriate questions for the teaching/learning binomial in our Numerical and Statistical Methods course.

The following summary could be useful to future evaluations and teaching/learning formats:

- questions with lower difficult value have been practiced in several moments. This suggests a web tool to help students practicing the basic concepts when time in classes is not enough for all students;

- questions designed to evaluate theoretical concepts could demand a higher ability to be answered but they are not necessarily strong discriminators between different levels of ability. This may represent a problem to define an optimal format of the test: how to design a discriminative question? A possible solution came from one question, where a simple combination of known concepts strongly increased the difficulty value. An electronic database of this type of more demanding problems could be created for students with more ability in this course;
- knowing the properties of difficulty and discrimination can help the team to prepare exams that avoid the oscillatory effect in overall difficulty and avoid the dropout rate.

Given the good results achieved in the last three years, with a careful balance between MCQ and open questions, we plan to keep applying and improving these evaluation procedures in our Numerical and Statistical Methods course.

ACKNOWLEDGEMENTS

This work is supported in part by the Portuguese Foundation for Science and Technology (FCT - Fundação para a Ciência e a Tecnologia), through CIDMA - Center for Research and Development in Mathematics and Applications, within project UID/MAT/04106/2013.

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Comparing students' learning experiences during a major educational curriculum reform in engineering

Findings of a mixed-method study

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ABSTRACT

Over the past four years, the Faculty of Engineering Sciences at University College London (UCL) has been implementing a multi-disciplinary curriculum review of engineering education – the Integrated Engineering Programme (IEP) – where

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students, from the very beginning of their degree, engage with the practical application of engineering and skills needed to undertake engineering projects effectively.

The IEP was implemented at the start of the 2014/15 academic year for a new cohort of nearly 700 engineering students, and has recently graduated its first class of BEng/BSc students. Since September 2014, approximately 3,000 students have participated in this cross-faculty programme and the current 2017/18 academic year is the first year where all UCL undergraduates studying engineering are IEP students.

In order to explore the student experiences in navigating the IEP, data were collected through focus groups and an online survey, based on the National Survey of Student Engagement (NSSE), by the end of second term for five consecutive academic years.

This paper reports the findings of a mixed-method study comparing the motivations, expectations and learning experiences of IEP and non-IEP students. The results suggest that IEP students were enthusiastic about their studies, as they were more likely to discuss ideas from their reading or lectures with others outside of class. They were also more likely to agree that UCL is contributing to their ability to solve complex real-world problems. IEP students also considered that the Minors contribute to broadening their skillset education, and enables wider career options.

Conference Key Areas: Curriculum Development; Innovative Teaching and Learning Methods

Keywords: students' learning experiences; integrated curriculum; mixed-methods

INTRODUCTION

Over the past years it has been argued by industry, professional bodies and students that engineering higher education must ensure that engineering graduates are given opportunities to develop a wide range of technical knowledge and problem-solving skills to work effectively in diverse professional contexts [1]

Back in 2014, the Faculty of Engineering Sciences at UCL implemented a multi-disciplinary curriculum review of engineering education – the Integrated Engineering Programme (IEP) – where students engage with the practical application of engineering from the very beginning of their degree [2]. This curricular reform was motivated by the need to change the traditional educational approach – with very little group work and practical projects in the first two years, and with departments operating in traditional silos – in order to provide engineering graduates with the breadth of professional skills required by engineering careers.

A new cohort of nearly 700 engineering students started their studies in the IEP in September 2014. Since then, approximately 3,000 students have participated in this cross-faculty programme and the current 2017/18 academic year is the first year where all UCL undergraduates studying engineering are IEP students.

In order to explore the student experiences in navigating the IEP, data collection was planned to provide evidence-based findings and support further refinement and development initiatives. Assessing and monitoring student progress is fundamental to understand student's motivations, attitudes towards teaching and learning, and expectations about career outcomes. Researchers in engineering education have found that individual's perceptions and previous experiences, at the beginning of an engineering course, have a strong influence on student persistence [3][4]. Data was

gathered before the implementation of the IEP, to provide a baseline level for future comparisons. Collection of baseline data, before the beginning of an instructional intervention is known to be one of the most common quantitative approaches used in engineering educational research [5]. Data was also collected during the initial three years of the programme.

This paper compares the motivations, expectations and learning experiences of IEP and non-IEP students in order to explore the impact of the new engineering programme on students' experience.

1 METHODS & RESEARCH DESIGN

To assess the student's experience in the IEP, a mixed methods approach was used. Data was collected through an online survey, and focus groups by the end of second term and for five consecutive academic years starting in 2012/13. To encourage academic honesty, staff from UCL Arena Centre were commissioned to organize and run both surveys and focus groups. In line with the university's education strategy, the UCL Arena Centre works with academic and professional colleagues from across UCL to develop engaging, research-based approaches to education, and to improve the standard of learning, teaching and assessment at UCL.

1.1 Online Survey

An online survey was based on the National Survey of Student Engagement (NSSE). It comprised 29 questions about students experience during their current academic year. All engineering students were invited to participate in the survey by the end of the second term in five consecutive academic years.

The first set of questions in the survey addressed demographic data (age, sex, ethnicity, fee status, mode of study, year of study, level of study, current grades, accommodation, parents' highest level of education, students' highest level of education, and engineering department). The findings presented in this paper focus on questions addressing: students' learning experience at UCL, and how often they enrolled in certain types of academic activities, such as asking questions in class or making class presentations (very much, often, sometimes, never, or not applicable); what mental activities were emphasized by coursework, such as memorizing, synthesizing and organizing ideas (very much, quite a bit, some, very little, none, or not applicable); relationship with other students, academic staff, and administrative personnel and offices using a scale ranging from 1 (unfriendly, unsupportive, sense of alienation/ unavailable, unhelpful, unsympathetic/ unhelpful, inconsiderate/rigid) to 6 (friendly, supportive, sense of belonging/ available, helpful, sympathetic/ helpful, considerate/flexible); and how students' experience at UCL contributed to their knowledge, skills, and personal development in different areas such as acquiring a broad general education, writing clearly and effectively (very much, quite a bit, some, very little, none, or not applicable).

For reporting purposes, the level for statistical significance was set at 0.05. The chi-square statistic was used for testing relationships between categorical variables. T-tests were conducted to assess whether the means of two independent groups (IEP and non-IEP) were statistically different from each other.

1.2 Focus groups

Focus groups were run at the end of the second term in five consecutive academic years, focusing on three main research questions: 1) what students like about their current degrees? (subject; what do they learn and how do they learn; what job can they get from doing it); 2) what could be further developed? (what changes would students

like to see in their degrees; are they happy with the lecturers, group work, assessment?); 3) What changes have they seen in the past year and how do they view these? However, students were allowed to explore questions that emerged.

The sessions run in 2012/13 and 2013/14 were pre-IEP. In the three following academic years, focus groups sessions were run with IEP students and non-IEP students separately.

2 RESULTS

Descriptive statistics

Participants that were studying at postgraduate level (MSc, Doctorate) or were undergraduates in Y4 (MEng) were excluded from the analysis, as no comparable IEP data was available by 2016/17. A total sample of 396 students (208 IEP and 188 non-IEP) was analysed. The breakdown by student group (IEP or non-IEP) and year of study is provided in Table 1. The majority of students were between 18-21 years old, and 35% were female. Half of the participants identified as 'White' and 36% as 'Asian'. The proportion of UK students was significantly lower in the IEP group (31.3%) in comparison to the non-IEP group (47.6%) ($\chi^2 = 11.111$, $p = .004$), meaning that the IEP cohort was more international.

Table 1. Participants by student group and year of study

	Year of study				Gender	Age	Domicile	Ethnicity		
Student group	1	2	3	total	Female	18-21	UK	White	Asian	Black
Non-IEP	64	56	68	188	33.0%	83.4%	47.6%	50.5%	35.6%	4.3%
IEP	111	55	42	208	36.9%	81.3%	31.1%	50.5%	35.6%	3.4%

Results

IEP students were significantly more likely to have made a class presentation (86.5%) than non-IEP students (77.4%) ($\chi^2(4) = 7.358$, $p = .025$). IEP students were significantly more likely to report having used an electronic medium to discuss or complete an assignment *very often* (51.9%) than non-IEP students (39.9%) ($\chi^2(4) = 9.757$, $p = .045$). These findings align with the high proportion of active learning and teamwork that feature in the IEP.

IEP students were also significantly more likely to have discussed ideas from their readings or classes with others outside of class more *often* (41.5%) than non-IEP students (26.1%) ($\chi^2(4) = 11.707$, $p = .020$), suggesting the enthusiasm of students with their teaching and learning experience in the new programme, by having the opportunity to work in projects targeting real-world problems, and also having the chance to work with students from different disciplines. As IEP students mentioned,

[IEP] *"I mean I tell people from ... my friends from other unis about how I had this Integrated Engineering sort of module and they were really impressed with it because they'd never heard of such a thing before where loads of different disciplines had worked together for a project. And yeah they were pretty impressed by it and I think enjoyed it quite a lot"*

[IEP] *"We had two summer challenges. The second one was actually a collaboration between Mechanical Engineering and Civil Engineering. So we were a big group of about 10 students, 5 were mechanical engineers and 5 were civil. And the idea of that challenge was to essentially build or design a water dam and distribute energy to a town. So it was a nice collaboration because in mechanical engineering you're thinking about in thermodynamics, the energy flow in water dams and how energy is provided. And then civil engineers were helping as well with creating designs for the towers that were going to hold the dam and get the power cables to the town. I actually like that collaboration ... and also we ended up making friends with people in Civil Engineering"*

[IEP] *"(...) research is really actual, we work on a current topic and current problems. So even if it's biofuel, because there are kind of two different sides (...) PGTAs are currently working on virus for Zika so it's really actual research"*

[IEP] *"I think scenarios are useful because allows us to put in practice all the theories that we learned, and also they are very different. This year we had four scenarios, one was a pilot plant [and] the one before that was about producing sufficient bioethanol for the UK transport necessities, so it was very interesting because in the first we had one really lab focussed, and then the previous one was about building the overall plant and thinking of what you do, how do you recycle the water, your energy, thinking a bit about legislation, fuel. And the one before was about production of the bio ethanol but on a really close focus point. And it also allow us to go around in the labs, meet people from the departments, which was really nice, because we don't have many occasions to do so. So it kinds of gives us the opportunity to catch up on the research that's currently going on in the department"*

No major differences were found between IEP and non-IEP groups regarding coursework typology, with both groups of students equally likely to report: some memorization; *quite a bit* of analytical, synthesis and judgement skills; and *very much* applied theories to practical problems or new situations.

Students were asked to rate their relationship with other students, academic staff, and administrative personnel and offices using a scale ranging from 1 to 6. No differences were found between IEP and non-IEP students regarding the assessment of their relationship with other students (IEP $M = 4.64$, $sd = 1.200$; non-IEP $M = 4.61$, $sd = 1.116$), and academic staff (IEP $M = 3.94$, $sd = 1.246$; non-IEP $M = 3.98$, $sd = 1.325$). However, IEP students were significantly more likely to rate their relationship with administrative personnel and offices less positively than non-IEP students (IEP $M = 3.88$, $sd = 1.282$; non-IEP $M = 4.33$, $sd = 1.312$; $t(386) = 3.437$, $p = .001$). In order to further explore this result, relationship ratings were analysed by year of study. Data showed that IEP students' rating of their relationship with both academic and administrative staff decreased in year 2 (Figure 1).

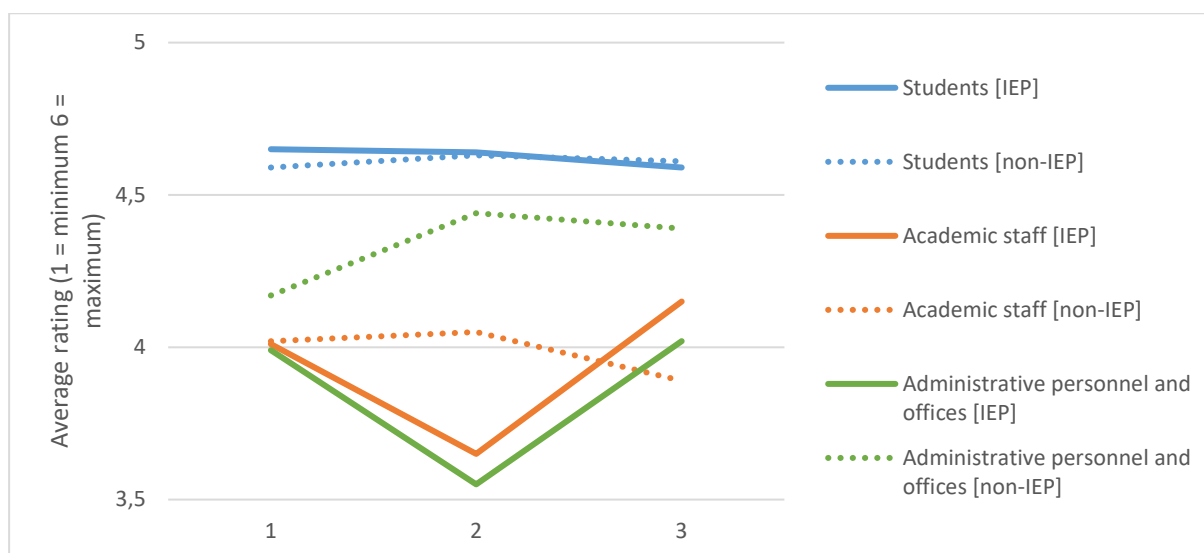


Fig. 1. Students' relationship with other students, academic staff and administrative personnel and offices by IEP status and academic year

A decrease in satisfaction was mentioned by second year IEP students during focus groups sessions, with participants saying that coursework was more intensive than expected.

[IEP] *"Second year is getting better, but probably we expect something more. Because second year when we are doing with labs we focus so much more on lab reports and how to write a lab report"*

[IEP] *"The second year is better but from a student perspective it's far more challenging. And we spend so much more time on like studies to anything else compared to last year. And I would say it's very intense"*

[IEP] *"You know in the first year you've got some time to read a bit, read outside that, but second year you just ... okay I'm done, I'm done. But by the time you say I'm done it's probably like Sunday night, which leaves you no room for preparation for the next Monday. Whereas like the first year let's say you've got the weekend I'm done probably like Saturday morning and (...) maybe I can hang out with my friends"*

This may have had an impact on IEP students' relationship with academic staff, but not necessarily with administrative staff. No particular mention to the relationship with administrative staff was found in the focus groups.

Second year students in the non-IEP focus groups shared different perceptions. Some students mentioned year 1 and year 2 as being the heavily theoretical and year 3 as being more applied,

[non-IEP] *"It's like the first and second year, they teach you the theory of it, and then the third year is when you're supposed to apply that theory, actually building the plant for example"*

Whereas other students referred to year 1 as being either more challenging or less interesting than years 2 and 3.

[non-IEP] *"Second year we didn't have much, and then third year again it was just small courseworks, small programming courseworks, and ... yeah just lectures and stuff like that. So second and third year there wasn't much, and then first year there was a lot, which was really good"*

[non-IEP] *"first year was very ... cos we didn't do IEP so it was very much oh take a Maths class here, a Chemistry class here and a BioChem class here, and then we'll have (inaudible) BioChem Eng (...) And then the second year was more sort of integrated but .. I feel like first year was more getting everything up to speed, coming from different... coming from different degrees and qualifications and things. So to make sure we're all on the same standard (...) [First year] I found a lot of that repetitive from school. And then second year was more integrated definitely and more actual engineering and applied engineering. And that's continuing in third year. So I was just a bit bored in first year so that's why I was less motivated"*

When asked to what extent their experience at UCL contributed to their knowledge, skills, and personal development, IEP students were more likely to think that UCL contributed to 'acquiring a broad general education' (86.7%) than non-IEP students (80.9%); and 'solving complex real-world problems' (87.2%) than non-IEP students (81.4%).

This was also reflected in the focus groups with IEP students, as one of the students said,

[IEP] *"Whereas the IEP is ... I would say it's interesting (...) Because it's ... they give you a real problem that ... which makes perfect logic sense which is daily life (...) It's not like what you really have to just you know put some equations and get it done, you really need to think about it. And you're doing something that you can actually do in real world where I mean ... not like coursework ... it's not just experiment, you're doing on like a real world scale basis, so it's very different from what we usually learn and what we usually have. That's why everyone likes it"*

To give students a distinctive edge after graduation, all students study an IEP Minor option as part of their degree. Most IEP Minors are either topics from disciplines complementary to engineering (such as Biomechanics or Programming), or interdisciplinary subjects based on UCL's research strengths (such as Finance & Accounting or Engineering and Public Policy), taught by cross-disciplinary teams. IEP Minors are selected in the first year and taught across the second and third years (three modules equalling 45 credits in total). Although not specifically asked in the survey and focus groups sessions, IEP students considered the Minors to be an important feature of the programme. Overall, they agreed that the Minors have a positive contribution to broadening their skillset education, as illustrated by the following quote from one of the IEP students,

[IEP] *"I choose Public Policy because I missed Social Sciences in the degree. Which it was nice to have (...) a topic that's not Biochemical Engineering related. And also it can link together because (...) transdisciplinary training depending on the professional pathway you want to follow (...) I think the minors is really cool actually (...) I kind of see it as a way to do something different to my degree, and kind of broaden my skillset."*

3 FUTURE WORK

Although the IEP is in its early years, the results described in this paper seem to suggest that the programme has a positive impact in students' enthusiasm about their studies and is contributing to develop students' ability to solve complex real-world problems.

However, to better assess the impact of the programme, more data needs to be planned, collected and analysed. A pre- and post-survey study with the first cohort of students starting the IEP in 2014/15 is currently being analysed, comparing students expectations and career plans when entering UCL (Year 1 in 2014/15) and at the end of their MEng degree (Year 4 in 2017/18). A follow-up study is also being planned with alumni to explore the impact of the IEP on career choices and pathways.

It would also be interesting to further explore the expectations and perceptions of students about their relationships with administrative staff, since they support various aspects of the student journey and experience.

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Retention of conceptual understanding The impact of time, pedagogy and teaching activity

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Conference Key Areas: Continuing Engineering Education and Lifelong Learning, Innovative Teaching and Learning Methods

Keywords: long-term knowledge retention, conceptual understanding, effect of teaching on learning, active learning vs. traditional instruction

INTRODUCTION

Instruction should enable students to develop sound understanding, not only in the short run (until being tested in an examination) but also as a basis for further studies and subsequent professional practice. For this matter, the long-term effect of instruction needs to be investigated.

For a continuous period of twelve years, engineering students at Hamburg University of Technology (TUHH) were given the Concept Assessment Tool for Statics (CATS) [1] at the end of their first statics course. Over the same period of time, pedagogy was changed: first, from a traditional setting to one including interactive elements, and later, due to change in faculty, back to the traditional setting. The CATS was re-administered to self-selected samples from those students who had been tested at post-instruction level. This so-called reTest was performed twice, once in 2014, just before pedagogy changed back to the traditional setting, and again at the end of 2017. By comparing

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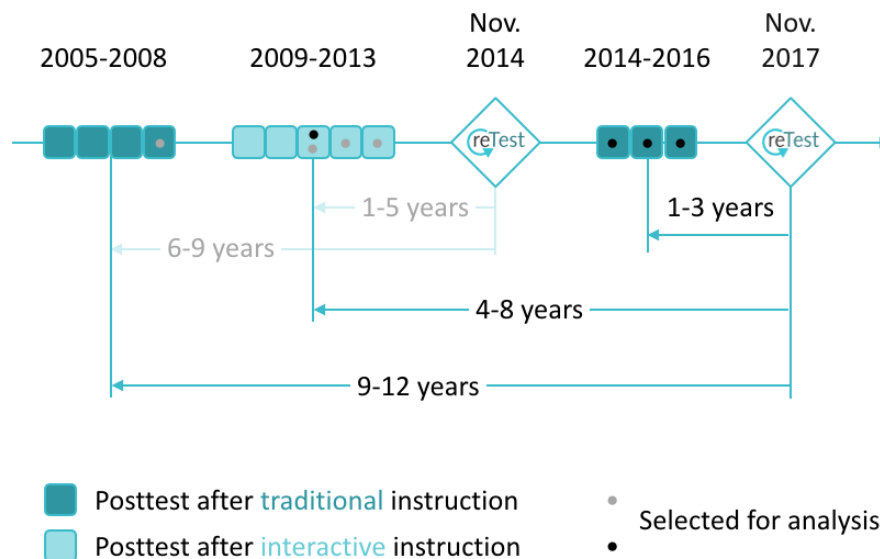


Fig. 1. Study design timeline

absolute scores as well as normalised change scores from the reTest participants, we examine the influence of time, pedagogy, and activity as teaching assistant on retention of conceptual knowledge in the field of statics.

1 METHODOLOGY

In order to investigate the retention of conceptual understanding, the following test-retest study design was implemented. As illustrated by Fig. 1, a post-test was administered every academic year in the same course. From 2009 to 2013, the pedagogic concept of the course included interactive elements described below. Following Hake [2], the instruction during those five years is therefore categorised as interactive engagement (IE) while the instruction during the courses beginning in 2005 to 2008 and 2014 to 2016 is missing such elements and is therefore categorised as traditional (T).

In contrast to the continuous collection of post-test data, the reTest data was obtained at two distinct events in November 2014 and 2017. The target population were all students whose post-test data was found in our database up to the respective reTest event. As a result, we obtained post-test/reTest score pairs with various retention intervals (RIs), i. e. the time interval between post-test and reTest. In theory, the range of RIs spans one to twelve years.

Using only the 2014 reTest data, it is impossible to attribute any observed effect to either length of RI or type of pedagogy because they are coupled (see [3]). With the pedagogy changing back to traditional and the 2017 reTest, time and pedagogy are uncoupled. We now have data for RIs of one to three years as well as six to eight years for both types of pedagogy.

1.1 Traditional and interactive instruction

As mentioned above, we consider two types of pedagogies. Traditional (T) instruction includes a lecture with little to no active participation by the students, plenary recitation sessions where students are presented with solutions to quantitative problems, but also smaller recitation sessions where students actively solve quantitative problems under the supervision of a teaching assistant (TA). In our context, the term interactive

engagement (IE) stands for a modification in the small recitation sessions. About half the time, students solve quantitative problems, whereas the other half, they work on Tutorial worksheets, in part taken from and in part newly designed after the "Tutorials in Introductory Physics" by McDermott and Shaffer [4]. These worksheets are evidence-based learning materials designed for implementation in small groups of three to five students. The guidance of an instructor who is well-trained in socratic dialogue poses a necessary component for effective learning with Tutorials [5]. Tutorial worksheets purely aim at understanding concepts instead of traditional end-of-chapter problem solving. The lecture component of the course was held by different instructors for both types of pedagogy.

1.2 Test administration

The post-test data was collected in an introductory mechanics course at TUHH. A major part of the course content is on statics, therefore the CATS [1] was chosen as a post-instruction test. It was neither graded nor was participation rewarded in any kind. We motivated the students solely by stating our research objectives. It was stressed that not the students are tested, but the instruction. The lecture time spent on the test administration was limited to 45 minutes by the instructor in the first run. This limit resulted in 32 minutes of actual time on the tasks. For consistency, this time was set as standard for all subsequent test administrations.

The reTest events took place in November 2014 and 2017. While the post-tests could be administered in one single class during lecture time, this was not possible for the reTest as we wanted to reach students from all cohorts. Instead, the events were advertised on campus and in 2014 also to the alumni network. The advertisement channels used were mailing lists to all students and research assistants, posters and flyers, as well as short announcements in selected lectures. To acquire as many participants as possible, the test could be taken offline on campus or online. To reduce the self-selection effect, the following incentives were given: a lottery for all participants with four drones and four audio speakers as prizes, as well as chocolate for the offline participants only. Before starting the CATS, reTest participants were asked to fill out a questionnaire asking for demographic data on their physics and mechanics background, on their personal teaching activity, as well as on their study progress. Of these aspects, only personal teaching activity is included in the analysis in this paper.

During the first nine years, the students were identified by their matriculation numbers. In 2014, we decided to use self-generated identification codes (SGICs) for various reasons, including data privacy and higher matching rates. See [6] for details.

1.3 Post-test results

On the post-test, the cohorts using Tutorials outperformed the traditionally taught cohorts, independent of instructor and controlling for pre-instruction understanding of forces by using the Force Concept Inventory (FCI) [7]. In the IE-cohorts, students performing in the middle range on the FCI pre-test performed on average 2.8 ± 0.5 out of 27 points higher on the post-test. For less well-prepared students the difference was somewhat smaller, for above-average students correspondingly higher. When comparing the reTest results of groups with different pedagogies, this post-instruction difference in conceptual understanding must be taken into account.

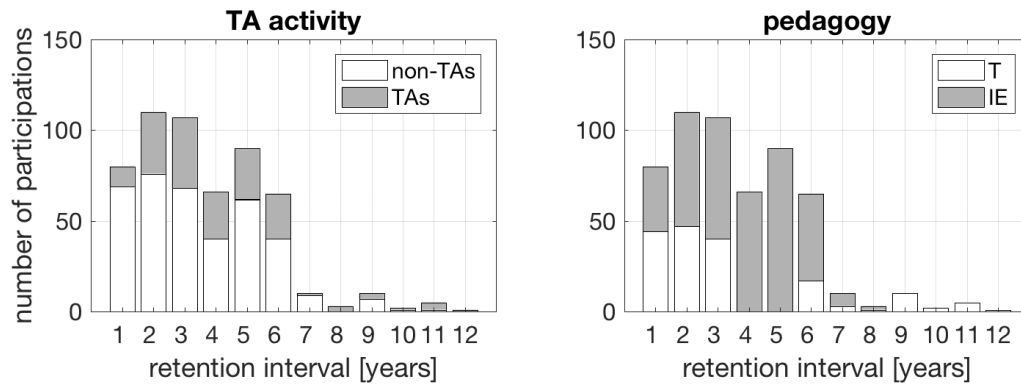


Fig. 2. Number of valid participations per RI, indicating the share of TAs as well as the distribution of pedagogies.

1.4 Methods: Normalised Change

To account for the difference in post-instruction CATS-scores among the groups with different pedagogies, a normalised change metric c according to Eq. (1) will be applied. The raw change scores from post- to reTest are normalised with respect to the maximum possible gain in case of a positive change or with respect to the maximum possible loss in case of a negative change [8].

$$c = \begin{cases} \frac{re - post}{100 - post} & re > post \\ \text{drop} & re = post = 100 \text{ or } 0 \\ 0 & re = post \\ \frac{re - post}{post} & re < post \end{cases} \quad (1)$$

2 THE SAMPLE

In total, 656 participations were counted in both reTest events. We expected to observe cases of unserious participation, which we define as less than 9 items answered, or less than 10 minutes time spent on the test (as devised by Steif and Hansen [9]), provided the total score does not exceed 14 out of 27 points. The total number of cases of unserious participation was 83, which were all observed among the online participants, possibly due to unsupervised and distraction-rich test-taking settings. Furthermore, 24 cases had to be eliminated because they could not be uniquely matched to a post-test. The result is a total number of 549 valid participations over all RIs.

Fig. 2 shows the distribution of reTest participations over the RIs for TAs and non-TAs as well as for T and IE pedagogy. We can see that sample sizes drop after six years RI as most students graduate within this period. The data set includes data with RIs of one to three years as well as six to eight years for both types of pedagogy. Because of the small sample sizes n_i in the pedagogy subgroups for RIs 7 and 8 ($n_7 = 3, n_8 = 1$ for the traditionally instructed and $n_7 = 7, n_8 = 2$ for the interactively instructed), we limit the analysis to the data with RIs of one, two, three and six years. The selected subset corresponds to a total number of 347 participations. Among those, 109 were categorised as having TA-experience in relevant subjects which include Mechanics,

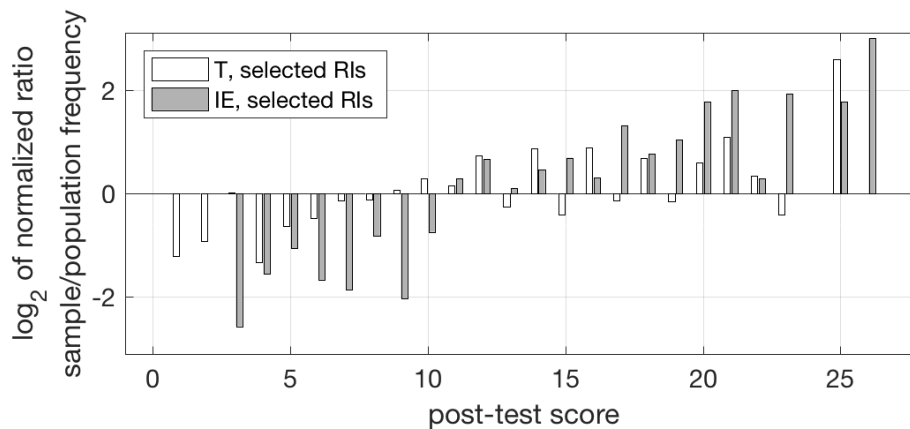


Fig. 3. Does the sample represent the population for each pedagogy subgroup? A value close to zero means that the sample represents the population well in the respective posttest score value. A value of positive/negative y indicates an overrepresentation/underrepresentation by the factor 2^y . Note that the cases for which either frequency is zero would have to be represented by $\pm\infty$ and are therefore not displayed.

Physics, Engineering Design as well as others specified by the participants. The majority, i. e. 214 of the 347 participants, had IE instruction.

In general, a representative sample is required in order to make inferences from the sample to the population. As this sample is self-selected, it does not necessarily represent the population. Comparing the distributions of the post-test scores from the sample to the ones from the population reveals that the stronger students are slightly overrepresented in the sample. Here, self-selection bias can play a role. Also, the advertisement for the reTest events did not reach (supposedly weaker) dropout students. In *Fig. 3*, the effect of pedagogy on the representation is investigated. The relative frequencies of the possible post-test scores in the sample are compared to the ones in the population for the selected RIs. Transformation to the log₂ scale allows for easy visualisation of over- and underrepresented scores. For the T-participants, the higher scores are overrepresented while the lower scores are underrepresented. The same tendency can be seen even more pronounced for the IE-groups.

Comparing the post-test scores among the different subgroups (*Fig. 4*) reveals significantly higher average scores for IE over T pedagogy, slightly higher average scores for TAs over non-TAs, as well as slightly higher scores in RIs 1 and 2 over RIs 3 and 6.

3 RESULTS

The results are first examined in terms of absolute scores before examining the normalised changes achieved by the various subgroups which differ in terms of the three variables pedagogy, personal TA-activity, and retention interval.

Fig. 4 shows the mean post- and reTest scores. All subgroups exhibit a mean gain from post- to reTest, indicated as the grey part of the bars. While the non-TA groups with RIs of one and two years have managed to reach similar reTest scores as their interactively learning peers, the difference between the pedagogies remains visible in the non-TA subgroups with RIs of three and six years. The reTest scores among the TA groups show no difference with respect to RI. Comparing TAs to non-TAs, we see higher reTest scores only for the T-taught TAs, while the scores are comparable in case of IE pedagogy.

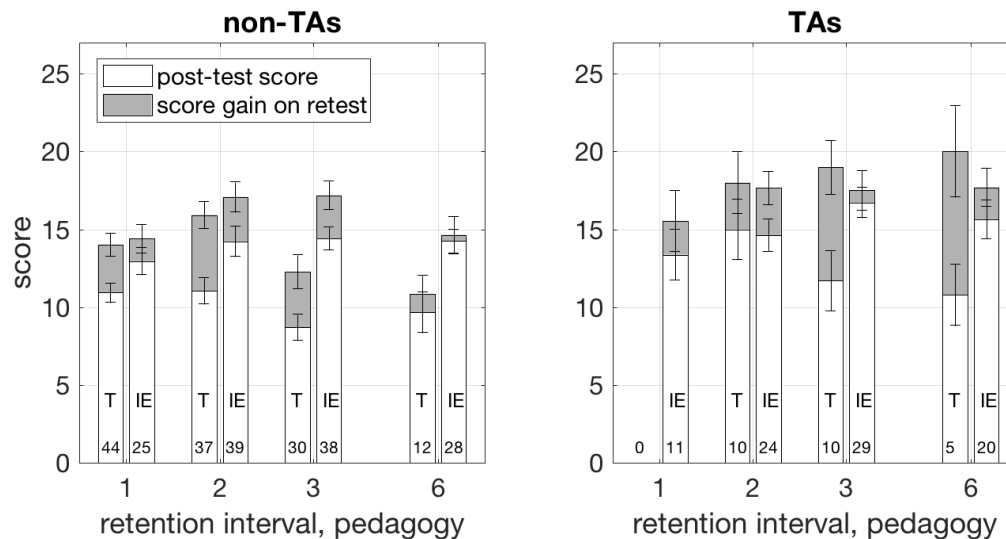


Fig. 4. Mean post- and reTest scores for the various subgroups. The reTest score is displayed as the score gain on the reTest stacked onto the post-test score. The error bars indicate the standard errors of the mean post- and reTest scores (not the error of the score gain). Subgroup sample sizes are displayed at the bottom of the bars.

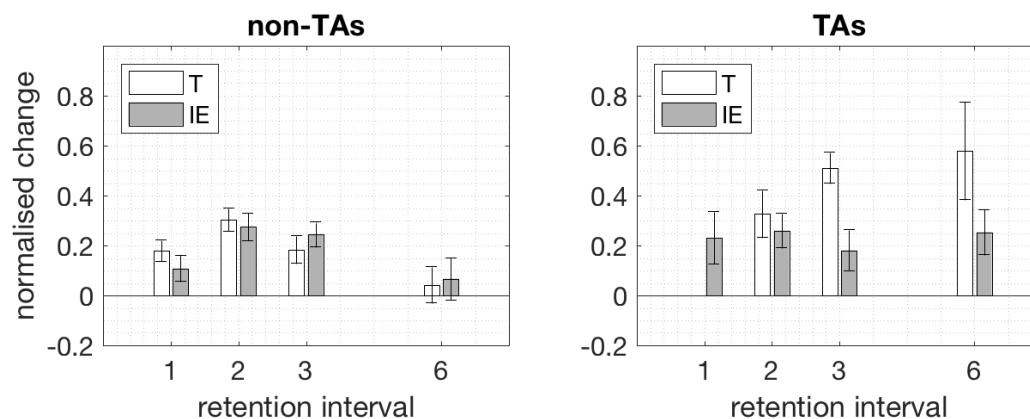


Fig. 5. Mean normalised change for the various subgroups. The error bars indicate the standard errors of the means.

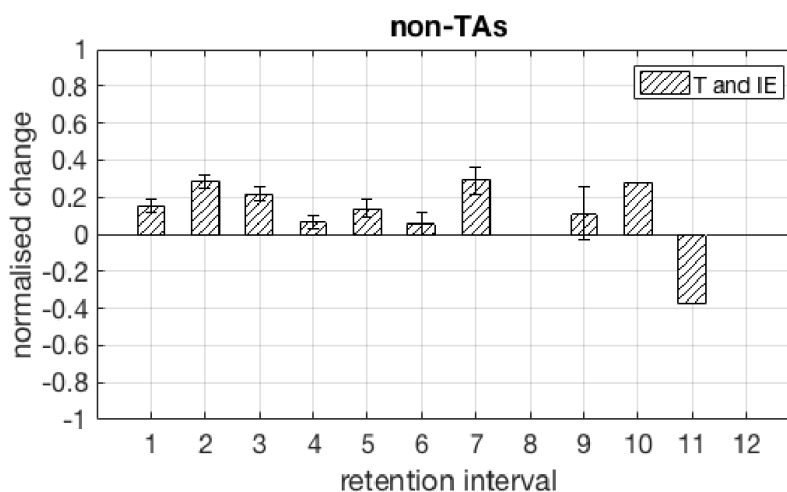


Fig. 6. Normalised Change independent of pedagogy. For the time of their studies (i. e. 5 to 6 years), the level of understanding does not fall below the post-instruction level. Sample sizes are too small for RIs 7 to 12 (see Fig. 2) to interpret the data.

Fig. 5 shows the average normalised change for the various subgroups. All subgroups exhibit on average positive normalised changes, interpretable as a gain in understanding. For TAs, pedagogy seems to be a relevant factor in combination with time. While we have no data to compare the pedagogy groups in RI 1, the traditionally taught TAs show a much larger gain in RIs 3 and 6 than the interactively taught TAs. The gain seems to increase with time for the traditionally taught TAs while it remains constant for the interactively taught TAs. For the non-TAs, pedagogy cannot be determined as a relevant factor on the average normalised change due to the overlapping error bars in every RI.

With respect to the time factor, a clear trend cannot be seen among the non-TAs. If pedagogy is indeed an irrelevant factor in terms of average normalised change scores for the group of non-TAs, the data can be aggregated and re-examined. In that case, the restriction to RIs 1, 2, 3, and 6 is no longer necessary. *Fig. 6* shows the average normalised change of the group of non-TAs over all RIs. The sample sizes are very small for RI 7 and longer and the respective change scores should therefore not be generalised. For RIs 1 to 6, the level of understanding does not fall below the post-instruction level ($c = 0$). The largest gain is achieved by the cohorts who took the reTest two to three years after the post-test.

4 DISCUSSION AND IMPLICATIONS FOR ENGINEERING EDUCATION

Both, the post-test and the reTest data, are biased by self-selection of the participants. For the post-test, this effect is expected to be lower as students had to actively decide to leave the class before the test started ("opt-out") while for the reTest, students had to actively decide to come to the test lab or to the website ("opt-in"). We tried to level out this difference with the incentives. The bias of not recruiting dropout students can be neglected as only students pursuing their studies are of interest to this investigation.

The large gain by TAs in the traditionally taught groups poses the most radical effect seen in the data. A possible interpretation is that personal TA-activity results in interactive engagement with the concepts, which leads to high gains. It can be assumed that many TAs carry out their teaching activity for more than one year. Therefore, TAs with higher RIs can be assumed to have repeatedly engaged in the concepts and gained even more experience. Traditionally taught students thus achieve high gains by means of their TA-activity. Those students who had interactive instruction, already experienced these gains before the post-test and thus do not exhibit such high gains from post- to reTest.

Although a large part of the sample are TAs, instruction must be implemented for the default case, i. e. non-TAs. For this group, the results presented in this paper mainly suggest two conclusions: (1) The average level of understanding does not decay for any RI group up to at least six years after instruction, on the contrary, it increases. This indicates that conceptual knowledge, other than rote knowledge, is retained, and/or that the concepts are used in subsequent courses. (2) The normalised gain seems to be independent of pedagogy. This leads to the conclusion that higher post-instruction levels (achieved here by the cohorts using Tutorials) also result in higher levels of understanding in the long run. As we deal with uncertainties, indicated by the error bars, this mathematical reasoning is not always reflected in the plots (see RIs 1/2 in *Fig. 4*).

When interpreting the absolute scores in *Fig. 4*, we must refrain from viewing the data as longitudinal. The traditionally taught RI-groups 3 and 6 exhibit a lower average post-test score than their counterparts in RIs 1 and 2. Comparing pedagogies, we must come to different conclusions for RIs 1/2 and RIs 3/6. In the first case, T-taught students were able to catch up to the same level as their IE-taught colleagues within periods of one and

two years, respectively. For RIs 3 and 6, we must conclude the opposite, i. e. that they still lag behind three or six years after instruction in terms of conceptual understanding.

The new insights gained by the 2017 reTest do not change the conclusions made in [3]. For non-TAs nothing changes. For TAs, the observed change of the group including T-taught students (the long RI group with 5 to 9 years) might be influenced by pedagogy effects.

It is the responsibility of instructors to help students with their learning. Even though we could show that, independent of pedagogy, the average level of understanding does not fall below the post-instruction level, the results of this study indicate that instruction should be implemented with evidence-based activating learning methods in order to promote sound understanding by instruction. Otherwise, it is the opportunity and decision to take on a job as teaching assistant which strongly influences the level of conceptual understanding to be reached in the long run.

5 ACKNOWLEDGEMENTS

Sponsored by the German Federal Ministry of Education and Research (BMBF) (grant no. 01PL11047). Any opinions expressed here are those of the authors.



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Teaching Sustainable Development and innovation in Engineering Education: Students' perception

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Conference Key Areas: Sustainable Development Goals in Engineering Education, Innovation as the context for Engineering Education

Keywords: Sustainable Development, Innovation, Higher Education, Engineering School, Students

INTRODUCTION AND BACKGROUND

According to Fullan [1] (p. 6) "the education system was thought to be one of the major societal vehicles for reducing social inequality". The educational system has evolved, adapting to economic and technical requirements. The awareness of the physical and natural limits of the planet leads to a new evolution.

Wright [2] studied multiple international declarations that refer to the need to include Sustainable Development (SD) across the curriculum and to develop interdisciplinary and transdisciplinary research as well as public outreach. Sterling [3] (p. 806) argued that "the sustainability does not simply require an 'add-on' to existing structures and curricula, but implies a change of the fundamental epistemology in our culture and in our educational thinking and practice [...], sustainability is a gateway to a different view of curriculum, of pedagogy, of organizational change...".

We adopted the traditional definition of SD, from the Brundtland Report [4] that specifically emphasizes the requirement to "meet the needs of the present without compromising the ability of future generations to meet their own needs." SD is a challenge for the future for which the higher education institutions should contribute.

Two themes of education science are presented in this section: the first one is the integration of SD in higher education. The second one is about SD and educational innovation.

Lozano et al. [5] presented five main approaches for integrating SD into higher education curricula: i) coverage of some environmental issues in an existing course or courses; ii) a specific SD course; iii) SD intertwined as a concept in regular disciplinary courses; iv) SD as a possibility for specialization within the framework of each faculty; v) SD as an undergraduate or post-graduate program. So, integrating SD approaches differ from one institution to another.

Van Bellen [6] explained that the measure of sustainability must establish a connection from past to present and from present to future. Sustainability is a process of perpetual adaptation and actions should concern the three pillars. Moldavska and Welo [7] insist on the fact that the three pillars of SD should be addressed equally. Here, we focus our attention on how teaching could be transformed in order to be in adequacy with the global aim of SD.

There are tools for evaluating integration of academic SD initiatives in universities. Most studies are focused on the environmental pillar [8], [9]. Olszak [10], integrated economic and social pillars. Urbanski and Rowland [11] evaluated academic SD initiatives by using “STARS as a multi-purpose tool” in the campus sustainability movement. This tool was released by the Higher Education Associations Sustainability Consortium (HEASC) in 2006, and “would address all the dimensions of sustainability and all the sectors and functions of a university”. This type of tool evaluates the “sustainability performance” of colleges and universities, without understanding how different performances are achieved.

On the basis of this statement, our hypothesis is that the implementation of SD in a higher education engineering school, should lead to educational innovation, taking into account its relationship with research.

Since 2000, many studies have dealt with sustainable development and innovation, technological transitions, based on the idea that innovation is a key factor for SD [12]. Conceptual work has dealt with SD for engineers [13], [14], [15], [16]. The relationship between sustainable development and teaching innovation has been explored [17], [12].

It appeared necessary to think about the integration of SD in educational programs as well as innovation for a sustainable educational system [13], [18].

In education, the study of each stage of incremental transformation becomes a strategic priority for the integration of SD [16]. The change should begin with the educational leaders and then spread to the teaching staff. Our research question is: What are the students' perceptions about the value of integrating Sustainable Development and innovation into the curriculum?

Therefore, this communication presents previous SD research and a review context in Section 2; the research methodology is described in Section 3. The students' perceptions about the integration of SD and educational innovation in their academic field (UniLaSalle Beauvais) are presented in Section 4. Some conclusions are drawn in Section 5.

1 PREVIOUS SD RESEARCH AND REVIEW CONTEXT AT UNILASALLE

Since 2009, French institutions of higher education have engaged in the integration of SD in their strategies actions. The Conference of University Presidents (CPU) and the Conference of higher education (CGE) proposed the Green Plan (Article 55 of 3 August 2009 of the Grenelle 1 law) and the integration of sustainability in higher education.

We present a case study at “Institut Polytechnique UniLaSalle¹” focused on the education of engineers. UniLaSalle aims to train young engineers or managers in fields directly concerned

¹ In January 2016, the « Institut Polytechnique LaSalle Beauvais », a French engineering school, merged with another higher education engineering school (ESITPA, Rouen). Both campuses (Beauvais and Rouen) have a common name: UniLaSalle (www.unilasalle.fr). This communication describes the students' perception of the Beauvais campus. It is an extension of a study released on the perception of the executive management and curricula manager's teams (2016-2017).

by SD. The teaching of SD at UniLaSalle is adapted to the nature of each specialty² (Agriculture, Nutrition and Health, Geology and Environment). SD approach is integrated in UniLaSalle at three levels: campus life, teaching and research. UniLaSalle decided to be part of the pioneers to use the self-evaluation referential as a guide to build its action plan [19].

In recent years, the executive management team believed that “sustainable strategies within an engineering school is a holistic approach which links governance and strategy, teaching and research and campus life. It is a work at both individual and institutional levels concerning all dimensions of sustainability” [19] (p. 233).

In this context, as presented in a previous article [19], the question was: how to place an integrated approach of SD in the strategy of UniLaSalle? This article focused on the study of sustainability by using two perspectives: integration and evaluation by the executive management team.

Fourati-Jamoussi et al. [20] extended this idea of sustainability through the perception of the executive management and curricula managers' teams. A qualitative methodology [21] was chosen, based on the case study of UniLaSalle. Data were collected from 27 semi-structured interviews (during 45 min) with two groups: the executive management and the curricula management teams. The interview guide was built on six themes/questions: i) what is the definition of innovation in engineering education? ; ii) what are the different types of innovations? ; iii) what are the reasons to innovate at UniLaSalle? ; iv) what is the definition of SD? ; v) what are the reasons for integrating SD in the engineer training? ; vi) what is the link between SD and innovation in engineering education?

The results of this study are submitted for a publication under revision and can be summed up as follows:

- i) The reasons for integrating innovation in the engineering curriculum at UniLaSalle: The executive management team is more concerned by the issue of global environment and the evolution of education while the curricula management team looks for the best compromise between companies' needs and students' needs and wants.
- ii) The reasons for integrating SD in the engineering curriculum: According to the executive management team, the first reason for integrating SD is to train Responsible Engineers. The curricula management team, in charge of professional-qualification modules, precisely focusses on an ethical dimension. Regulatory and environmental issues are also important for this group.
- iii) The perceived pillars of SD: An important element of previous results is the emergence of a fourth pillar. Three respondents insisted on this fourth dimension and affirmed that the governance of energy and mineral resources is specific and different from environmental issues which are more connected to the natural living world. This fourth pillar was integrated during the elaboration of the survey submitted to the students. The three pillars, economic/ social and environmental, are well integrated by the executive and curricula management teams.
- iv) The link between SD and innovation in engineering education: SD is now perceived as a stimulus to innovation for the majority of respondents (both teams). SD is considered as a

² In Geology, Agriculture or Nutrition and Health curricula, the challenge of SD is integrated in specific pluridisciplinary courses which describe the challenges from SD requirements in their discipline.

constraint which induces innovation and sometimes as a factor which both promotes and restricts innovation.

The challenge of this work is to study the impact of integrating SD and innovation in the engineering curriculum on the students' perception at UniLasalle.

2 METHODOLOGY

A survey based on four themes was designed in order to compare the objectives of the executive and curricula management teams to the students' perceptions and experience: i) the reasons for integrating innovation in the engineering curriculum at UniLaSalle; ii) the reasons for integrating SD in the engineering curriculum; iii) the perceived pillars of SD; iv) and the link between SD and innovation in engineering education.

2.1 Subjects

291 engineering students (148 female and 143 male; mean age = 21.2, SD = 0.9 years) from three specialties (agriculture, nutrition and health sciences, and geology) participated in the study (Table 1). Data were collected in November 2017.

Table 1. Distribution of population by specialty and sex

		Sex		Total
		Female	Male	
Specialty	Agriculture	59	85	144
	Nutrition and health sciences	51	10	61
	Geology	38	48	86
Total		148	143	291

2.2. Measures

The questionnaire comprises 22 items. Three items concern sociodemographic data (age, sex) and the field of study (specialty). Ten items relate to innovation in the engineering curriculum. On a 5-point Likert scale (1 = not probable to 5 = very probable), students express their opinion about the reasons for integrating innovation in the engineering curriculum at UniLaSalle (eg, to satisfy companies' needs). Four items relate to the integration of SD in the curriculum. On a 5-point Likert scale (1 = not probable to 5 = very probable), students comment on UniLaSalle's reasons for integrating SD in the engineering curriculum (eg, to increase the level of responsibility of the future engineer). Students are then asked about the four pillars of SD (economic, environmental, social, energy & mineral resources). For each pillar, they indicate on a 5-point Likert scale (1 = very rarely addressed to 5 = very often addressed) to which extent each pillar is addressed in their curriculum. On the links between innovation and SD, students have finally to choose one of the following statements: i) SD promotes innovation in the engineering curriculum at UniLaSalle, ii) SD restricts innovation in the engineering curriculum at UniLaSalle or (iii) SD promotes and restricts innovation in the engineering curriculum at UniLaSalle.

3 RESULTS

Out of the ten reasons for integrating innovation in the engineering curriculum at UniLaSalle, the four main reasons put forward by students regardless of their specialty, are (Fig. 1):

- To satisfy the job market's needs
- To satisfy companies' needs
- To adapt training to the engineer's profile
- To improve teaching quality

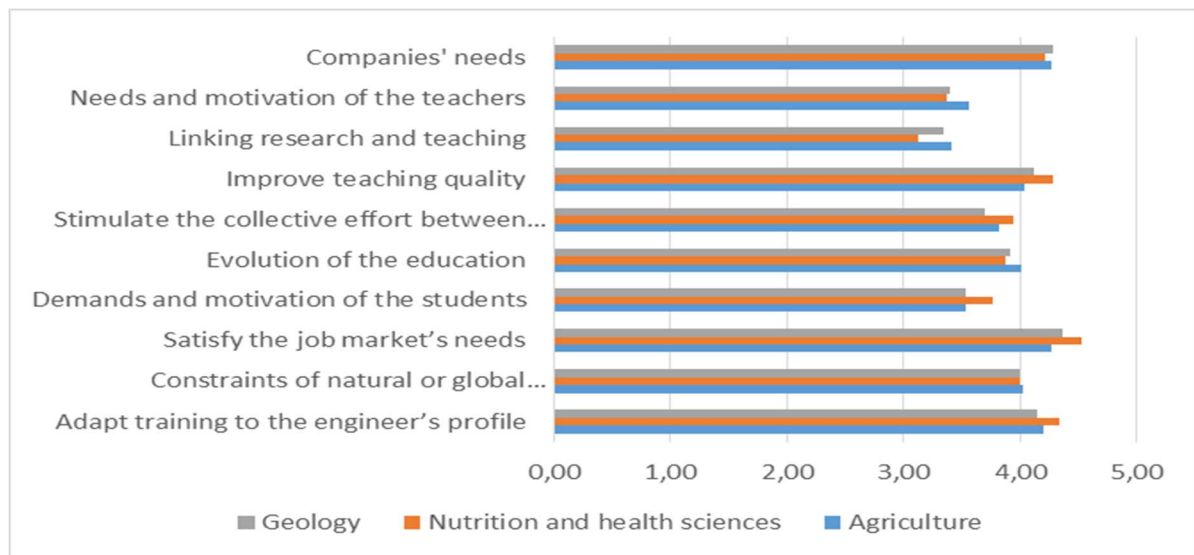


Fig. 1. Students' opinion about the reasons for integrating innovation in the engineering curriculum at UniLaSalle.

Regardless of their specialty students consider the reasons for integrating SD in the engineering curriculum in the following descending order of importance (Fig. 2):

- To allow students to understand environmental and regulatory issues,
- To increase the level of responsibility of the future engineer
- To satisfy European directives
- To take into account an ethical dimension

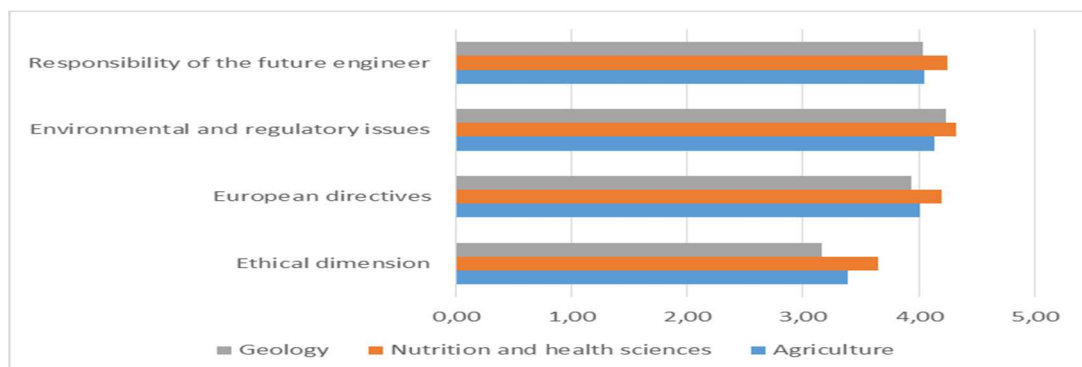


Fig. 2. Students' opinion about the reasons for integrating SD in the engineering curriculum at UniLaSalle.

Depending on their specialty, students consider that the pillars of SD are not addressed with the same intensity in their curriculum (Table 2). One-way analysis of variance (ANOVA) indicate that significant differences are observed by specialty on the environmental ($F(2, 284) = 12.58, p < .001$) and the energy pillars ($F(2, 284) = 92.16, p < .001$). Tukey's post hoc tests indicate that i) the environmental pillar is more addressed in the geology ($M = 3.85, SD = 1.08$) and agriculture ($M = 3.74, SD = 1.04$) specialties compared to the nutrition and health sciences specialty ($M = 3.00, SD = 1.10$) and that ii) the energy pillar is more addressed in the geology specialty ($M = 4.26, SD = 0.83$) compared to the agriculture specialty ($M = 2.78, SD = 1.18$); it is also more addressed in the agriculture specialty compared to the nutrition and health sciences specialty ($M = 1.96, SD = 0.98$).

Table 2. Student's opinion about the intensity (mean levels) to which each DD pillar is addressed in their curriculum depending on their specialty

	Agriculture (n = 144)		Nutrition and health sciences (n = 61)		Geology (n = 86)	
	M	SD	M	SD	M	SD
Economic pillar	3.73	1.08	3.46	1.20	3.65	1.08
Environmental pillar	3.74	1.04	3.00	1.10	3.85	1.08
Social pillar	3.17	1.10	3.47	.97	3.15	1.05
Governance energy and mineral resources pillar	2.78	1.18	1.96	.98	4.26	0.83

Finally, 66% of the students consider that SD promotes innovation in the engineering curriculum, 30% consider that SD promotes and restricts innovation in the curriculum. Only 4% assess that DD restricts innovation in the engineering curriculum at UniLaSalle. The result is the same for the three specialties.

4 DISCUSSION AND CONCLUSION

We can notice that the students' answers are converging with those of the curricula management team. Most of the students think that SD is a factor of innovation in their curricula. Depending on their specialty the different pillars of SD are not treated with the same intensity.

The speciality of our future engineers (Table 2) has a strong influence on their perception of the three pillars of SD and the fourth pillar on the governance of energy and mineral resources. Differences in the perception of the SD pillars integration between the specialties can be linked to their respective curricula [9] and corresponding work experience. The role of training and the need to balance the integration of the four pillars in the different curricula suggest differentiated actions according to the specialties. This study can help curricula management team and teachers to identify the dimensions of SD that need to be strengthened, as well as the implementation of specific resources and tools for teachers to innovate in training and to be aware of the reasons for innovation at the institutional level. It can be described according to different formalized situations and implies a change in the relationship between students, their involvement, and the teacher.

When a strategy for innovation and SD is implemented in training at all levels of the institution, from the executive management to curricula managers, this study shows that students also feel concerned by this visionary approach (eg. Figures 1 and 2).

The results of the link between SD and innovation showed that 66% of the students consider that SD promotes innovation in the engineering curriculum and 30% consider that SD promotes and restricts innovation in the curriculum, so we can confirm that the implementation of SD in a higher education engineering school is perceived as and should lead to educational innovation.

The internal variability of responses in each specialty appears surprisingly high. This may be due to an internal heterogeneity in the population for each specialty: eg. the different parents' level of education and socio-professional categories. A stratification approach (cluster analysis) could be set up and may show that the specialties are not the most important criteria.

This particular reflexivity, both from staff, curricula managers and students, can bring valuable insights in the support for any engineering institute that wishes to incorporate more social responsibility in its own development. It can also promote training and research as a vector for alignment of the job market's needs with the knowledge and skills acquired by future engineers.

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Initial impact of Brexit on European students and academic staff in UK's engineering higher education

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Conference Key Areas: Recruitment & Retention of students; Gender and diversity

Keywords: European students; European staff; Brexit

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1 INTRODUCTION

The United Kingdom has a long tradition of excellence in higher education and is recognised as being an important player in global engineering education and research.

Higher education relies on international mobility more than most sectors of society in terms of attracting experts from all over the world to research and teach in the UK and attracting international students. Moreover, engineering relies on international mobility more than most other academic disciplines.

The United Kingdom European Union membership referendum, also known as the Brexit referendum, took place on 23 June 2016, and its impact is still unfolding and under continuing analysis. However, it is widely anticipated that it is likely to disrupt student and staff mobility with negative repercussions for broader European society through research, innovation, skills shortages and economic impact.

This paper intends to start a debate on the initial findings about the emerging changes of Brexit not only for the UK's HEIs, but also the potential implications to other countries' education systems, research policies and infrastructures and the disruption of European research projects that include UK researchers and institutions.

In the UK, the Higher Education Statistics Agency (HESA) holds large datasets on all aspects of the higher education sector in England, Scotland, Wales and Northern Ireland. It includes data on students, academic and non-academic staff, universities and other education providers. These datasets can be accessed by subscribers (higher education providers and not-for-profits) on the Heidi Plus platform which allows data analysis tailored to answer to specific research questions.

Reports on HESA data prior to the Brexit referendum showed an increase in the proportion of European (EU) academic staff in Engineering and Technology in the UK sector, rising from 10% in 2006/07 to 19% in 2015/16 [1]. As for students, a 71% majority of those entering a first degree in engineering and technology (undergraduate) were of UK origin. 6% were from EU countries and 23% from other nationalities [2]. The opposite was found at postgraduate level, with only 25% UK, 15% EU and 60% other nations.

This paper presents descriptive figures of the latest student and academic staff datasets, to understand the changes in study and demographic distributions (EU nationality/domicile country) in UK HE Engineering before (up until 2015/16) and after (post 2016/17) the Brexit referendum. The study compares the latest annual growth rate of the student and academic staff numbers over time using compound annual growth rates (CAGR), following the type of data analysis that is usually adopted by the sector [1], and form the basis for a longer term assessment of the impact of Brexit on UK Engineering HE. It also analyses data trends in different HE providers, to better understand the initial impact of Brexit in research-led universities that are highly competitive in international rankings (Russell Group) in comparison to other universities. This paper aims to discuss the initial impact of the UK's decision to leave the UK by answering the following research questions:

- Has the proportion of EU engineering students decreased in 2016/17 for both undergraduate and postgraduate degrees? What are the data trends by type of university, and by nationality?
- Has the proportion of EU engineering academic staff decreased in 2016/17, in particular 'research only' staff? What are the data trends by type of university, and by nationality?

2 METHODOLOGICAL APPROACH

2.1 Data analysis

The figures provided by HESA for both students and academic staff are full person equivalent (FPE). FPE looks at how much of one person's studying or working time is engaged in a particular activity.

Compound annual growth rates (CAGR) were calculated to compare academic staff and student numbers over nine academic years, using the formula below (1),

$$CAGR(t_0, t_1) = \left(\frac{V(t_1)}{V(t_0)} \right)^{\frac{1}{t_1 - t_0}} - 1 \quad (1).$$

Where, t_0 – the first year of observations; t_1 – the last year of observations; $V(t_0)$ – the start value; and $V(t_1)$ – the last value observed.

2.2 Students' data

Data for students were selected by domicile continent (Europe) and country (excluding England, Scotland, Northern Ireland and Wales), and further analysed by level of study, engineering discipline and 'mission group'.

Level of study provides the breakdown figures by: first degree/undergraduate (UG), postgraduate research, and postgraduate taught. Postgraduate research (PGR) includes doctorate, master's degree and postgraduate diplomas or certificates studied primarily through research. PGR students are trained in research methods and are expected to do a research project. Full-time programmes usually last 18 months. Because there are lower teaching costs, fees for master's by research are usually lower than for a taught master's. On the other hand, postgraduate taught students (PGT) are those studying for a qualification mostly by a taught method (learning by teaching), although there may be a research element. Full-time courses are normally one year long [3].

In the UK, higher education institutions are commonly grouped in 'mission groups'. The Russell Group is a self-selected group of research-led universities. Data was filtered by university type (Russell Group's member vs. non-members).

2.3 Academics' data

Data for academic staff was extracted by academic employment (academic staff only, including teaching, research, teaching and research, or neither teaching nor research) [4]. It relates to the contract of employment and not to the actual work undertaken.

3 DATA FINDINGS

3.1 European Students

The first student data released by HESA post-Brexit referendum, referring to 2016/17, shows an overall annual increase in undergraduate (8.2%) and postgraduate taught degrees (2.9%) and a decrease in postgraduate research (-1.4%) for all subjects. For engineering subjects, an overall increase was also registered in UG degrees (6.5%), but a decrease in both PGT (-1.8%) and PGR (-2.9%). These results were not expected, taking into account that the pre-Brexit trend, based on compound annual growth figures, was relatively stable for UG and PGT (0.5% and 0.9%, respectively) and showed a positive increase for PGR (4%) (Fig. 1).

Type of university

When analysing these data by type of university, Russell Group (RG) members have registered an annual increase in both UG (8.3%) and in PGT (12.8%), but a decrease in PGR degrees (-4.2%) in 2016/17, compared to the previous year. For these universities, the compound annual growth pre-Brexit was 7.8% for UG, -0.9% for PGT and 6.5% for PGR. Non-member institutions (NM) have registered an annual increase in UG (5.1%), and a decrease in both PGT (-6.7%) and PGR (-0.7%) in 2016/17 compared to 2015/16 (Fig. 2).

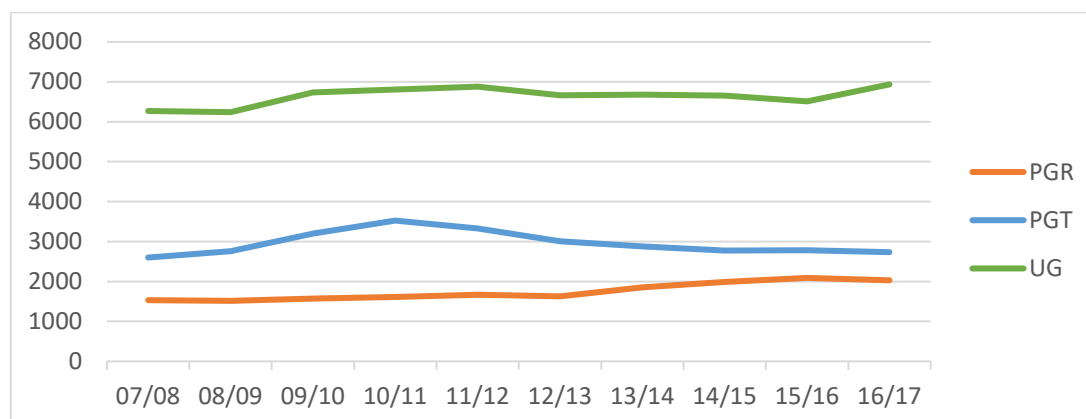


Fig. 1. Number of EU engineering students by degree level

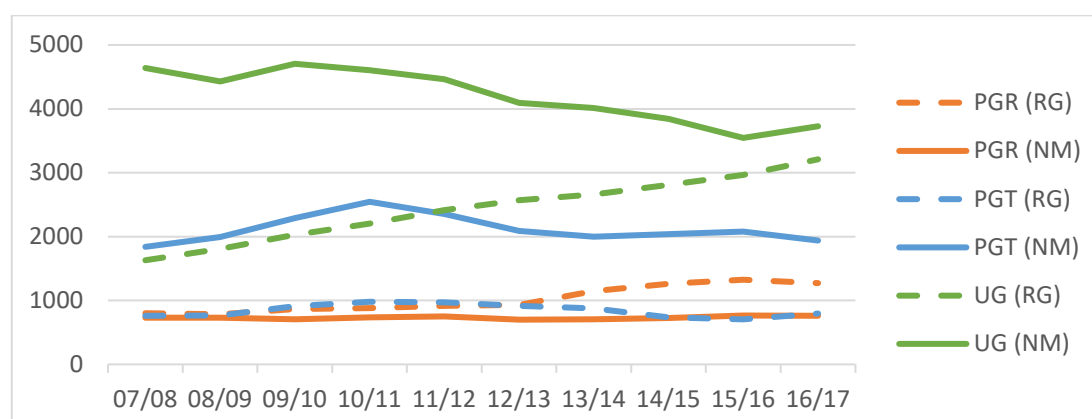


Fig. 2. Number of EU engineering students by degree level and type of university

Domicile country

A breakdown by country showed that the top five EU countries exporting engineering students, both at undergraduate and postgraduate levels, into UK Higher Education institutions in the last two years were France, Germany, Greece, Italy and Spain.

After the decision for the UK to leave the EU, with the exception of Greece (with a decrease of -0.7% in their UG numbers), the UK's universities had registered an overall annual increase in the numbers of engineering UG students from Germany (25.3%), Italy (19.8%), France (17.6%), and Spain (12.3%). This contrasts with the figures in postgraduate study (Fig. 3). Post-referendum figures were:

- France (FR): PGR (-2.8%) and PGT (-8.0%);
- Greece (EL): PGR (-7.1%) and PGT (-9.8%);
- Germany (DE): PGR (-1.8%) and PGT (1.5%);
- Italy (IT): PGR (0%) and PGT (-5.0%);
- Spain (ES): PGR (-4.9%) and PGT (-1.3%).

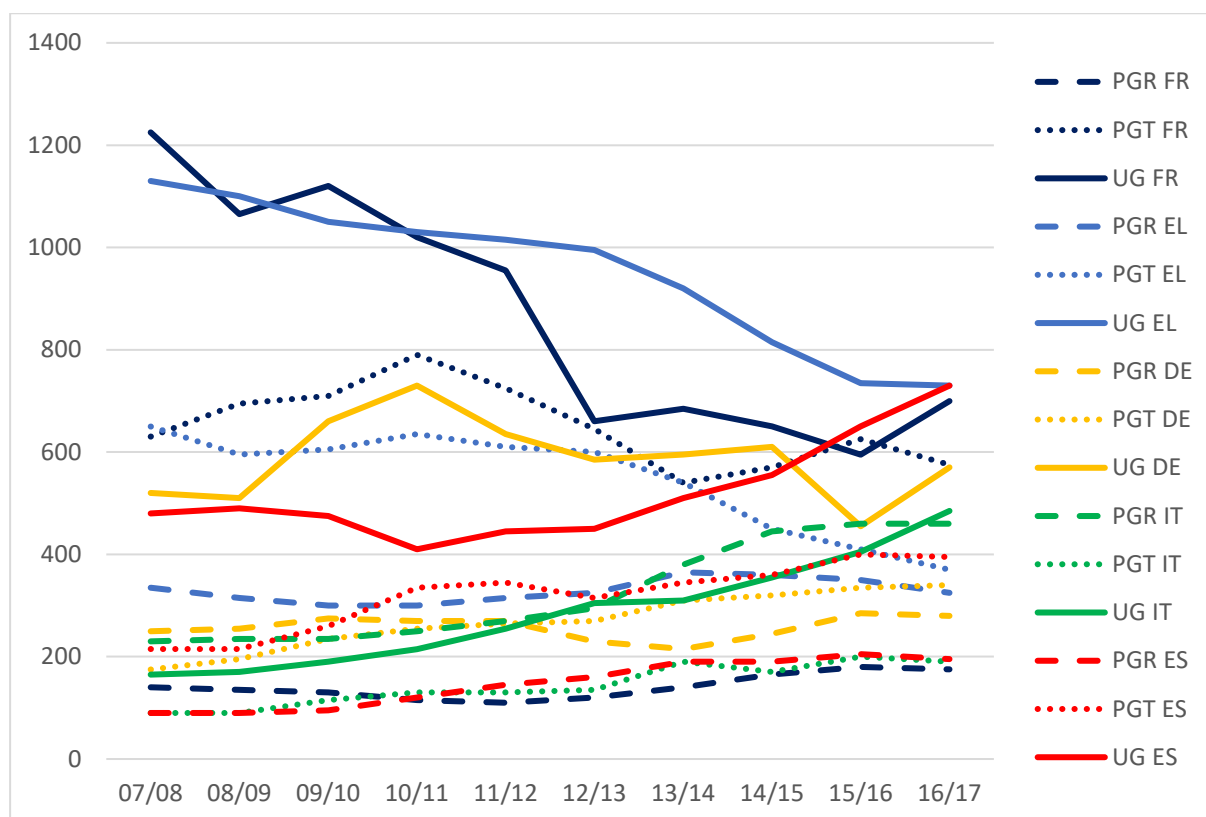


Fig. 3. Number of students by EU country and degree level

In 2015/16, UG degrees were the most popular among students from Greece, Germany and Spain; PGT was the most popular among students from France, and PGR from Italy. In 2016/17, UG degrees were the most popular among students from all the above top five European countries.

3.2 European Academic Staff

The first post-referendum staff data released by HESA, referring to 2016/17, shows that the proportion of European engineering academic staff (including teaching, research, teaching and research, or neither teaching and research) in engineering HEIs is 17.4%. When analysing research staff only, one in four research academics was European (26.4%).

Data analysis revealed an overall annual increase for all academic staff (all domiciles) working in engineering HEIs in the UK (2.7%) and a smaller increase for research-only staff (0.9%) in 2016/17 compared to 2015/16. The figures for European staff were 6.5% for all academic staff and 3.1% for research-only (Fig. 4)

Type of university

Data analysis of type of academic employment and university group revealed that the proportion of EU academic staff working in Russell Group universities was 22.8% (27.2% in 'research-only' contracts) and 13.4% in non-member universities (23.9% in 'research-only' contracts).

Both groups of universities were able to contract EU academic staff in 2016/17 (increase of 5.1% in Russell Group and 8.2% in non-members) (Fig. 5). However, when data on 'research-only' staff was analysed, Russell Group universities increased the number of EU staff by 3.9% (whereas the CAGR up until 2015/16 was 7.8%) and non-members increased just 0.2% (whereas the CAGR up until 2015/16 was 5.2%). These findings may suggest the potential negative impact of the UK's

Brexit decision on EU engineering academic staff recruitment, particularly staff in 'research-only' contracts.

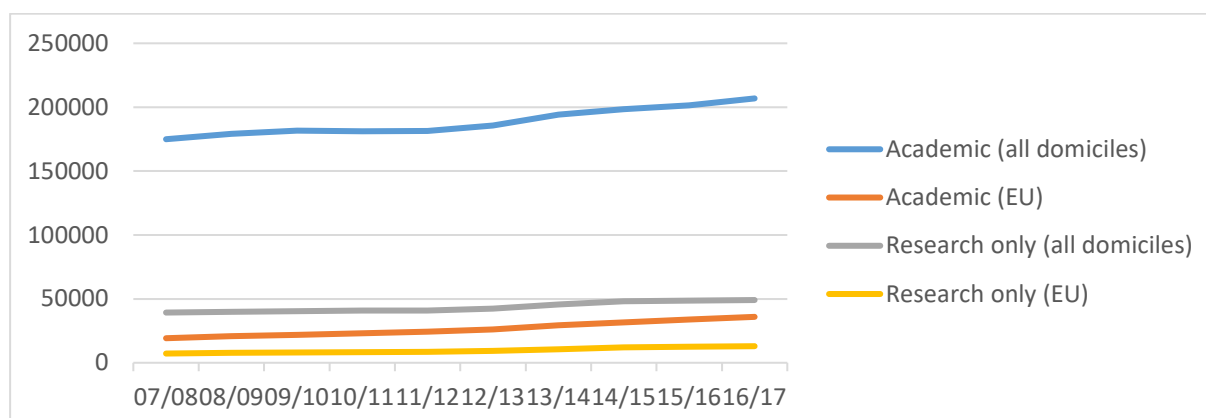


Fig. 4. Number of staff by domicile and academic contract

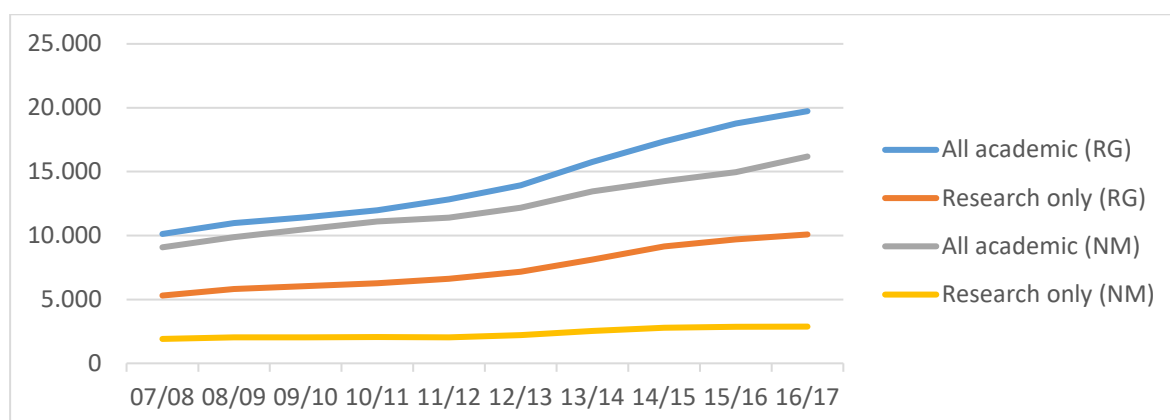


Fig. 5. Number of EU staff by academic contract and university group

Nationality

Similarly to what was found for students, the most represented countries of EU academic staff in the last two years were France, Germany, Greece, Italy and Spain, but also Ireland, followed by the Netherlands, Poland and Portugal. In 2016/17, within each nationality, the proportion of 'research-only' staff was 44.3% for France, 29.8% for Germany, 30.3% for Greece, 39.6% for Italy, and 47.5% for Spain.

4 DISCUSSION

Data analysis revealed an increase in the number of engineering undergraduate students from EU countries in the academic year following the referendum. This may suggest that EU students are taking the opportunity to study engineering in the UK as a 'last chance' before fees, funding and visa requirements change. The fall in the pound's value since the referendum has made studying in the UK more affordable and this may be particularly attractive to non-UK students.

In terms of recruitment of undergraduates and postgraduate taught degrees, Russell Group universities have thrived. Other universities have fared less well suggesting universities with international brands have greater resilience in the face of political realignments.

The decline in EU students in PGR degrees, particularly in Russell Group universities, needs further research: for many, these degrees represent a longer-term commitment in terms of both study and career and so, even for resilient brands, the prospect of moving to the UK as a country outside the EU may have undermined its attractiveness as a destination.

The increase in rates of EU academic staff recruitment seem to have been negatively impacted as well, particularly for staff in 'research-only' contracts [5]. Currently, the lack of clarity over the right to remain in the UK and the uncertainty about the UK's capability to host EU-funded projects seem to be two of the main drivers of EU academics leaving the UK [6].

More data analysis is needed to better understand the impact of the Brexit decision on European students and staff studying and working in the UK. Data on the 2017/18 academic year, available in early 2019, may help to provide a clear picture.

It is important to remember that, although the Brexit referendum triggered a process of withdrawal from the EU, the UK will remain a member until at least 29th March 2019 and UK Government policy is to remain within EU structures for a transition period of 21 months thereafter.

Therefore the significance of any patterns remains to be demonstrated, not least because of the concurrent impact of other factors such as the attractiveness of Trump-era USA as a destination for students and academics. Our research and the available data to date provide no basis to draw conclusions, but they do raise questions:

Will the UK remain as significant an international hub for engineering higher education and research post-Brexit?

Certain universities seem to have avoided most negative effects so far, but how deep is their resilience?

Other universities appear to be experience an impact already. Will this pattern grow or disappear?

Is there an opportunity or a threat to other EU institutions?

What would the impact on ongoing and future research projects and infrastructures be in the EU?

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How entrepreneurial is engineering education?

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Conference Key Areas: Fostering entrepreneurship, curriculum development, teaching creativity and innovation

Keywords: Curriculum development, entrepreneurship education, engineering education

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INTRODUCTION

SEFI 2018 proclaims in its introduction “Creativity, innovation and entrepreneurship must obviously be part of any engineering educational program”. Discussing this pronouncement from an entrepreneurship education research perspective, it is questionable whether entrepreneurship *is* actually part of engineering study programs. This article aims to enrich the scientific discourse in engineering education research by contributing to specific foundations of entrepreneurship education in STEM degree programs. While politically and practically driven debates on employability or entrepreneurial activity call for advanced entrepreneurial agility at universities, the question of whether entrepreneurship is “part of any program” has not yet been exhaustively researched. Even though an international discourse on approaches to entrepreneurship education arouse in the last decades, it is usually assumed that for non-business students, especially in STEM degree programs, entrepreneurship education is rarely embedded in the curriculum. However, nobody really knows because exhaustive curriculum analysis is a bumpy road to success. Thus, our main question is: How is entrepreneurship embedded in higher education STEM degree programs?

1 RESEARCH BACKGROUND

1.1 Exploring: Research in engineering and entrepreneurship education

This paper aims to bring together two research communities. First, we are looking at the development of engineering education research (EER) in the last decades [1, 2, 3]. While it is still under discussion whether EER can be described as a discipline, a community or a field [3], a lot of research on the core questions of EER topics has been conducted so far [1]. On the one side, general and broad-ranging topics are discussed, e.g. “the nature of engineering knowledge, which topics should be taught and how they should be taught, and the social and organizational contexts of engineering and engineering education” [1, p22]. On the other side, quite specific questions are addressed, such as chances and challenges of e-learning or problem-based learning, skills, diversity, recruitment, engineering educators, student learning processes [1]. Much work has been devoted to questions of curriculum development [1, 4], where aspects of embedding entrepreneurship are also discussed [5].

Second, we observe a vivid community of research in entrepreneurship education (REE) in the last decades [6]. Within this discipline (community or field), issues are discussed in a complex and heterogeneous way. To date, the terminology of entrepreneurship education is unclear [6], and heterogeneous questions are being debated. On the one side, we see general questions of the character and issues of entrepreneurship education as a research field [6]. On the other side, we see a more narrow perspective on specific questions, e.g. contrasts between a “traditional” and “entrepreneurial” way of teaching, other pedagogical approaches, effects of entrepreneurship education, entrepreneurial mindsets and embedding of entrepreneurship in so called non-business disciplines curricula [6]. Within this field, most research is carried out with business students, as most entrepreneurship researchers themselves have this background and entrepreneurship is often taught to this target group. While the embedding of entrepreneurship in engineering curricula was already proclaimed as one of the hottest topics in the USA about 15 years ago [7], we are still faced with the situation that little research has been done on this question to date [8]. Reflecting this brief overview,

this paper aims to explore the specific question of the integration of entrepreneurship into engineering curricula and thus to link relevant issues of both communities.

1.2 Focusing: Core definitions

To do so, there is a need to set some core definitions in EER and REE. To explore the question “How entrepreneurial is engineering education?” we define engineering education in the context of higher education in STEM fields, known as abbreviation for science, technology, engineering and mathematics. However clear this classification may appear, it remains unclear which teaching and learning contents, fields of study or subjects are meant exactly. This paper defines STEM according to ISCED-F educational classification, published by OECD and UNESCO [9], as broad fields of education and training: natural sciences, mathematics and statistics (MS), information and communication technologies (ICT) and engineering, manufacturing and construction (ENG). Consequently, engineering education is a very broad field, being split up in six narrow fields (a) chemical engineering and processes, environmental protection technology (ENG-CH), (b) electricity and energy, electronics and automation (ENG-EL), (c) mechanics and metal trades, motor vehicles, ships and aircraft (ENG-ME), (d) manufacturing and processing (ENG-MP), (e) architecture and construction (ENG-AC), and (f) other engineering sciences including industrial engineering and management (ENG-OS).

Entrepreneurship education can be defined based on a wide or a narrow notion of entrepreneurship. Narrow definitions focus on uncovering entrepreneurial opportunities, business development, self-employment, business creation and growth, i.e. the question of how to become an entrepreneur. In contrast, broad definitions focus on aspects of personality development, creativity, initiative, action orientation, i.e. the question of how an entrepreneurial thinking and acting person can be developed [6]. In addition, the common starting point of all variations of entrepreneurship education remains the concept of value creation – and this term can be understood in a broad sense as financial, cultural or social value. The common goal of entrepreneurship education seems to be the development of entrepreneurial competences [6]. Some typologies of entrepreneurship education exist. For our research, we chose a new typology that differentiates entrepreneurship education types into traditional (TEE), creation (CEE), value creation (VaCEE), venture creation (VeCEE) and sustainable venture (SVEE) approaches [11].

1.3 Questioning: How entrepreneurial is engineering education?

The debate in EER shows that there is a discussion around the question of how to improve engineering curricula. Arguing from the perspective of REE we assume that in general the curricular anchoring of entrepreneurship education has positive effects [10]. A brief overview of the status quo of research shows that many case studies for several universities exist. For the case of Germany, we find the specific situation that associations (e.g. German Association of Engineers) explicitly advocate entrepreneurship education in higher education for engineers, but up to now, the concrete status quo of embedding entrepreneurship education in curricula is not known. To sum up: Even though the relevance of entrepreneurship education for engineering is known in research and praxis, there is no knowledge about the extent to which engineering students are confronted with contents of entrepreneurship education in Germany. Therefore, we address the question: How entrepreneurial is engineering education?

2 EMPIRICAL STUDY

2.1 Method and data description

A comprehensive document search and analysis of study course documents of all STEM study programs in six German Laender has been carried out in the period of 04/2017-12/2017. All programs have been selected from the database of the Hochschulrektorenkonferenz (German Rectors' Conference). The adjusted sample includes 1361 study programs at 58 higher education institutions. In a second step, N=2220 documents have been collected (study and examination regulations, module regulations and descriptions) and digitally stored. Those documents were searched for subjects related to entrepreneurship education using the digital search function. A positive list was used to search relevant terms such as "gründ*" or "entre*" (for founding, start-up management, entrepreneurship etc.). Finally, those course descriptions including elements of entrepreneurship education were analysed via content analysis.

The sample is almost equally distributed between study programs at universities (n=684) and study programs at universities of applied sciences (n=674). Almost exclusively, study programs are offered by public universities (n=1311). Private universities provide 4 percent of the study programs in this sample (n=50). According to degrees, the sample shows a balanced distribution of bachelor's degree programs (46 percent) and master's programs (47 percent). Allocation over six German Laender reaches from 10.4 percent (n=142 study programs) in Brandenburg to 29.2 percent (n=397 study programs) in Saxony.

2.2 Curricular anchoring referred to broad and narrow fields of study

A binary variable has been used to code whether or not a study program includes entrepreneurship. In the complete sample, 19.3 percent of study programs (n=263 out of 1361) include entrepreneurship. The ISCED-F categories allow a comparison of the broad field of ENG with the two other broad STEM fields MS and ICT. Results show (Fig.1) that 18.33 percent of engineering curricula include entrepreneurship, which is almost average. While ICT has the biggest share with 31.58 percent, study programs in the broad field of MS have the lowest share with 13.02 percent of programs including entrepreneurship

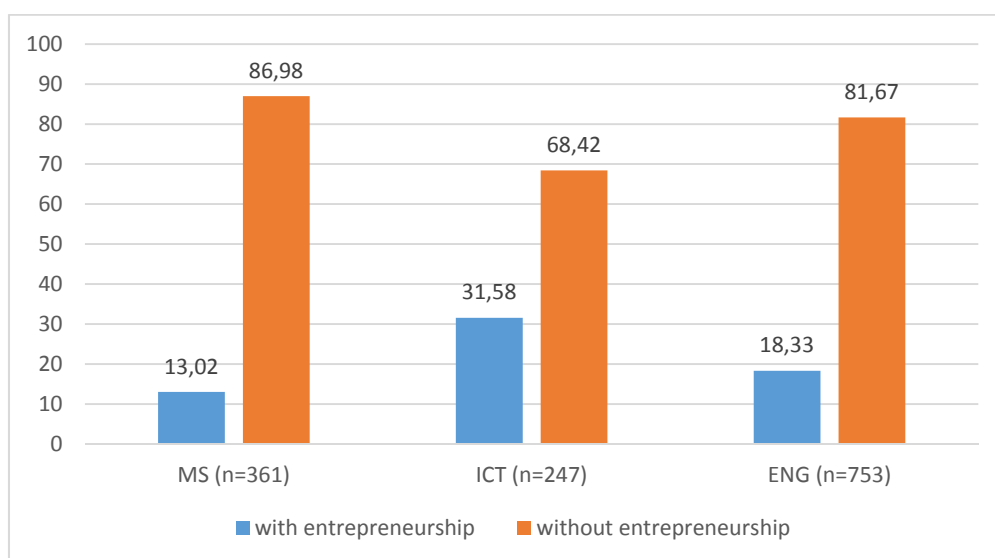


Fig. 1 – Study programs with/without entrepreneurship according to broad fields of study, numbers in percent

A detailed view on the narrow fields of ENG shows that especially study programs in the narrow fields of ENG-OS and ENG-ME include entrepreneurship above average with 27.2 and 21 percent. For the remaining narrow fields of ENG, entrepreneurship is included in 15.6 percent of the cases.

Reflecting the results from the perspective of different university types (Fig. 2), it can be observed that 21 percent of ENG study programs at universities of applied sciences include entrepreneurship while only 13.3 percent of ENG study programs at universities do so. Compared to the other broad fields, a similar observation can be made here. In both fields, the share of study programs that include entrepreneurship is higher at universities of applied sciences than at universities.

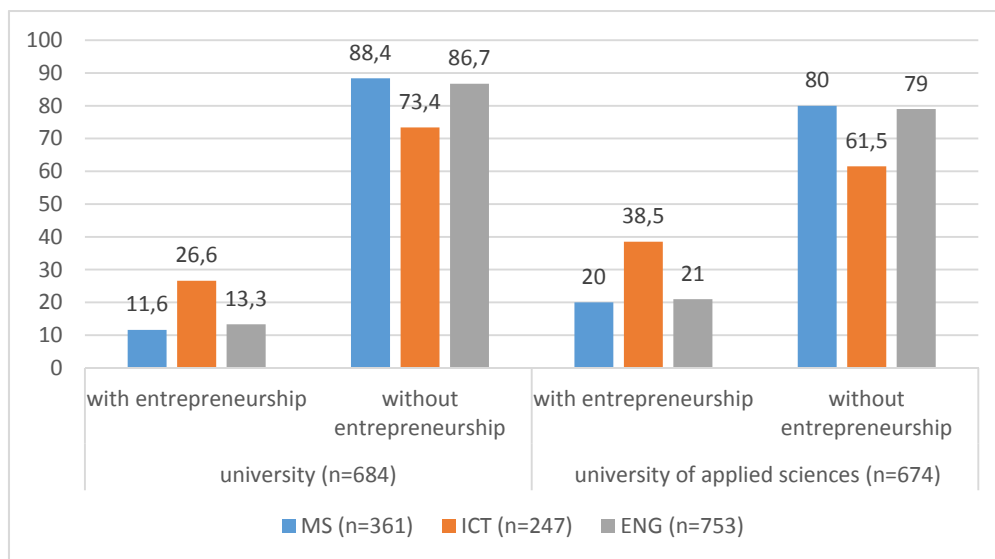


Fig. 2 Study programs with/without entrepreneurship according to university types and broad fields of study, numbers in percent

Furthermore, it can be highlighted that there is almost no difference between Bachelor and Master programs regarding the embedding of entrepreneurship. 19.9 percent of ENG study programs on bachelor level and 18.7 percent of ENG study programs on master level include entrepreneurship. It is remarkable that the German Diploma still exists in the field of ENG. Only 8.8 percent of ENG diploma study programs include entrepreneurship.

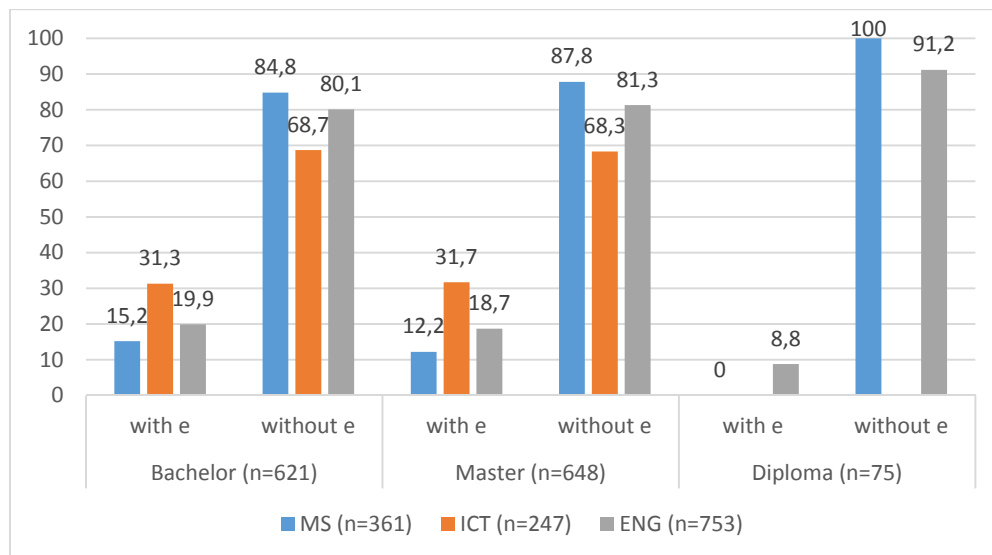


Fig. 3 Study programs with/without entrepreneurship according to degrees and broad fields of study, numbers in percent

2.3 Course analysis

In a second step, we analysed in detail the identified courses on entrepreneurship in STEM curricula. Up to six courses related to entrepreneurship were identified in one study program (Fig.4). Usually, ENG study programs include one course with content related to entrepreneurship. A maximum of four courses in one study program could be found. Compared to the other broad fields, some differences can be observed. While MS study programs include up to six courses, the common model is one course including entrepreneurship. In ICT, more study programs were identified including two (16,67 percent) or three (12,82 percent) courses.

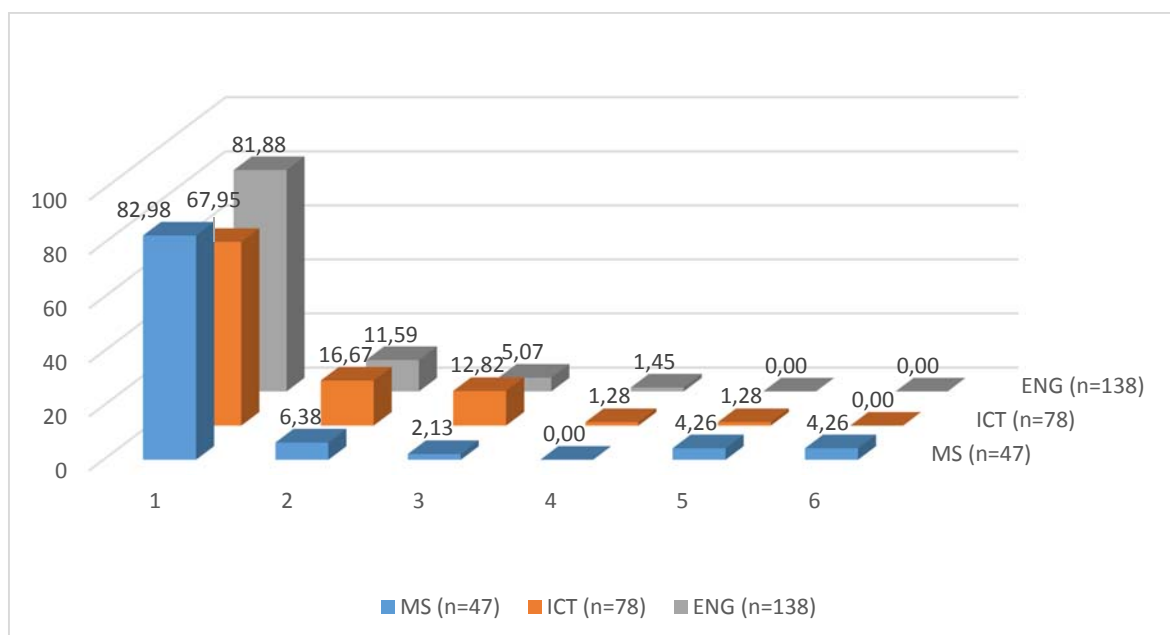


Fig. 4 Total amount of courses related to entrepreneurship in one study program, sorted by broad fields, numbers in percent

Furthermore, the courses in all broad fields mainly have a duration of one term. 86.96 percent of entrepreneurship courses provided by ENG study programs are one term courses, 13.04 percent are two term courses. 58.71 percent of courses provided by ENG study programs are compulsory optional subjects, 38.06 percent are core subject. Compared to the broad fields of ICT and MS, in ENG the biggest amount of courses has the character of a compulsory subject (ICT – 28.42 percent compulsory subjects, MS – 15.52 percent compulsory subjects). In addition, the character of courses has been identified. Typically, entrepreneurship related courses in ENG study programs are combined lectures with seminars (59.76 percent). Compared to other broad fields, this is the biggest amount. Only 15.85 percent of entrepreneurship related courses in ENG study programs are solely lectures and 21.34 percent are solely seminars.

Finally, we analysed course descriptions of the courses related to entrepreneurship. We illustrate the results by the example of the narrow field ENG-EL (Fig.5). Out of 43 detected courses in 32 ENG-EL study programs for n=33 courses sufficient descriptions were available and analysed. The contextual relevance of entrepreneurship in these courses shows two extremes: either a complete course is dedicated to entrepreneurship education (contextual relevance 'high') (e.g. courses in which all themes and subthemes are oriented to the overarching agenda of business plan writing) or a single subtheme is oriented to entrepreneurship (contextual relevance 'low') (e.g. courses in marketing which include entrepreneurship as one topic beneath ten or twelve others). In addition, we categorized courses according to the underlying approaches of entrepreneurship education [11]. Two thirds of the courses examined show elements of the type TEE (traditional entrepreneurship education), while one third shows elements of the type CEE (creative entrepreneurship education). The other more advanced and complex approaches to entrepreneurship education (VaCEE, VeCEE and SVEE) were not identified in the course descriptions.

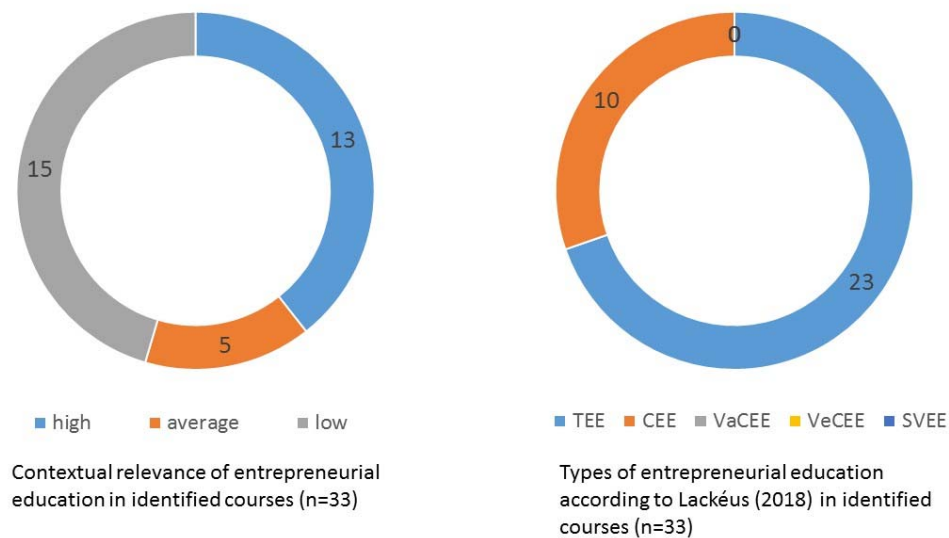


Fig. 5 Course analysis regarding contextual relevance and types of entrepreneurship education, subsample ENG-EL (n=33)

3 CONCLUDING REMARKS

If – as SEFI 2018 introduction proclaims - “creativity, innovation and entrepreneurship must obviously be part of any engineering educational program”, there is a lot to do for STEM study programs in Germany. Only 19.3 percent of the study programs embed entrepreneurship education in their curriculum. Looking into the details, only 50 percent of the identified courses (in our example ENG-EL) have a high contextual relevance of entrepreneurship. If we reflect on this result, entrepreneurship education does not seem to have the status of one of the “hottest topics” at engineering schools, as was the case in the USA 15 years ago [7]. For future research, we still have to understand the reasons why engineering education in Germany does not seem to be entrepreneurial. We are currently seeing these three aspects. (1) Entrepreneurship education is in the hands of the Faculties of Economic Sciences. Often enough, students in these subjects are the primary target group of their teaching. For future research, it could be a fruitful idea to investigate whether or not the institutional affiliation of the lecturers is a relevant factor for a successful integration of entrepreneurship into non-business study programs. (2) In view of the broad and narrow definitions of entrepreneurship education, interesting research questions also arise: Which peculiarities and specificities does engineering entrepreneurship education have with regard to the questions of “how an engineer becomes an entrepreneur” and “how an entrepreneurially thinking and acting engineer can be developed”. (3) Since 1998 there has been a state-aided programme in Germany with the aim of promoting entrepreneurship at universities. The permeation of university teaching is among the objectives of the program. In light of our results, the question arises as to why this goal has not yet been achieved to a greater extent. In particular, it would be important to explore how government support affects entrepreneurship education of non-business students. Taking these observations into account, we look forward to discussing our findings with the SEFI community to gain a deeper reflection of our work from an international perspective.

4 ACKNOWLEDGEMENTS

This study is financially supported by the German Federal Government Commissioner for the New Laender. Extracts of this study will be discussed at other conferences.

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Pragmatic Research Tactics for Starting IT Engineers

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Conference Key Areas: Engineering skills, Innovative teaching and Learning Methods, Teaching Creativity & Innovation

Keywords: Pragmatics, Research, Tactic, Inquiry

1 INTRODUCTION

The research for this paper started with our fascination for the pragmatic ways engineering professionals do research, in order to close the knowledge gaps occurring during their problem solving processes. Take for example an engineer who is called to an emergency at headquarters when the internet satellite connection to a remote offshore production plant is down. The engineer can either work around the problem or try to find its cause. Finding the cause of the problem requires thorough investigation on a distant location and it is not clear whether the required spare parts are available. Working around the problem could be faster, but the engineer is not sure if an alternative connection can be created. The engineer decides to probe both ways,

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analyse the information he receives and subsequently continue on the most promising path. This way, he first succeeds in creating a low bandwidth work-around for the internet connection. Later he finds the cause of the problem so a helicopter can bring replacement parts with the next supplies. (example taken from participant D in this research)

The example illustrates that engineers work in pragmatic ways to close knowledge gaps. They employ pragmatic research tactics that take constraints of time and resources into account and aim for the highest chance to close knowledge gaps. These pragmatic research tactics aim for answers that fit just good enough rather than perfect, to close gaps (e.g. a low bandwidth solution) The answers just need to fit sufficiently in order to solve the problem. To find answers, an engineer can flexibly choose whether to simply look up an answer, investigate the situation more thoroughly or design a rigorous research plan. In summary we define that pragmatic research tactics aim for the highest chance to find answers that fit sufficiently to close knowledge gaps in order to solve the problem with optimal use of time and resources.

As research methodology teachers in engineering education, we would like to have a meaningful discussions based on literature with students and teachers about the use of pragmatic research tactics. A first place to search is the literature on (pragmatic) problem-solving methods in engineering. This literature can be found in the form of best practices for an engineering subject (e.g. ITIL, Six Sigma) or can have a more general life cycle approach with recursive (e.g. problem solving cycle), sequential (e.g. V-model) or incremental (e.g. agile) methods as can be found in systems engineering handbooks [e.g. 1, pp. 32–36]. These problem-solving methods include steps that require research, such as determining user requirements, finding an algorithm or testing a proof of concept. But within problem-solving literature, research methods, and especially their corresponding pragmatic tactics, only receive a global treatment.

Another place to search for research pragmatics is the literature on research methodology in engineering (e.g. [2]–[5]). However, research pragmatics are a topic of interest in most academic textbooks, they are seldom presented as a central concern. And when they are treated as in [6]–[8], pragmatics are discussed with respect to a particular research practice and with corresponding pragmatics in mind. So, although this literature might for example treat how to deal with small samples or missing data, it does not provide help for switching dynamically between small scale or informal research to more thorough approaches.

All in all, the literature on problem-solving and research methods richly supplies solid research strategies suitable to plan research in various types of projects. However, literature on flexible pragmatic research tactics suitable to discuss ways to adapt to the changing situation within projects, is rare and scattered.

To learn more about pragmatic research tactics we set up an empirical study with novice engineering professionals because that is the aspiration level of our students. Since the authors work in bachelor of IT engineering education, the scope was restricted to this area. This resulted in the following research question for this study:

What are pragmatic research tactics that novice bachelor of IT engineering professionals use to acquire sufficiently good answers to close the knowledge gaps that occur in the context of their project assignments?

2 METHODS

2.1 Design

In order to research what novice engineers actually do when closing knowledge gaps, a qualitative approach based on grounded theory [9] was chosen. A concern with the data collection was that part of the process happens invisible and even unconsciously. This entails that written research reports and observations will keep aspects of the process out from view. An interview is a way to collect more anecdotal stories that include part of the unconscious process. Another way to stimulate this is to visualize the process with timeline mapping [10]. To create a rich source of information, the two were combined in a semi-structured visualization interview. The interviews were analysed according to grounded theory, starting with open coding to organize the raw data into labels, followed by axial coding to identify research activities in the labels. The process was concluded by selective coding to find integrating categories of pragmatic research tactics. More explanation of the process, in the paragraphs below.

2.2 Participants

In order to obtain information concerning the research pragmatics of novice IT engineers, interviews were conducted with professionals who have a working experience of three to five years. Within this timeframe, engineers are expected to work professionally and be able to discuss their ways of working in a reflective way. At the same time, they are not yet promoted to senior jobs with different characteristics. Bachelor alumni from the IT program of the University of Applied Sciences in Utrecht were contacted by e-mail. From the positive responses, engineers out of the four IT specializations were incorporated into the study. In this way a broad spectrum of engineers ranging from Technical Software Engineers (TSE), System & Network Engineers (SNE), Software & Information Engineers (SIE) and Business & IT Management (BIM), were included in the study. See Table 1.

Table 1. Participants that were interviewed. See text for explanation of specializations.

Participant	Specialization	Years' experience	Job Title	Practice
A	TSE	4	Test lead medical applications	Multinational
B	TSE	3	Application developer	Own business start-up
C	TSE	5	Product owner	Start-up
D	SNE	4	Network engineer	Offshore industry
E	SNE	5	Network engineer	System consultancy
F	SNE	4	High end network developer	Internet exchange
G	SIE	5	Web developer	Own business
H	SIE	5	High end AV app developer	Secondment, Broadcast company
I	BIM	4	Business analyst	Major consumer web shop
J	BIM	3	Business IT consultant	Development & consultancy
K	BIM	5	BI data warehouse designer	Development & consultancy

2.3 Visualization interviews

For the semi-structured interviews, a form of timeline mapping was used. The participants were asked to reconstruct a recent project by visualizing the problem-solving steps of the timeline with sticky notes and tell stories around the way questions were raised and answered (see Fig. 1a). The sticky notes acted as a visual aid to

enable the conversation to switch back and forth between the different problem-solving steps. Since not all research is done as part of a project, the respondents were also asked about the way general knowledge issues were raised and answered in their organization. The face-to-face interviews were conducted by two researchers and took around 90 minutes.

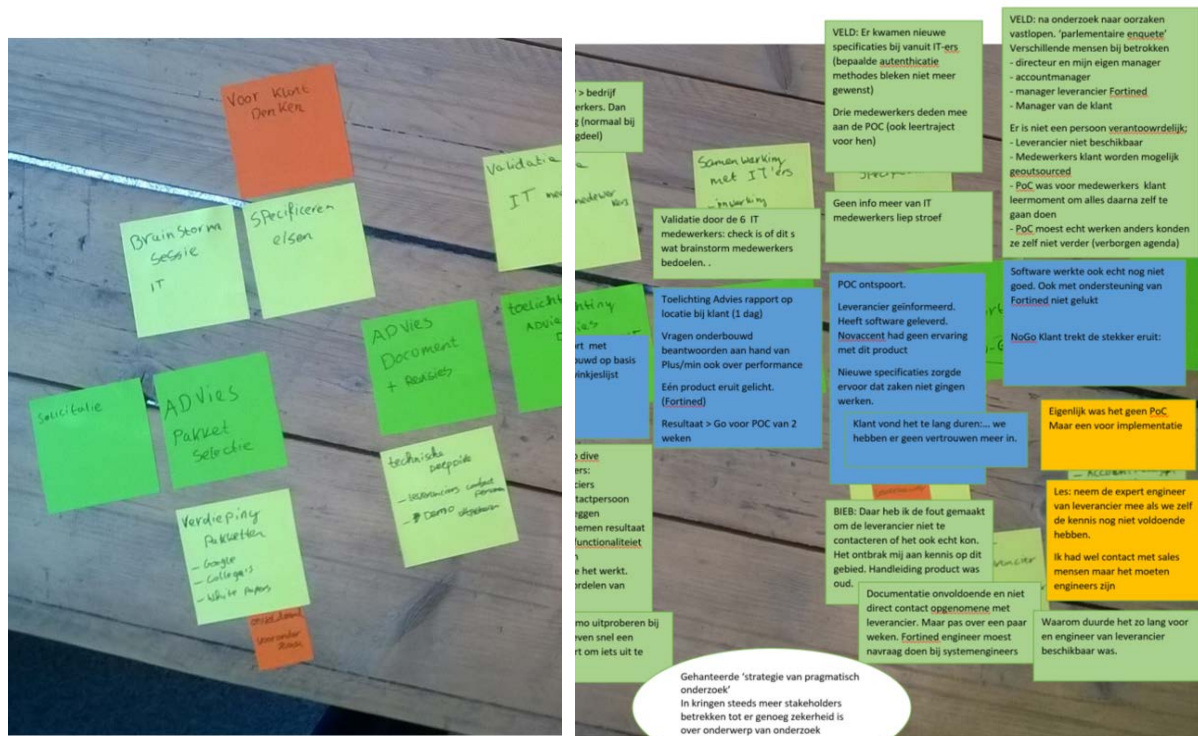


Fig. 1a. Visualization of the project. The sticky-notes were written by the participant during the interview. From left to right in darker green the problem-solving steps in time. To the top and bottom sticky-notes referring to research and knowledge. (Participant E)

Fig. 1b. Open coding labelling of the interview, based on visualization and the recording, by one of the researchers. From left to right in blue the labels for the problem-solving steps. To the top and bottom labels referring to research and knowledge.

2.4 Analysis of the interviews

Each interviewer analysed half of the interviews based on the visualization and the recordings in a process of open coding to create labels [9]. This resulted in a detailed description of the process steps of the project in the visualization (see figure 1b.). To create uniformity and mutual understanding the other interviewer checked and completed the work and vice versa. Based on this detailed description of the visualization, labels about research activities were identified in a process of axial coding [9]. This resulted in the description of 77 research activities that were placed in Excel by one of the researchers and checked by the other. The quotes on the research activities were split in accordance to the approach en the sufficiency of the research activity. Below an example of a research activity from participant A:

Research approach: Before we commit software it is always reviewed. Not so much because the code gets tidier (also happens) but especially that you are together and the other person knows what you did.

Research process sufficient when : *I do not like that piece of code because ... and then the other person says: yes I did that because ... and then you say: oh yes. What is important in a review is human contact. Do not crack down on someone else's code with a tool without contact.*

During and after this process of identifying the research activities, several integrating categories of research activities were defined in a process of selective coding [9]. The resulting categories were subsequently contributed to the research activities after mutual understanding between the two interviewers. The integrating categories are described in the results section below.

3 RESULTS

In the introduction of this paper, we defined that pragmatic research tactics aim for the *highest chance to find* answers that *fit sufficiently* to close knowledge gaps in order to solve the problem with optimal use of time and resources. This section will describe what pragmatic research tactics were found with selective coding in the research activities of the participants. Firstly, we will describe three categories of tactics that aim for the highest chance to find answers. Secondly, three categories of sufficiency to determine whether answers fit sufficiently to close the knowledge gap.

3.1 Tactics

In the research activities, three different tactics could be identified that aim for the highest chance to find answers: concentric, iterative and probe-response. A research activity is categorised as **concentric** (found in 21 research activities in 11 projects) when it contributes to research that starts with sources of information directly accessible to the researcher and the circle of possible sources is widened until the answer is sufficient. An example from participant E is a brainstorm meeting with clients from the IT department to specify a new system. These specs were the starting point for the development and were later validated and supplemented by a group of users.

A research activity is categorised as **iterative** (22 activities in 8 projects) when it contributes to research that starts with an answer that bridges a basic part of the knowledge gap. If necessary, the knowledge gap can be closed more thoroughly in an iterative way. An example is a research activity of participant F. He works as a network engineer for a big internet exchange provider. As part of a project, he had to test network equipment that was merely on the market and uses innovative fibre technology. He created a basic test setup and asked several suppliers for a demo with the test setup. With every test demo, he accumulated more knowledge about the technology and the test equipment until he had a test setup that met the highest industry standards.

A research activity is categorised as **probe-response** (7 activities in 5 projects) when it contributes to research that starts with an educated guess (probe) and draws upon the received response whether the result is satisfying or requires a new probe. An example is a research activity of participant G. He had to select a pdf generator for the web application he was building. He assumed this was standard technology and looked for commonly used solutions on Google, picked one, tried it for five minutes, found some usability issues he did not like, tried the next, and found it more satisfying. He knew this was not perfect either, but he could handle it so he continued to use it in the application.

It is relevant to mention here, that the research activities of all 11 projects show that the research tactics are not always matching with the problem solving strategy of the project as a whole. In 34 activities in 10 projects the research tactic and the problem-

solving strategy of the project match each other's respectively concentric/recursive (e.g. problem-solving cycle) or iterative/incremental (e.g. agile) nature [1]. But in 20 activities in 11 projects, they do not have the same nature. Participant H for example works in an environment with an incremental iterative problem-solving strategy (Scrum). But he uses a concentric research tactic when he is not able to find programming solutions *'as rule we ask for help in our team if we get stuck for more than 30 minutes. Often a team member knows the answer, if not, we move on to support groups'*.

3.2 Sufficiency levels

The first paragraph described three tactics that aim for the highest chance to find answers. But when can an engineer stop the concentric cycling, the iterations or the probing? When does the answer fit sufficiently to close the knowledge gap in order to solve the problem? The results show that this depends on the ambition of the project and that the research activities could be categorised into three levels of sufficiency: check for viable answers, boost critical demand and change the game.

The minimal sufficiency level that could be found were research activities with answers that just fit sufficiently to make the solution viable. These activities were categorised as **check for viable answers** (found in 34 research activities in 11 projects). The 30 minute rule to call for help, described in the paragraph above, is an example of looking for this minimal level of sufficiency.

The following level of sufficiency was categorised as **boost critical demand** (24 activities in 9 projects). At this level participants looked for critical demands in the project and put extra effort in the related research activities to find a major improvement. The remaining research activities of these projects typically showed a *check for viable answers* sufficiency level. This indicates that the *boost critical demand* level **works on top of a check for viable answer** level. The *boost critical demand* level aims at solutions that are considerably better than prior solutions. An example can be found in a research activity of participant J who had a really tough issue with response times for an application. In consultation with the client they directed significant project resources to this problem. Interestingly they used a *probe-response* tactic because they did not start with weeks of diagnostic research but picked a promising part of the problem and tried to solve it with trial and error. After a couple of days it turned out this did not work so they stopped and inspired by the results picked another promising part for a next series of trial and error etc. After two weeks the delay was reduced to 90% and the client was satisfied.

The highest level of sufficiency was categorised as **change the game** (8 activities in 3 projects) and found in projects where engineers looked for new avenues to gain a competitive advantage. In these projects several research activities were only sufficient if the solution changed the game. Other activities in these projects could have a *check* or a *boost* level. A *change the game* example is participant F who works as a network engineer for a big internet exchange provider. The project assignment was to test the feasibility of using equipment that was merely on the market with Dense Wavelength Division Multiplexing on colored lasers and advanced forms of modulation (QWAM) in order to significantly reduce setup time for new fiber connections. He applied a concentric research tactic to find the desired information. He started with product specifications and went on to the white papers from the manufacturers, all the way into the original scientific articles. Later he applied an iterative tactic to create a test setup that met the industry standard (see example in paragraph on iterative tactics). The bar was raised to the highest possible level and the solutions were only sufficient

when all criteria were met in the test setup. Only one of the world top suppliers succeeded.

Table 2. Examples of Sufficiency levels of Tactics for Pragmatic Research Tactics
(Participants are represented by letters A...K. See table 1 for explanation)

Pragmatic Research Tactics				
Sufficiency level		Check for viable answers	Boost critical demand	Change the game
Pragmatic				
Tactics	Concentric	G: Satisfying solution + one quick win = OK. E: Validation of user requirements from brainstorm with 6 users. A & H: Do not mess around, ask questions in team: if quick answer fine; else move on.	G: Solution should work fluent on graphically limited screens. C: Backend that is uniform and scalable for all our client applications. I: Priority workshop with UX, BA, Search and product experts.	F: All specifications are grounded in peer reviewed papers. F: Formulate extremely high functional and maintenance requirements; Design a lab test; No compromise, only solutions that pass all tests are accepted.
	Iterative	A: Automation of smoke test (daily test of new code) as starting point for continuous integration. C: Minimal Viable Product. G: Until it works and I dare to take the next step.	A: Developers use test automation as part of daily routine for continuous integration. J: Risky Assumption Test: early checks with customer. Learning whether or not you are wrong as early as possible.	A: Test automation program is accepted as evidence for our medical application by very critical Food and Drugs Authority (FDA) in USA. (which would take away an enormous load of paperwork in our organisation)
	Probe-response	D: Temporary solution works (low bandwidth internet in example from introduction).	J: (critical) delay in application was reduced with 90% and acceptable for client.	No example from the participants in the data.

4 CONCLUSION AND DISCUSSION

The results show that potentially valuable contributions to the literature are pragmatic research tactics that consist of:

- Three different tactics to aim for the highest chance to find answers: *concentric*, *iterative* and *probe-response*.
- Three levels of sufficiency to close knowledge gaps in order to solve the problem at hand that correlate with the ambition of the project: *check for viable answers*, *boost critical demand* and *change the game*

Furthermore, the results reveal that in all the projects the research tactics do not always match with the problem-solving strategy of the project as a whole. This strongly indicates that pragmatic research tactics actually have a distinctive level in the whole problem-solving process. Additionally, we can conclude from the results that the three

tactics have a cumulative information gathering approach in common. These cumulative tactics make it possible to move flexibly up and down in what can be called the *pragmatic research spectrum* of simply looking up an answer, investigating the situation more thoroughly or researching it in a planned and rigorous way.

With the results of this study, it should be possible to make students and teachers aware of pragmatic research tactics and discuss the use of them in a meaningful way. Starting for example from the ambition of the project, the sufficiency level of different research activities can be discussed. Subsequently, the choice of a pragmatic tactic can be deliberated and the chance it provides to flexibly close the knowledge gap, with optimal use of time and resources in mind. Furthermore, the results provide various examples to illustrate the abstract parts of the discussion and make it practical.

Although the research has focused on IT engineering, it seems reasonable to expect similar pragmatic tactics in other engineering practices.

Finally, this research of course has several limitations that leave room for further research. One aim should be to validate whether and to what extent the tactics and sufficiency levels can be found in other (IT) engineering projects. Another interesting subject of research is to determine how engineers (can) make the right choices in de use of pragmatic research tactics and how engineers can perform them properly.

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Differences in company projects - a way of inspiring educational design for employability

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Conference Key Areas: University-Business cooperation

Keywords: Types of company projects, employability, student-company relations, progression, project-based learning

1 INTRODUCTION

The skills expected of tomorrow's engineers and demanded by accrediting institutions and employers point clearly in the direction of more generic and employability competencies in addition to the technical knowledge, skills and competences. Reports have identified a major problem in the transition from education to work and characterised this problem as a skills gap [1].

Research indicates that employers have not been satisfied with the graduates and it has been pointed out that ways to change the curriculum is to integrate work related situations [2]–[4]. Especially project work in collaboration with industry has been one of the ways to foster employability competencies, e.g. by letting students work with authentic real life problems in a company context [5]–[6]. Most often, engineering students are doing this by working on projects involving company collaboration in one or more of the project phases from problem identification to problem solving.

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In general, collaboration between two different types of organisations and cultures will always create challenges because of different practices and norms. Internally at the university, such types of collaboration might therefore be challenging both for the curriculum design and for the practice as academic facilitator. On the other hand, research indicates increase of students' motivation for learning when there is an end-user or customer for their projects and that the engineering students feel more ready for entering into the labour market [7]. Internationally, engineering projects and engineering practice become a more dominant element of the engineering curriculum [8].

The increased focus on types of company collaboration in the engineering education society, and the increased student-company interaction in company projects, creates a need for curriculum design that includes external stakeholders – especially companies. Not much research exists to inspire the integration of company project in curriculum design, and therefore, this study contributes to this field by addressing the following research question:

What types of collaboration can be identified between companies and universities for student projects and what impact will the different types of collaboration have for curriculum design?

In the following, we will address this question by presenting results from a new study on student-company collaboration in students' project work. This study on student-company collaboration in engineering education is supported by the Danish Anniversary Fond for Technical Engineering 1980. Aalborg University serve as case, due to its strong tradition for student-company collaboration, as noted by the IRIS Group [9].

2 METHODOLOGY

The overall purpose of the study was to identify if very different practices occur for how students collaborate with the companies in their projects and by the results to provide inspiration for educational designers when they consider strategies for change to integrate company projects further in the curricula.

Therefore, qualitative methods were applied in order to gain an understanding of the nature of the collaboration. The methodology for the study was a combination of qualitative content analyses of curricula and interviews with involved stakeholders. The content analyses included screening of curricula from the School of Engineering and Science in order to identify how the collaboration with companies was described at the formal level. The interviews were semi-structured interviews to include openness and to catch the different nature of the collaboration. In total, 16 were conducted, of which 12 interviews have been carried out in person and 4 by telephone.

The aim was to include a broad range of expertise, including educational designers and practitioners from university staff, students, employers as well as researchers. The 16 interviews were distributed with 8 interviews with university staff, 2 interviews with students, 4 interviews with employers and 2 interviews with researchers. The employers were selected by a screening of the AAU database for projects with specific focus on company-projects.

The interviews were partly transcribed for a thematic cross-cutting analysis of collaboration patterns.

3 FINDINGS

From the analyses of the curricula descriptions, it became clear that company-student collaboration in projects was more implicit mentioned – and much more as a possibility and not a requirement. From this analysis, it was not possible to distinguish requests on different types of company-student collaboration.

The interviews, however, showed significant differences in the role that the company plays in the students' projects and thereby also the type of collaboration taking place. Four roles were distinguished, at which the company respectively serves as an informant, a case, a client or a partner in the project.

As the pattern of diversity emerged, it became clear that the different types of roles were not mutually exclusive, but interrelated and mutually inclusive, as shown in figure 1. There was a clear difference in the role of the company as an informant and a case, but of course the information is the first step of both a case and a more shared collaboration and partnership.

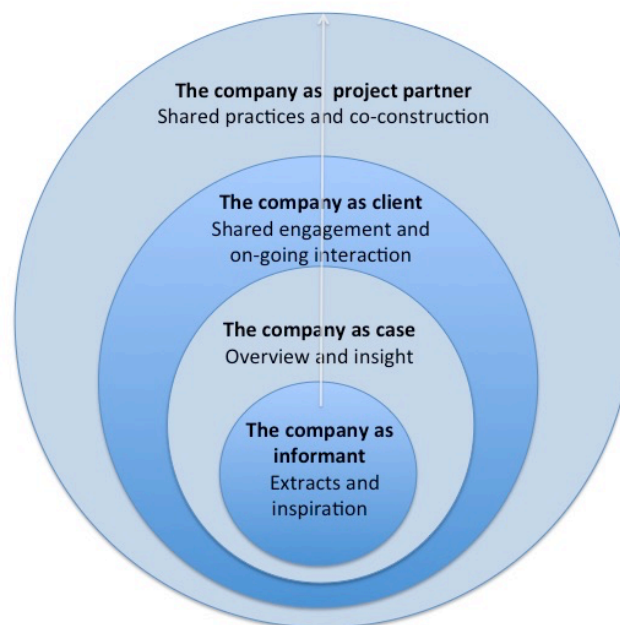


Fig. 1. Model in the different types of company relations in company projects.
The arrow indicates the line of progression.

In the following, we elaborate on the roles in a step-wise fashion. We are moving from the inside to the outside of figure 1, from the informant to the partner role, and as we do so, the scope of the student-company projects is gradually expanded.

2.1 The company as an informant

If a project is to be characterised as a company project, it will include interaction with one or more companies, and students have to at least have a contact to the company making them able to integrate first hand knowledge into their project – in this case, the company acts as

an informant. It can be that the students seek information from one or more companies to understand a problem, a practice or a technology. In any case, the staff interviewed stresses the importance of providing the students with the opportunity to interact with companies, e.g. by arranging company visits, guest lectures or providing access to the research networks. Furthermore, they also emphasise the importance of having students trained in approaching and collecting information from business relations. As noted by one of the university staff members (Staff 1, Personal interview, September, 2017):

“It is really not the technical competences that matter, when we find that this is a good student to send into a company, as much as the ability to manage oneself in a business environment. Having the sense of how to behave, what questions to ask and which not to ask, what you prepare for in advance and what you have to ask for. It is about having a sense of propriety”

The ability to redraw information from a company relation is, furthermore, underlined by the following quote (Staff 2, Personal interview, September, 2017):

“Some students are better at in-depth questioning than others and they are able to draw out valuable experiences. Others are a bit quick, getting too focused on what they want to do in their projects themselves, and they do get the same benefit. The most beneficial process typically happens when the students asks openly and humbly to study what the real problem is, and what the company knows and what is not known.”

The ability to approach and collect data from companies and other informants can, therefore, be seen as a basic inquiry for company-student projects, and therefore, it can be argued that this also should be integrated into the curriculum as a learning objective in the very beginning of the study. For the documentation of the learning outcomes of this type of student-company collaboration, students can include the data from the company as empirical material and include a reflection on the student-company collaboration as part of the methodological reflection in their project reports.

2.2 The company as a case

The next level including the company as a case includes a higher and continuous level of interaction. This means a stronger commitment from the company and thereby also a stronger company interest for the outcome. In the case-perspective, the company gains an outsiders view on company processes, which can be very valuable. As one of the company partners noted (Employer 1, Telephone interview, September, 2017):

“Regarding our own current innovation tasks, we receive new, fresh ideas to include in further internal or external research tasks”.

Another company partner, who at that time worked together with a student on a case-project, supplements with a statement about the value of having a student work in a case-based approach (Employer 2, Personal interview, September, 2017):

“It simply provides new energy to the organisations, when a young person steps in with engagement and curiosity in the way we are doing things. We get some new perspectives, and at the same time we get an opportunity to impact the project along the way”.

Even though the company partner can impact the project along the way, there are no clear expectations on the outcome of the project, which lowers the pressure on student performance, and therefore, it can be argued that these projects can take place from early on in the curriculum, and, of course, with increasing depth throughout the study.

For the documentation of learning outcomes of this type of student-company collaboration, students can document the case-study as part of a project report, and furthermore, several of the interviewed stress the importance of providing the company more targeted feedback, e.g. by making an oral presentation at the company to report on the case-study.

2.3 The company as a client

If the company acts as a client or customer, the company raises a specific need or problem that they want the students to address. In this case, students still have to get overview of business processes and understand the particularities of the company, although the case-analysis might not be as in-depth as in a case-project. Compared to the case-projects, the client projects, furthermore, provide some clearer expectations from the company regarding the output, and, typically, a certain degree of progression in technical competences is needed in order for students to cope with these types of projects and provide unique solutions of value for the company. A student directed learning environment will, however, imply that the students are free to shape the project considering their own interest, as this student explains (Student 1, Personal interview, September, 2017):

“When the company is a client in a project it is never 100%. It has never been like that they wanted a certain kind of product, and then we just have to deliver it. We have a high degree of ownership of the project.”

It is a negotiation between the learning objectives and the company objectives, the student interests and the interests of the companies, and also between the academic communities and the business communities. This is exemplified by the following quote (Staff 1, Personal interview, September, 2017):

“It is a challenge to balance company requests with the learning objective. The easy answer is that it is all about the students, and student learning, and that the benefit for the company is just a side-product. But in reality, it is not completely like that as we really want the companies to have some value in return, and it is also much more fun for the students when this happens. In sum we are very interested in creating value for our collaborative partners, because then they will also continue to work with us. It is a balance.”

It can also be argued that this situation of being in the middle of mutual and maybe sometimes conflicting interests, in fact will help the student to gain important competences in balancing different needs in projects as well as in the innovation of new products.

For the documentation of the learning outcomes of this type of student-company collaboration, students might document their outcome by a prototype as a supplement to the project report and oral presentation targeted the company. Furthermore, the company as well as the university might also be interested in a more detailed process-report considering the developments.

In the School of Engineering and Science at Aalborg University, the guideline for internship requests that student include a reflection in the documentation of their project considering [10]:

- a description of the external organisation, including structure and areas of work
- an overview of the work areas in which the student has been involved
- a report on the actual work performed by the student, an analysis of how the student has benefited from the traineeship academically, professionally and socially
- the student's experience with the traineeship, including any possible suggestions for changing the curriculum, procedures etc.
- a reflection on the knowledge exchange between the external organisation and the study programme
- an evaluation of the learning outcome of the traineeship.

In this way, the student-company collaboration is captured by letting the student reflect on the type of company and the type of interaction, and also the learning outcome as well as the learning process.

2.4 The company as a partner

Last but not least, examples do exist of students working on projects together with companies to the extent where they share, not only the same engagement in the project, but also the same practice. The student and the company have established what Lave & Wenger [11] have called a community of practise, where the participants, driven by a shared engagement, share information and experiences.

If the students are to work together with the company in a community of practice, they have to understand the core interest and engagement embedded in the role as a client, which the company brings into the project. But it also works the other way around. The company has to understand where the students are coming from and respect that they have to live up to the intended learning outcomes stated in the curricula, as note by one of the staff members (Staff 3, September, 2017):

"The good company, in terms of creating the most optimal conditions for an internship, is a company, which is aware of the intended learning outcomes, which the students have to live up to. This is for examples the case when we collaborate with some of our former students"

In some projects, students engage in several company projects during internships (Staff 3, Personal interview, September, 2017). In other projects, the representatives from the company join the group for analysis or experiments, as in the following example (Staff 2, Personal interview, September, 2017):

"In this project about recuperation of phosphor in waste-water, the students was involved in some experiments at a pilot-test-facility, and the other company partners was also involved, and made some measures, and then the results were discussed. It was also discussed which samples that should be taken and how they should be analysed. The students and company partners have several meetings along the way."

These types of communities of practice can be considered the highest order of learning for employability, and for some students close to graduation, a successful community of practice

can be the first step to employment. Students are not only being present, observing and interacting. They are also being trusted to enter a company community and engage in co-constructions as illustrated by the following quote (Staff 4, Personal interview, September, 2017):

“Especially one year, it was so obvious, when we had a gathered seminar to finalise the semester that the students came with a whole different charisma and attitude than before they have been in internship. A lot of self-confidence was added - they were changed from being students to being professionals. They learn, and sometimes because they just have to, to be outgoing, stand on their own feet and trust in themselves – yes, I can do it – it provides self confidence”.

This process of becoming able to “stand on their own feet” and trust in themselves seems however to be gradual, as explained by a student (Student 1, Personal interview, September, 2017):

“In the beginning, at the first and second semester, the supervisor was present at least at the first meeting with the company, acted like a chair of the meeting and was like the one who took care of our interests and learning. That was really nice at the first semesters, but it felt like an enormous vote of confidence when the supervisor suddenly said: I do not have to go with you. You can manage yourself”

This quote moves the discussion of progression and appropriation to the scaffolding of students. It is a matter of gradually letting go and providing the students the opportunities to take the lead, as elaborated by de Graaff et al [12].

But even though we might agree on the importance of this development, the learning outcomes are however hard to grasp and put into words for students as well as assessors. This however does not mean that it cannot be done. Our study especially point to the diary as a way for students to be able to capture the personal developments, as noted in the following quote (Staff 3, Personal interview, September, 2017):

“Students are recommended to write a diary during the project, to capture the relations and reflect on the experience in relation to their personal role, for example by asking: what surprised me, what interest was in play, how did I contribute to the praxis unfolding, how do I consider the process from a more critical perspective, etc.”

Being, is a personal matter, and therefore there is also an issue of willingness from the student to share with their supervisor their personal reflections in the diary (Staff 5, Personal interview, September, 2017). However, the diary holds a potential to gather data on-going to a level of detail that will enable student to exemplify and document personal growth in the context of a company community of practice.

4 CONCLUDING REMARKS

In this paper, we reported from experiences with student-company collaboration supporting students' project work, we have presented four different types of student-company collaborations, which is presented in figure 1.

As the patterns of diversity emerged, it became clear that the different types of collaboration were not mutually exclusive; rather they could be seen as building blocks in progression from projects where the company was merely acting as an informant to projects where students worked closely together with the company in a community of practice.

We hope that the different roles of the company in the company projects, as informants, cases, clients or partners, can inspire curriculum designer to make the progression of learning outcomes of company projects more planned, explicit and documented.

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Space driven Educational Innovation SEFI 2018 Conference

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Conference Key Areas: How Learning space support innovative T&L, Innovation as the context for EE

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Keywords: Maker Spaces, Engineering Education, Educational Innovation, Solving Complex Problems

INTRODUCTION

In days long past, before the implementation of the scientific methods in engineering education, there was a lot of “shop work” in education. The implementation of the scientific methods, such analysis and mathematics resulted in a loss of building and designing in engineering programmes [2], [3]. In the 90's, however, under the influence of constructivist learning and student centeredness it was suggested by both industry and students, particularly in engineering, but also in general, that students should have more hands-on experiences [1]. In “The Engineer of 2020”, it recognizes that creating, inventing, and cross disciplinary fertilization are essential skills for engineers [4b]. The National Research Council [4a] in education in the USA felt that the pace of skills learning was not fast enough and did not result in the required fluency to solve problems in a labour market setting with the technological developments and democratisation of production technology in mind [1]. It was felt learning to prototype and creating social communities in which learning could flourish, would be essential to bring learning up to speed with 21st- Century developments [3].

The Michigan Institute of Technology (MIT), Media lab was the first to establish maker spaces within higher engineering education. They created Fablabs around the US, with equipment for participants to tinker and engineer their “product” solutions. It became a huge success resulting in a network of over a 1000 fabrication spaces throughout more than 78 Countries [6]. These spaces span different and multiple disciplines as they are housed in colleges of architecture, design, engineering, and general university and community settings [7]. The developments from the first Fablabs to the exponential growth of learning/makers space is taking place much more rapidly.

Universities started to create libraries spaces, learning or design factories, innovation spaces and maker spaces. Each of the spaces had a slightly different purpose. The common denominator is that these are spaces in which students can (1) run and try their own projects, while (2) having expensive equipment available (machine driven locations), (3) the opportunity to meet, (4) co-participate and (5) ask guidance from academia and industry in the spaces available [8]. In Engineering terms Keppel [9] defines a space as ‘spaces where both teachers, professional experts and learners optimise the perceived and actual affordances of the space.’ These academic oriented spaces are mostly non-accessible for members outside their own community[3]

1 PROBLEM DEFINITION

Having a long tradition of design labs not embedded in the curriculum, the wish to embed maker activities into the curriculum, is a growing wish of the 4 technical Universities in the Netherlands Eindhoven University of Technology (TU/e), University of Twente (UT), Delft University of Technology (TU-D), and Wageningen University (WUR).

This informal investigation at TU/e, UT and TU-D was used to obtain an overview of the ongoing activities and concerns at our institutions. The investigative question we worked with is: “What key projects are currently running? and Which concerns need to be addressed to use design spaces for “curriculum” learning?

“Which questions need to be answered or researched to create or design effective spaces combining both the aspiration of hands on and curriculum learning, preparing our students with, amongst others, creative skills beyond the regular curriculum?”

This question is not as simple as is presumed. To begin with it is not so clear how we should coin maker or learning spaces in our institutions. What type of spaces do we aim for? Which learning experiences are already in the curriculum or learning environment that might also be classified amongst “maker space like activities”, but are presently not identified as such?

To gather data, around 10 key-stakeholders of the maker spaces in UT, TU-D and TU/e have been approached via e-mail, informally and occasionally via follow up phone calls. Addressing the following questions; What projects are currently ongoing and what are the project goals? Which concerns / questions are currently addressed in the projects?

In the analysis we decided to focus on initiatives that have their grounds in constructivist educational approaches to learning and have the aim to strengthen the link to the real world and innovation. Blikstein [2] and Libow Martinez & Stager [10] identify the educational philosophies of Dewey, Freire and Papert to be the driving forces, for the maker spaces phenomenon:

- J. Dewey stated that experiential learning should be connected to real world objects.
- P. Freire stated engagement with meaningful problems is a precondition for exploring possible solutions and finding viable new solutions to become empowered and learn.
- S. Papert states that construction taking place in the head improves and is supported, when also constructed in the world, supporting constructionist learning and knowledge creation, while strengthening learning, building and sharing objects and experiences about topics of enthusiasm and passion.

The key characteristics of “spaces” derived from this constructionist view within education seem to be:

- Meaningful real world challenge based problems,
- Experiential learning
- Construction of knowledge and creation of objects (affordances) in the world
- Intrinsic motivation
- Sharing

These characteristics were used as a first selection of relevant projects.

Secondly, we decided to categorise via a matrix model of academic (credited), (extra)curricular and personal design activities, designed by Ecole Polytechnique Français Lausanne (EPFL) as a basis for their discovery labs. EPFL frames the space driven organisation for higher education as interdisciplinary work realised in credited or non-credited courses and coordinated and non or semi -coordinated (interdisciplinary) activities (figure 1). Particularly, in the Thematic-context and Maker Space context it remains rather difficult to identify how it should be embedded and in what way in the Educational Context [11].

<p>Thematic context –</p> <p>Part of the curriculum</p> <p>Ensure project outcome</p> <p>Skills practice linked to discipline or between different disciplines not too far apart.</p> <p>More importantly projects across different disciplines</p> <p>(living labs/architectural building (EPFL))</p>	Credited	<p>Master projects for credit</p> <p>Project oriented learning activities often in competitions or to extracurricular for credit activities</p> <p>Internship,</p> <p>IGEM, bioengineering world wide competition</p> <p>Solar Decathlon; sustainable building competition</p> <p>Honours projects for excellent students</p>
<p>Coordinated</p>		<p>Non or Semi-Coordinated</p>
<p>Student projects (associations)</p> <p>Student are organized in association to build the next Nuna, solar boats, often culminating in a competition</p> <p>Students are responsible for running the entire project but can ask help from staff/industry</p> <p>In TU Delft the Dreamhall is one such example.</p>	Non - credited	<p>Maker spaces</p> <p>Stimulating Bottom up student initiatives</p> <p>A meeting ground for exploring and making individual or team prototypes, 24/7 opening hours</p> <p>Offering workshops on e.g. mill, lathe, band saw, welding equipment, hand tools, and bench-top electronics</p> <p>Equipment</p> <p>Support space for capstone projects</p>

Figure 1: Model adapted from EPFL Lausanne [11] , different spaces to stimulate discovery – learning.

2 RESULTS

The e-mails and calls resulted in an overview of ongoing or starting projects. Framed in the quadrants, we see the projects are predominantly as maker space and to a lesser extent thematic context induced. This means either it is not so clear yet how the link should be made between the curriculum and the innovation space and the institutions are still (on purpose or by accident) thinking about it as separate situations happening beyond the curriculum. Framing should be one of the issues addressed in creating a vision on maker spaces linked to the curriculum

Thematic context – <ul style="list-style-type: none"> - Describe good teacher coaching for interdisciplinary hand on projects in order to facilitate teachers better (G) - How to prepare teachers to provide effective guidance (staff development) (G/I) - Position of entrepreneurship in Engineering Education (B/I) - Developing a trajectory for hands-on physics learning, building science instruments for physics learning. (I/E) - Encourage innovative teaching methods (such as Student-Driven Learning) by the use of innovative learning spaces. (D) 	Credited	Master /BSc projects for credit <ul style="list-style-type: none"> - Working on a model for multilevel, multi- disciplinary and multi-stakeholder assignments (V/I)
Coordinated		Non or Semi- Coordinated
Student projects (associations) <ul style="list-style-type: none"> - Bridging the gap and becoming a linking pin between industry, education and community (V/I) - Independent upskilling (in math and programming) as a facility to students (I) 	Non - credited	Maker spaces <ul style="list-style-type: none"> - Collect international experiences on Innovative Learning Spaces (B) - Develop a Vision on hands on learning (V) - To translate the experiences from our experiments in innovative learning spaces towards the whole campus and its community (D) - To lower the thresholds between facilities such as the Design Lab, VR Lab, CotF, XP Lab and the rest of the campus (D) - How to guide students effectively in maker/learner spaces (teams in control and responsible for their own results) (G) - Handbook for teachers to organize design challenges / Inspirational booklet to inspire teachers (G) - Describe the possibilities of assessment within innovative learning spaces (I) - Describe the effect of learning spaces on student behaviour and effective learning (E)

Figure 2: Overview of projects within maker spaces at 4TU's*

*Note these project description or the project foci are not exhaustive and there are likely to be many more, we have not yet received or heard of.

At least 7 of the projects are from UT, 6 of the projects from TU/e and 7 from TU-D. Most overlap in questions or content addressed was found between UT and TU/e as these projects were more guided by support staff compared to TU-D, where we found more teaching staff experimenting with these forms of education.

We have further clustered the projects under the headings benchmarking (B= 2), vision (V= 3), implementation (I= 6), Guidance for teachers and students (G= 4), Dissemination of results towards stakeholders (D= 3) and the effect of the spaces on learning outcomes (E= 2).

The questions are often purely pragmatic or not even questions but rather ideas to be worked out for hands-on implementation. Some projects are mainly focused on the innovation spaces and some specifically on how to bridge the gap towards the regular curriculum (thematic context). Questions or concerns are particularly focused on Implementation and Guidance of teachers and students to make the most of the learning experience:

- What could be the strategic vision of our institution and/or how to effectively implement this in our context.
- What do we need to do in terms of staffing and staff development, student tutorials to run their own teams and entrepreneurial mindsets (needed to make this a success)
- What to do to make all our lab/maker space facilities built on the same knowledge framework and how can we co-create learning in the institution.
- What is the effect or learning outcome (added value for learning). What are effective ways to realise assessment.

To get a better insight in what the literature has to offer as a general answer to these questions we, in the remainder of this article, will discuss these questions and possible answers from the literature. Topics are strategic focus, visions on maker spaces, staff development and added value to learning. Albeit not exhaustively, we think this may give a peak insight into the state of the art on research in maker space research.

2.1 Strategic Foci

The unique institutional purpose of library, learning and maker spaces or any other type of learning encounters in space like environments is grounded in different strategic foci according to the literature. Policy arguments are amongst others stimulating;

- interdisciplinary learning, project oriented teaching, experimentation and prototyping [11] – Education Polytechnique Francais Lausanne (EPFL) ,
- providing educational support for each discipline, stimulating cross disciplinary dialogues– capstone design prototyping lab (Innovation studio Georgia tech), [1], [2]
- fostering close ties between students and employers by exploratory learning or design thinking methods – realised by hands on learning at TU/e and Aalto University which is an entrepreneurial, interdisciplinary hot spot (Aalto university) [12]
- Design thinking as problem solving approach advocated by Stanford D-school for business innovation(Potsdam, Paris, Stanford)
- Real world engineering experiences that integrates multidisciplinary design solutions to prepare students for the workforce – O.T. Swanson Multidisciplinary Design Laboratory at Rensselaer
- Empowering the learner in authentic learning and assessment, which have real life relevance and the application of skills [13], [14].

The additional perspective taken in the discovery learning labs (EPFL) is that it becomes permanently visible to the institution (1) where interdisciplinary spaces are used and (2) what for and (3) how one may get involved, (4) a wish to involve industry and (5) create a fertile ground for innovation. Key driving forces as stated above (derived from existing spaces) at the institutional level are: interdisciplinary learning, involving and bonding with industry and government, connecting science to society, realising a playground for innovation and preparing students for professional work. The educational philosophies of maker spaces are amongst other extensively described in [10].

TU/e, UT and TU-D are looking for one or more of these qualities. Yet the main strategic focus is on interdisciplinarity, involvement of industry to stimulate authentic learning and hands on learning. In TU/e the entire bachelor curriculum will focus more on hands on learning and innovation in challenge based innovation spaces.

UT is emphasizing the connection of science to society, the encouragement of innovative teaching methods (such as student driven learning). The UT is currently working to the transfer the experiences from innovative learning spaces to campus and staff development to increase the educational value of the space.

Whereas TU-D has an extra ambition to involve and bond with industry and preparing students for professional work in innovation spaces. It is amongst other exploring a concurrent design lab with the European Space Agency, creating a TEC Factory with SSR Mainports, urban living labs at the Amsterdam Metropolitan Solutions Institute and creating on campus opportunities for hands on experiences closely related to or integrated with the (interdisciplinary) curriculum.

2.2 Staff Development

For Maker spaces to be a success staff involvement and development seems to be crucial (this includes learning students to take responsibility for the maker space environment). It means that staff and students are trained in, amongst others:

- Using the machines in a safe way
- Doing collaborative teamwork
- Creating a mind-set of co-creation/entrepreneurship
- Creating educational experiments
- Having a well distributed guidance and support system to make experimentation possible
- Intermediary staff between industry and teaching staff, as well as between industry and students

Additional conditions should be met to create a maker space that is successful and should definitely not be underestimated [2],[12].

The UT, TU-D and TU/e are now focusing on using teaching scenario's and pedagogical methods suitable to use in the spaces or hands on experiences in the curriculum. UT's tacit experience was that operational boundaries should be taken care of and communication and collaboration is essential to make a maker or design space work for the wider curriculum.

2.3 Lab-spaces and a framework for knowledge transfer

In [12] [15] Mattila and Turner (p.202) point out the importance of having strong and weak ties for diversity to flourish. Strong or formal ties help to create a culture of knowledge transfer, yet weak informal ties, often in networks and or chance encounters, stimulate innovation. One of the precondition is a diverse population that may be encountered in this network.

As Hynes & Hynes [7] point out current maker spaces are white male oriented in their design

Having them close to a library may help to attract women, but to seriously attract more women and possibly other types of students beyond engineering, one also needs to consider ideas for storage, seating, and design aesthetic to create orderly, clean spaces that still welcome a sort of free exploration where you can mess about [7].

Mattila and Turner[15], equally point out the importance of identifying levels of collaborations, the dimensions of the collaboration e.g. which disciplines are involved, what type of relationships are created and what is the impact on the ecosystem. Is it different for each space or are there similarities which may be benefitted from, should there be liaisons or a community engagement coordinators between the different types of facilities in the institution and to the external world to ensure exposure and continuous upgrading of innovative endeavors in collaboration with industry to benefit both the institution and society?

At the UT they found involving a wider network of teachers in some spaces is harder to realise, causing possibly less effective use of the spaces as there were fewer strong and weak ties available. At TU- D many initiatives create their own scenario, running the risk of only realising strong ties and creating too little diversity for the optimum innovation capacity.

2.4 Added Value for Learning and methods of Assessment

Formal methods of assessment are on a tense footing with maker spaces, as the informal learning mode of sharing, experimenting and failing is one of the key assets of the learning process going on in Maker space environments. Bjorklund states [12] that learning spaces allow for experimenting with new behaviour, skills or ideas and roles in a simulated environment. It creates a microworld where the members can act outside the organisational constraints, while still retaining legitimate membership. The key is to learn how to be acting differently to the challenge based problems on offer. After practicing, reflection, generalisation, and formulation of hypothesis, re-test in a laboratory or in the real life environment, collecting immediate feedback is essential. Critical reflection helps to quickly improve performance by creating more effective behavioural models, which are fed back into the knowledge system. It should build bridges between intuition and the formal aspects of science by being able to better explain, measure and predict the world around us [10]. Particularly, the latter can be measured effectively in more formal assessment initiatives e.g. micro-credentials, or badges that show the skills acquired in a maker space area, ranging from working on a machine like 3D printing, to a working methods such as design thinking, leadership in product design to social/teamwork skills for effective collaboration [16].

Somehow the application of science learned elsewhere should become visible in the learning results of students. Results are encouraging as initiatives state that consistent better results are achieved on capstone or other science courses due to the participation in maker space activities. Or so it is assumed [20]. Haptic learning is considered as one of the reasons for better results [17] (Minogue & Jones, 2006). At the UT this connects to the Twente Educational model [19] in which students work on modules and project based work.

3 DISCUSSION AND CONCLUSIONS

This research has been conducted in a maker space way, exploring and experimental, via informal networking and information gathering. As such it does not built toward any scientific contribution in maker space as phenomenon. The information is an attempt of overview in what our institutions drives to create the best possible education for our students. Equally, many of the studies consulted are based in tacit knowledge creation and practical experiences. Notwithstanding the usefulness and relevance of this knowledge, we should carefully weigh and deliberate what the scientific value and increase of learning outcomes are and make an effort to make evidence based decisions. It shows there are numerous questions that have not been answered yet at the Technical Institutions and that many of the

questions we have at each technical institution have common denominators, such as the integrations of hands on learning experiences in the institutions, the position and added value of maker spaces vs thematic courses, the guidance of teachers and staff in realising the best possible learning experiences for students, the consolidation of the realized results for accreditation bodies, etc.

Making an artefact, as construction of learning, is a powerful, personal expression of intellect. Creating maker spaces is a powerful expression of an institutions footprint. It creates ownership of learning processes, even if it not perfect. However, like any individual persons, institutions are also subject to the “IKEA Effect”. The IKEA effect is when individuals value their own creation more, even if flawed, than those of experts [18]. Therefore Aalto University and MIT amongst others [21], wisely distribute a model that cannot make do without contextual adaptation [12]. Somewhere between these two truth will be our Maker Space. As in exploring the maker space questions together we may come up with the best possible scenarios.

SESSION SET UP

The Goal of the session is to identify the most important characteristics of the maker space in Higher education by using the Lego® Serious Play Method®. It will allow participants to share their expertise and co-create qualitative parameters for working in maker spaces. The workshop can be followed by max 20 persons and will last the allotted time.

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The Applicability of Feedback of Virtual Speech app metrics in a Presentation Technique Course

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Conference Key Areas: Engineering Education, Educational Innovation

Keywords: Engineering Skills, Innovative Teaching and Learning Methods

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1 INTRODUCTION

Industry 4.0 is up and running, the next industrial revolution of artificial intelligence and virtual reality systems are likely to profoundly change our world in general and our world of work in particular [1]. Virtual Reality systems might be a game changer as one of the emerging technologies in Education. Students have none or have very limited access to the new artificial and virtual reality systems techniques in the current educational system. Which causes students to have a (a shortage of skills that are in high demand) skills gap, if not confronted at an early stage with the techniques that will await them in the labour-market. Introducing VR/AR in education, is not that simple however, also because at present it is unclear to what extent VR/AR can contribute to a different kind of learning [2]. This paper is about the experiences with a practical experiment to better understand the consequences and value of such systems for education. The primary focus here is on feedback from a VR-system and reflection and their effects on the relevance for learning presentation skills. We experimented to find out the impact of a VR speech app as an additional practice tool in presentation techniques courses. The focus is on the organisation of the study and the outcomes including students' experiences in terms of relevant feedback for student learning and possible implications for learning activities in VR.

1.1 Presentation skills

The Academic Skills course "Presenting in Engineering" is considered highly relevant in the Engineering program (Meijers criteria). Academic presentation skills are included in both the Meijer's criteria and the Dublin descriptors [3]. Embedding soft skills into regular courses makes the acquisition of soft skills easier as a) content is provided, b) there is a purpose for practicing and c) it is just in time for application. This usually results into 1 or 2 ECTS courses running over the course of a semester parallel and integrated into a content course in one of the faculties. The number of participating students typically exceeds 50 student and runs up to 300 or more. The limited staff capacity and the time for guided practice do not suffice to coach all these students to a level of presentation skills considered acceptable within Engineering. As quite a few studies have shown immersive virtual reality learning environments (1) may boost learning outcomes and (2) reduce cognitive load due to fewer distractors[4],[5]. (3) It provides a representative practice in simulated situations or in other words; a sensing of what it will be like in real life [6]. So VR may offer an extra opportunity to practice presentation skills and boost learning outcomes.

1.2 Feedback in VR- speech research

This paragraph addresses what might be gained from using VR in practice situation. It is discussed what the findings are in Education, in using a three dimensional (3D) virtual reality systems for presentation skills.

Virtual reality speech applications and their relevance for education have been researched by quite a few large projects such as Metalogue, Rhema and Cicero [12],[13], [14],[15],[16]. The VR-trainers in these projects are specifically focused on screening non-verbal behaviours as these are easy to measure with available algorithms. Metalogue is a European project investigating the perceived benefits of a stand-alone presentation trainer when practicing elevator pitches. The presentation trainer provided immediate feedback on speech features such as loudness, speech rate, pitch/intonation and pauses. As well as body postures such

as body and hand-movements, eye tracking. [12], [13]. Rhema focuses on objective non-verbal cues from the speaker and the immediate (in action) feedback of these cues via google glass. The interface in the Rhema project allows for real time detection of speech volume and speaking rate and it provides feedback during real time delivery [14]. The researchers have tried to establish the optimum mode of feedback, differentiating between sparse feedback, continuous feedback and no feedback during the presentation. The same authors [15] studied body postures and the effect of immediate feedback during presentations on patterns in body postures

Cicero is a platform and project in which the observed objective data (flow of speech, vocal variety, eye-contact, intonations, arm-hand movement) are correlated with qualitative assessments of experts to determine “good” feedback[16].

The virtual audiences in speech-apps are used to provide non-verbal feedback to the presenter. All the systems made use of different audiences. The adaptation of the audience or audience feedback varies in two ways: 1) orchestrated by prior coding of the machine for a type of audience or 2) adapted on the basis of the ongoing analysis of cues in the system. The non-verbal feedback signals (1) elevated attention, (2) lack of interest or (3) disagreement with the speaker.

According to the analysed results using the presentation trainer did yield significant perceived benefits as opposed to a control group, whom did not train the elevator pitch with the presentation trainer (Metalogue). In the Rhema project the perceived learning did greatly improve on the basis of parsed immediate feedback during the presentation on speech features. In the second Rhema study body postures were analysed: the presenters as opposed to a control group did become more aware of their body postures. In the Cicero project it was established pacing, vocal variety/intonation and eye contact either positively or negatively correlated with the assessments realised by performance experts. Whether the performance objectively improved could actually not be established as perceptions of participants and observers are the closest means of evaluations to learning outcomes.

We used a virtual speech app from Virtualspeech.com, that supports “at home practice” with a smart phone and google cardboard and free body movement. The combination of these tools help students to immerse into the experience of being in front of a real-life audience and receiving immediate feedback. The app provides (objective) immediate feedback on the following parameters: voice loudness, filler words like uh, speech-rate (time used per slide), eye-tracking (looking around across the room) and pauses, such that the students could become individual drivers of their own learning. It allows for a choice of multiple presentation settings, such as a classroom, a ted talk and others. The virtual speech app is used among other at Oxford university and according to the Virtual speech company with “good” results. Details are not available.

Virtual reality in this study is defined as an immersive, interactive, experience based learning environment, allowing practice in a targeted artificial environment representing a realistic situation in real time [7], [8], [4]. According to Dillenbourg [6], the effectiveness of virtual 3D interventions is a careful balance between immersion, engagement and reflection of students. If the environment is too realistic or immersive it will make learners uncomfortable (uncanny

valley). If the engagement through gamification or exiting experiences is too much they will be engaged but the learning curve is not increasing. If the learner is comfortable and engaged with a little cognitive distance of the activity it will allow reflection and integration of knowledge into their own knowledge base. Before learning and reflection can take place, however, feedback is dearly needed [9]). *‘Students have to be able to judge the quality of what they are producing and be able to regulate what they are doing during the doing of it’* [10] . Strijbos [11] points out that feedback is used when it is perceived as useful, acceptable, creates positive affect and induces a willingness to change behaviour on the part of the learner. Reflection may thus result from a combination of objective metrics, the attitude with respect to the feedback (given the right learning environment) and the expectations of being able to act on these variables.

The research questions focused on:

- To what extent does feedback from VR systems compared with other sources induce behaviour (reflection) supportive of learning presentation techniques.
- To what extent does VR at this moment offer a reasonable additional practice for presentation skills practice

2 METHODS AND TOOLS

The quasi- experiment was applied in a Bachelor course conducted in the faculty of Applied Physics, the life science track, and is called Biopharmaceutical Technology. The subgroups have all been questioned with a 5 point Likert scale survey prior to the final presentation on the relevance of the feedback used, the level of reflection that was used and the expectations of improved performance. A reflection on the VR system and what the students did with it was included as a separate assignment.

2.1 Sample

The presentation lab at Applied physics holds 6 project groups learning about ethics in which a total N=66 participants are taking part and follow an embedded and supportive presentation techniques course. Each presentation technique group of around 10 participants with an individual lecturer is sub-divided in groups of 3 participants. The groups are distributed across two control groups, two VR groups and two Peer feedback groups. In each of these conditions they practice presentation techniques by themselves, with peers or with the virtual app The Peer group (N= 20 students) intervention will not be discussed here, due to the limited space.

- Two control groups- N =20: practice independently in what-ever way, whenever convenient. (non vr/non peer feedback groups)
- Two VR groups – N = 20 Practice with a virtual reality speech app, with Google cardboard with peers. The app provides immediate feedback (speech analysis) to the participants, if you give your presentation in English. The virtual speech app can be accessed here <https://virtualspeech.com/>

2.2 The Questionnaire

The acceptance of feedback questionnaire is validated by Strijbos [11] and was used to obtain information about the likelihood of the feedback received, from the lecturer, the peers during class sessions and the Virtual Reality app, being accepted. It is also used as an indicator of engagement.

- The Feedback is evaluated for usefulness, acceptance, the willingness to do something with it and its positive/negative affect (engagement with the material)

The extent to which the VR app, the lecturer and peers in class, induced reflection was measured through the RISE- model of Wray [17] and the perceived performance improvement on performance indicators.

- Reflection consists of questions about: the extent students expected to improve their grades, did awareness of outcomes increase reflection, did they take up suggestions and do things differently, did they identify strengths and weaknesses and would they re-use of this practice mode.

In each condition they received information on how to present. The groups are divided on the basis of a preliminary questionnaire. At that moment they were also informed about the pending interventions

2.3 Preliminary Survey Results

A preliminary survey was used for group division where students could choose for one of the options communicated as extra practice opportunities no extra practice/peer group/VR app. The 43 participants (those whom were enrolled in the supportive online learning environment) were asked to fill out a questionnaire, the others were allotted to the available places left.

The questionnaire addressed their experience and preferred mode of practice.

The response rate was N= 33. From this group 12 students had little experience with giving presentation, 17 had moderate experience and 4 students had a lot of experience. Most of them practiced giving presentation in secondary education (100%), some with friends 39% and some in front of the mirror (30%). When asked to give their preferred practice mode 58% voted for the peer group option, 27% for the control group and only 15% for the VR mode. When asked to give the second preferred practice 52% chose the control group and 21% peer group and 27% the virtual option. Showing that in practice this group would not necessarily use virtual reality, if it were not offered in a course.

3 RESULTS

The reliability of the overall questionnaire at the end of the course was Cronbach's alpha 0.79. The reliability of each of the constructs used are included in table 1 measured on the entire group N= 68. The sub-constructs are all sufficiently high to be considered for further analysis. The mean scores show the control group (N = 20) and VR group (N=24) means on these constructs.

Table 1. overview reliability/mean for feedback/Reflection constructs

Constructs	Sub-scales	Reliability Cronbach's alpha	Mean scores	
Feedback			Control (sd)	VR (sd)
	Usefulness of feedback	.80	4.3 (.60)	3.9 (.71)
	Acceptance of feedback	.83	1.47 (.88)	1.9 (1.3)

	Willingness to use feedback	.79	3.94 (.99)	3.8 (.59)
	Positive/negative affect	.82	3.60 (1.07)/1.3 (.97)	2.29 (1.25) /1.6 (1.14)
Reflection				
	Rise model questions	.76	3.42	

3.1 Useful, Helpful and supportive Feedback

The Usefulness construct consisted of the question “*I consider this feedback as useful, helpful and supportive to future learning*”, differentiated to feedback received from lecturers, peers and VR. Results on this scale show there are no significant differences between the experimental groups on the perceived feedback from lecturers peers in class. The VR group (N=24) was specifically asked whether they felt the VR speech app, was useful, helpful and supportive. The majority of the students felt it was not useful, not helpful and certainly not supportive to use a VR speech app.

Table 2. means scores usefulness constructs part 1. of the Feedback scale

Usefulness construct	VR-Mean (sd)	Frequencies
Useful	2.83 (1.59)	50% score 2 or lower
Helpful	2.67 (1.63)	54% scored 2 or lower
Supportive	2.42 (1.50)	62 % scored 2 or lower

The virtual reality group in general felt the Lecturer and peer feedback in class as less **useful**, to a significance level of .004 (F2.28) and slightly less **helpful** than the control group .010 (F2.36). It is not clear whether this is caused by the lecturer, the peers or the vr or the atmosphere in the group.

3.2 Acceptance of Feedback

Acceptance of feedback is discussed as in “*did the students dispute or reject the feedback given by the lecturer, their peers or the VR system*”.

Table 3. means scores acceptance constructs part 2. of the Feedback scale

Acceptance of Feedback	Control	VR Group
<i>Reject/Dispute</i>		
Feedback from lecturer	1.30 (.80)	1.29 (1.04)
Feedback from peer	1.20 (.83)	1.75 (1.7)
Feedback from VR	n.a.	2.79 (1.9)
Feedback from lecturer	1.80 (1.4)	2.17 (1.7)
Feedback from peer	1.60 (1.3)	2.46 (1.8)
Feedback from VR	n.a.	3.21 (1.8)

Likert scale 1 (strongly disagree to 5.strongly agree). A low score meant no dispute or no rejection

No significant differences were found between the control group or VR group with respect to disputing or rejecting feedback from the lecturer and peers in class. On average the VR group was a little more likely to dispute the feedback from the lecturer, peers in class and especially the feedback from the VR.

3.3 Willingness to accept feedback

The “Willingness” to use the received feedback was covered by two questions: (1)*I am willing to improve my performance on the basis of the feedback provided by the lecturer, peers, individual experience.* (2) *I am willing to invest a lot of effort in revisions on the basis of*

received feedback

Table 4. means scores “willingness to use feedback” construct part 3 feedback scale

Willingness to use feedback	Control Mean (sd)	VR Mean (sd)
To Improve performance		
Lecturers	4.50 (1.1)	4.58 (.58)
Peers in class	4.25 (1.2)	3.83 (.92)
Individual experience	4.05 (1.2)	3.38 (.88)
Virtual reality app		2.83 (1.77)
Revision effort based on feedback		
Lecturers	3.70 (.98)	4.17 (.76)
Peers in class	3.20 (1.28)	3.46 (1.10)
Based on VR		2.83 (1.74)

1 being strongly disagree and 5 strongly agree

The first question showed that each group was very ready to change their performance based on the feedback of the lecturer. They were equally ready to change their performance on the basis of peer feedback in class and on the basis of their individual experience. Note that none of the groups have significant within group-difference on this question. When we ask whether the students are willing to put effort in revision on the basis of the feedback from the lecturer, peers in class or VR practice, the lecturer is emerging as the undisputed authority, especially in the VR- group. (almost significant .08). VR was not really triggering a willingness to change.

3.4 Positive/Negative affect from Feedback

The last item on feedback concerns the positive or negative affect of the extra practice opportunity. The Control Group felt significantly more Satisfied, Confident and Successful on the basis of the feedback received in class (control group) than the VR practice (VR Group) felt about the feedback received from the vr speech app.(table 5).

Table 5. Mean scores/significance “Positive affect”

Positive affect	Control Mean (sd)	VR Mean (sd)	Control/vr significance
Satisfied	3.70 (1.08)	2.17 (1.27)	.000 (F1.82)
Confident	3.75 (1.30)	2.33 (1.31)	.001 (F1.31)
Successful	3.35 (1.13)	2.38 (1.27)	.011 (F1.00)

All calculations have been realised with an independent sample t-test. With respect to the Negative affect, no significant differences were found between any of the groups. Overall the mean scores were very low – indicating there was not an issue with being particularly angry, offended or frustrated.

3.5 Reflection Questions

The reflection questions pertained to (1) the expectations with respect to grade improvement.

(2) the effect on their changing their behaviour to become better and (3) the effect on subparts of the assessment metrics used for the presentation techniques course.

With respect to the 1st question “*has the practice experience improved your grade*”, the students overwhelmingly in both groups felt the practice in class helped the most (control mean = 4.60(.59)/vr mean = 4.25(.99). Practice with peers was also highly rated (control mean = 4.50(1.28))/vr mean = 4.08(1.74). The individual practice was not really experienced as grade increasing activity (control mean = 3.15 (.81))/vr mean = 3.42 (1.53). Finally, the practice in VR was hardly considered as grade improving (vr mean = 2.58(1.53).

With respect to the 2nd questions: “*Did students change their behaviour on the basis of in class, at home without VR or VR practice?*”. Behaviour was changed most based on in class practice M=4.00 (89), somewhat as a result of at home practice without VR M=2.54(1.24), and very little as a result of practice with VR M=2.08(1.5). The control group took their “at home” practice a little more serious (in class M=3.50(1.43) and at home M=3.00(1.4)). None of these results show significant difference. When we asked whether students were interested to use the VR practice mode again, most students answered they would not use it again. And when we asked by which practice mode they felt most motivated the VR group said they were most motivated by in class practice activities. With respect to the 3rd Question: Did you improve performance on? We found the following results.

Table 6. means related to improvement on performance indicators

Performance indicators improvement	Control Mean (sd)	VR Mean (sd)
Preparation	2.45 (1.45)	2.75 (.76)
Content	2.70 (1.18)	3.13 (.90)
Presentation techniques	3.80 (1.20)	3.88 (.74)
Questions Rounds	3.90 (1.07)	3.67 (1.05)

When we look at the differences between the two groups, the VR group improved most on presentation techniques and the control group on Question Rounds, this seem logical as the VR speech app drew more attention to presentation techniques and the physical class more towards interaction. Yet none of this significant, differences are very small and based on perception. Even if they were it can by no means be simply concluded that using VR would be a root cause. The VR group as compared to the control group improved more on preparation and on Content according to their perception. It is unclear to what this can be attributed.

3.6 Reflection assignment

The included reflection assignment on what might be done with the feedback, did not spark useful insights into presentation performance. This resulted from 1. a lack of technological access, causing students not to have any feedback at all (no immersion or engagement) with the VR speech app. 2. A lack of relevant feedback metrics in the system (no engagement and no reflection). 3. A lack of bridging the information gap between standards and system. Teachers already pointed out: “what is “good” varies in different contexts and therewith cannot be gauged by objective metrics from a system”. Despite the fact that teachers knew this, they have not actively been involved in guiding the students using the VR, due to amongst others lack of time. The lack of integration between classroom activities and the additional practice

may have caused students' to make limited investments.

4 CONCLUSIONS AND DISCUSSION

The purpose of this research was to apply an experiment to better understand the value and the consequences of the use of VR in education. This study is about the use of a VR app to support presentation skill development. We have seen that the feedback provided in class including standardized assessment criteria is the best possible mode of feedback at this moment. VR in this experiment only did little to support perceived learning from extra practice.

Yet there were conditions in this quasi-experiment that could not be controlled for sufficiently to warrant solid conclusions. E.g. We do not know whether the results are due to intergroup differences of the VR group with the control group and of the different lecturers which have been teaching the group. And we do not know the interaction effect of the intervention with the perceived opinion of the feedback from lecturers and peers in class. It is presumed however that there has been an interaction effect, altering the opinions of the feedback. The conclusion we may draw, however, is that the readiness to work with VR both from a systems, teacher and students perspective is still too limited at the time of this experiment and needs further study to create the best extra practice options in which VR is embedded as a serious tool for feedback in improving presentations techniques.

Acknowledgement: A special thank you goes to Jolien Strouss, Angeniet Kam and lecturers supporting this quasi-experiment at TU Delft

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A Consequence of AI on Engineering Education: Growing Demand for Deeper Understanding

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Conference Key Areas: Scientific fundamentals, Engineering skills, Lifelong learning

Keywords: Higher learning

INTRODUCTION

The revolution of information technology goes on, and one of the biggest ongoing changes in engineering is the development of artificial intelligence (AI). According to many views, during the following decades AI will replace a share of even such duties that are still today considered as expert jobs. According to Russell and Norvig, AI attempts to build intelligent entities. From the recent point of view, the emphasis of development has changed from the traditional approach of AI to machine learning. In the traditional approach, machine was given data and the rules, and the results were gained as an output. The essential difference in machine learning is that a machine is able to deduce rules. Thus, if machine is given the data and the answers, the rules will be the output. Consequently, machines are already able to prove mathematical theorems and to diagnose diseases. [1]

From engineering education point of view, it is of course important to stay on the crest of the wave and to include topical immediate engineering skills of AI in engineering curricula. However, another highly important goal is to promote such engineering skills that cannot be replaced with AI. As economic pressure and eagerness for increasing efficiency in universities have already decreased the role of thorough learning of fundamentals in engineering studies, recent development of AI may continue the trend, if caution is not taken. In this paper, the main scope is to promote such *long-term engineering skills* that cannot be easily replaced with AI. In engineering, they are closely related to higher learning, since they mainly arise from deeper understanding of scientific fundamentals.

1 ABOUT HIGHER LEARNING IN ENGINEERING EDUCATION

How do we define higher learning in engineering education? According to Keeling and Hersh, higher learning requires meaning making, as opposed to memorisation and just-in-time ingestion of facts. Higher learning prepares students to think creatively and critically, and to communicate effectively and actively. In order to figure out how new knowledge is linked to prior one, a deeper meaning of new knowledge has to be uncovered. Otherwise these links easily remain at least a bit unclear [2]. Consequently, a coherent and interconnected structure starting from the fundamentals of engineering substance is needed to truly gain higher learning [3]. We suggest that this kind of solid structure of substance is a necessary condition for higher learning in engineering education.

But how do we implement such a structure in engineering education? Everything starts from such thorough understanding of fundamentals, which during the history of science has been promoted by for example Albert Einstein and Richard Feynman. Then, we are talking about utilising hierarchical structure of natural sciences in engineering education. With the wise words of Feynman: "The goal is to understand basic phenomena in terms of the smallest set of fundamental laws." [4]

The hierarchical structure of natural sciences is described in *Fig. 1*. Although the all-encompassing theoretical framework of physics, *theory of everything*, still remains incomplete, we are constantly heading towards it [5]. Theory of everything represents the most *general* laws of physics, from where more *concrete* laws of different fields of engineering arise. Thus, the explanation of the structure presented in *Fig. 1* is culminated in the words generality and concretisation. When we recede from the theory of everything, concretisation increases. In practice this means that more and more details get fixed. As concretisation increases, engineering models get less general. And on the contrary, generality increases when we approach the theory of everything. In engineering modelling, we are always located on a certain level of concretisation, which are represented by dotted circles in *Fig. 1*. Consequently, we always have a certain set of necessary rules, which lay the foundation for modelling there. The dots in *Fig. 1* represent these necessary rules, which we call cornerstones. Thus, according to Feynman's principles, on each level of concretisation we utilise the smallest set of fundamental laws to carry out modelling.

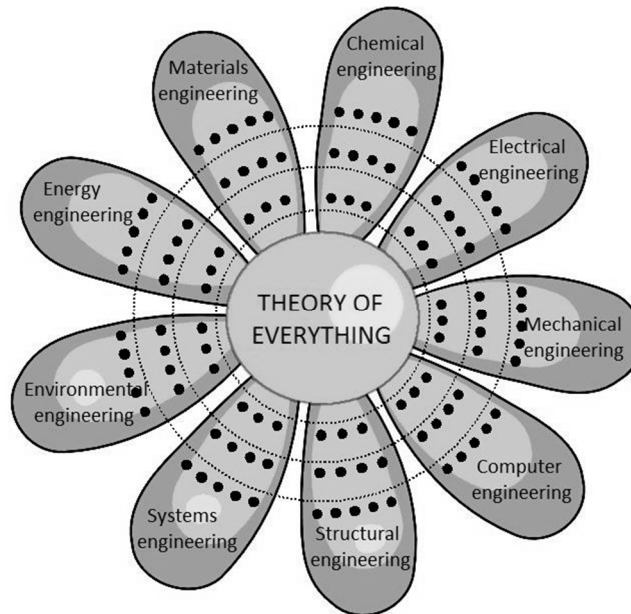


Fig. 1. Hierarchical structure of natural sciences [6].

In order to demonstrate the structure presented in *Fig. 1*, let's take an example. In electrical engineering, electromagnetic fields and waves represent more general level of modelling than circuit analysis. Thus, circuit analysis is more concrete. This simply comes from the fact that all the rules used in circuit analysis arise from more general laws of electromagnetic fields and waves by fixing some details. Thus, by fixing certain details, Kirchhoff's laws arise from Maxwell's equations. Because Maxwell's equations are more general than Kirchhoff's laws, the former can be used to model circuits, but the latter cannot be used to model fields and waves. This is the basic idea behind the terms general and concrete.

One essential detail in *Fig. 1* is to understand that the restrictions and assumptions validating the cornerstones on a certain level of concretisation always come from more general level of modelling. This is closely related to long-term engineering skills, which are not easily replaced with AI. For example, we can carry out the tasks of circuit analysis by Kirchhoff's laws only, but if we don't have understanding about more general Maxwell's equations, we lack self-criticism towards the results of modelling. This is important detail when considering the role of AI in engineering modelling. There will probably be no problems to solve unambiguous tasks of circuit analysis with AI, but we can easily generate situations, where the models of circuit analysis are not valid. Then, we are dealing with such deeper understanding that is much more difficult to replace with AI.

1.1 Problem of excessive efficiency in engineering education

During the current millennium, a global worry about the state of higher learning in higher education has arisen [2], [7]. One powerful statement was given at World Education Day 2017 conference, where the Nobel Prize winner Shuji Nakamura called for profundity and deeper understanding of scientific fundamentals in university education. He was worried and even angry about the recent efficiency-driven development [8].

The problem of excessive efficiency in engineering education refers to a general economy-driven development of current millennium. Mainly due to economical reasons, many universities have practically been forced to increase the number of accessed and graduated students, and at the same time, another goal has been to decrease the duration of graduation. In order to fulfil these quantitative goals, a common action in engineering education has been to invest in more concrete specialised studies and consequently, to decrease the role of scientific fundamentals. For example in Finland, worry about the reduced role of fundamentals in engineering education has already been a newsworthy event in the national news [9], [10].

The problem can be illustrated with the aid of *immediate* and *long-term engineering skills*. Immediate engineering skills mainly arise from the ability to utilise different engineering tools, which are used to solve versatile engineering problems. On the other hand, long-term engineering skills are closely related to understanding the assumptions and restrictions behind engineering tools [11]. In engineering education, the appropriate balance between immediate and long-term engineering skills is more or less an endless dilemma. However, due to excessive efficiency, recent development of engineering education has clearly overemphasised immediate engineering skills at the expense of thorough learning of fundamentals. And when the growing role of AI in engineering tasks is taken into account, we are honestly worried about this recent development of engineering education.

2 METHODOLOGICAL APPROACH: METHOD OF CORNERSTONES

In order to clarify the roles of immediate and long-term engineering skills, method of cornerstones was created. The big goal was to ensure and strengthen the role of scientific fundamentals in engineering education regardless of decreasing financial resources. In this chapter we present the basic principles of the method and its application to electrical engineering education in undergraduate level.

Implementation of the method of cornerstones to engineering education can be divided into two phases. In the phase 1, immediate engineering skills are emphasised by building modelling methods from the smallest set of fundamental rules, which we call cornerstones. In the phase 2, long-term engineering skills are promoted by questioning the validity of cornerstones. As already mentioned, this requires more general understanding about the assumptions validating the cornerstones.

2.1 Phase 1: building the modelling methods from cornerstones

As an example, we have implemented the method of cornerstones to education of electrical engineering at Tampere University of Applied Sciences. The work continues and evolves year after year, but we already have some concrete results of the experiment.

The implementation of the method of cornerstones was started four years ago from the first course of electrical engineering curriculum: direct current (DC) circuit analysis. This course has a crystal clear learning goal: how to systematically analyse electric circuits in such a way that, in the end, complicated circuits are not more difficult to solve than simple ones; they are just more laborious. And particularly DC circuits were chosen, since we wanted to emphasise the principles of solving the circuits and, at the same time, keep the electrical variables as simple as possible.

The substance of DC circuit analysis is pretty much summarised in *Fig. 2*. The house of DC circuits stands on three cornerstones, which represent the fundamental rules to solve any circuit. Thus, according to Feynman's principles, these three cornerstones represent the smallest set of fundamental laws to carry out modelling on this level of concretisation. The methods written inside the house are not fundamental rules. Instead, they are the modelling methods deduced from the cornerstones. Thus, they are not necessarily required to solve any DC circuits, but their existence is justified from decreasing the required work to solve problems. However, essential observation is that the methods written inside the house are not independent rules in any way, they just represent different options to apply the cornerstones. Consequently, immediate engineering skills mainly arise from the ability to apply different methods to solve DC circuits. On the other hand, long-term engineering skills are mainly related to deeper understanding behind the modelling methods; how do they arise from the cornerstones, and what are the assumptions validating the cornerstones.

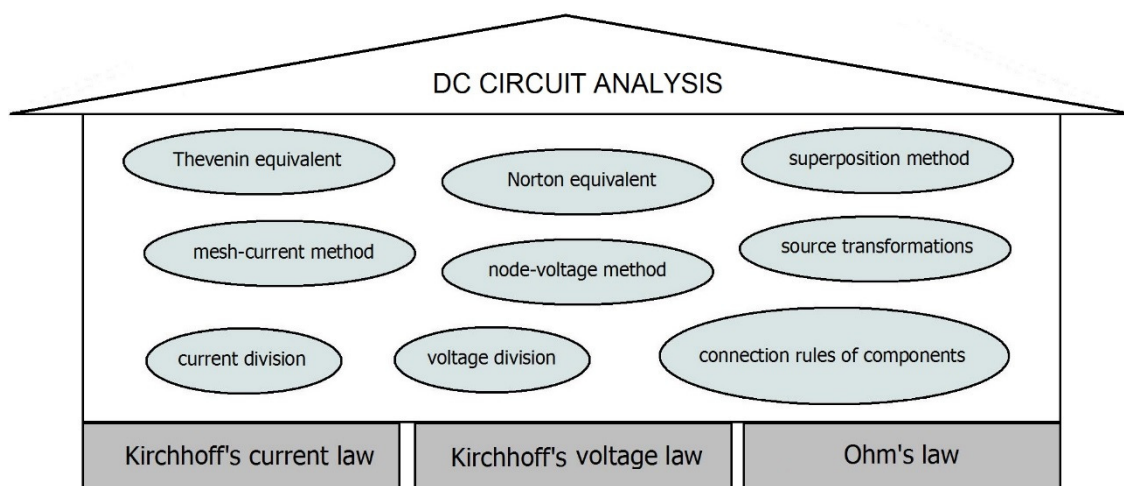


Fig. 2. Cornerstones and methods of DC electric circuits [6].

In practice, these principles were implemented to teaching in the following way. In the very first lessons of the course, the frame of reference is presented. Thus, the house of DC circuit analysis presented in *Fig. 2* is first positioned in the bigger modelling picture of electrical engineering. The idea of this is to show students that modelling of electromagnetic fields and waves and various applications of circuit analysis represent only different aspects of the same scientific phenomena. Then, it is briefly presented how the cornerstones of DC circuit analysis are related to more general laws of electromagnetic fields and waves. With this we want to emphasise that the cornerstones of circuit analysis are not unquestioned rules, but instead, they arise from more general Maxwell's equations with certain assumptions. Then, it is underlined that in DC circuit analysis we will not question the validity of cornerstones. They are assumed to be valid in any situation confronted in the course.

Then, after this introductory section, the essential substance of the course is presented to students. The building of systematic competence to analyse electric circuits is started from directly applying the cornerstones to solve the circuits. Thus, students will first learn how to analyse DC circuits by using the cornerstones only. A significant amount of contact lessons is invested in this learning goal. Only after mastering the utilisation of cornerstones, different methods of DC circuit analysis are deduced from the cornerstones. This comprises derivation of all the methods included in the house of *Fig. 2*. All the time it is emphasised to students that all the methods, starting from the rule of series-connected resistors and ending

to Thevenin equivalent, only arise from different options to apply the cornerstones. No specific method is necessarily required to analyse a circuit, since they all arise from the same foundation. The benefit of the methods compared to direct utilisation of cornerstones mainly comes from reduced workload and maybe more fluent solution of the problem.

The latter half of the course is more traditional one, since it is spent among learning the different methods to solve DC circuits. However, the primary learning goal of the course is to gain systematic ability to solve electric circuits. Thus, primary goal is not in learning different methods. This is where we give students the total freedom. All the different ways to solve DC circuit are carefully presented to students, and all the different ways are also practised in order to gain necessary routine. However, we don't want to force students to use a certain method, since they all arise from the same foundation. Thus, students have the freedom to solve electric circuits in such a way that they personally experience worthwhile and convenient. According to our experience, students' variety of personal preference to solve electric circuits in different ways is surprisingly rich.

2.2 Phase 2: questioning the validity of cornerstones

The key feature in the method of cornerstones is to present the substance in a systematic and coherent way by using the smallest set of fundamental rules on a certain level of concretisation. Due to its strong fundamental theory, electrical engineering offers a great example here, but the similar structure can also be found from other fields of engineering. In the phase 1, the level of concretisation and the corresponding cornerstones are fixed, and methods of modelling are deduced from the cornerstones. Then, in the phase 2, the validity of cornerstones is questioned by finding out their premises.

It has to be emphasized that we are dealing with undergraduate level here. Consequently, our main goal in promoting long-term engineering skills is a little bit different than in graduate level. In order to understand the assumptions behind the cornerstones of DC circuit analysis, the knowledge of electromagnetic fields and waves is required. However, they are not studied in a traditional way. Instead, our goal is to increase the responsibility of an engineer carrying out modelling tasks. In practice this means that we question the validity of cornerstones by arranging such learning situations, where cornerstones are invalid. As an example related to *Fig. 2*, we can arrange such situation in a laboratory, where for example Kirchhoff's voltage law is invalid. The main assumption behind this cornerstone is that the magnetic flux through a mesh doesn't vary with time. Magnetic flux is a quantity of electromagnetic fields, so more general knowledge is required here. By positioning a DC circuit in the vicinity of a transformer we can easily arrange a situation, where Kirchhoff's voltage law is invalid. Then we ask students to model the situation as a DC circuit, and also make measurements in a laboratory. Consequently, measured and modelled results do not match, and then students need to figure out, where does the difference come from. With such situations violating the validity of cornerstones we want to increase the self-criticism and responsibility of students in modelling. Another goal is to motivate students towards more general models of electrical engineering in order to gain deeper understanding of their modelling tools.

3 LEARNING RESULTS

In undergraduate level at Tampere University of Applied Sciences the method of cornerstones has been used for four years now to teach the courses of circuit analysis of

electrical engineering. This chapter presents some learning results of the experiment carried out in the substance of DC circuit analysis.

Altogether about 35 hours of contact lessons were organised with the principles presented in chapter 2. In addition, all the materials were available in the forms of short videos and pdf documents in the website of the course. Traditional exam is used as the assessment, since, in the end, it tests very well the learning goals of the course. On the other hand, the exam can also be considered untraditional, since its essential feature is the freedom of method. Thus, students are not forced to use any certain method in any problem of the exam. There are altogether four problems, and six points is the maximum of each problem. Thus, the total maximum is 24 points. Problems 1-3 are typical DC circuit analysis problems with increasing complexity, and in problem 4 students are asked to find Thevenin's equivalent for a certain circuit.

Results of the exam during the experiment of four academic years can be seen in *Fig. 3*. During one academic year the number of attending students has been between 40 and 50, and accordingly the total number of students during four academic years is 191. As the maximum number of points in the exam is 24, it can be seen from *Fig. 3* that the average is about 20 points. Naturally, there are many details that cannot be deduced from these results, but the big picture is still quite clear. Students really learn the fundamental principles of DC circuit analysis very well. And maybe surprisingly, the variety of different ways that students use to solve the problems is really a rich one. More precisely, in addition to the solutions based on plain cornerstones, also all the methods presented in *Fig. 2* commonly exist in the solutions made by students. This clearly indicates the realisation of *individual learning*, since the utilisation of the smallest set of fundamental laws gives students a freedom to comply their personal strengths and preferences.

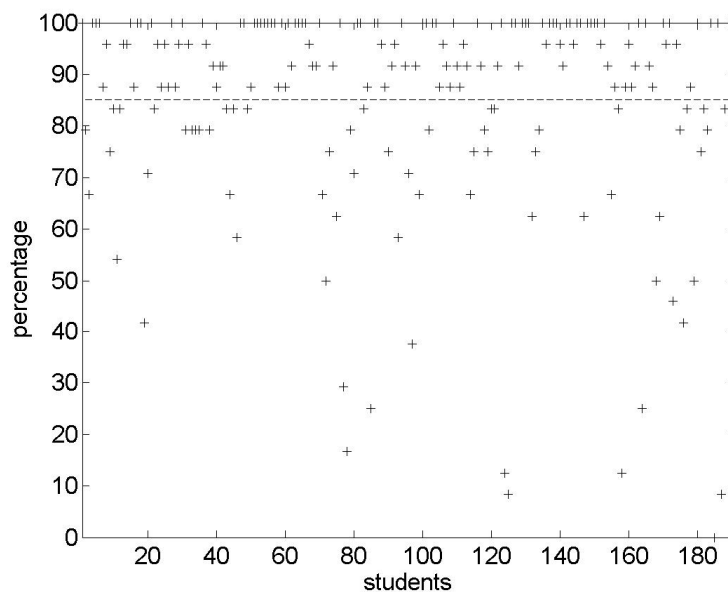


Fig. 3. Percentages of maximum exam points.

For now, our assessment of DC circuit analysis only tests the learning goals presented in chapter 2.1. Thus, learning related to questioning the validity of cornerstones is not yet really assessed. This is the aspect that we are investigating at the moment. Long-term engineering skills are not as straightforward to assess as immediate ones, but we are currently working

on this subject. However, we don't yet have reliable learning results of the long-term engineering skills to be presented here.

4 DISCUSSION AND CONCLUSION

In this paper we wanted to promote such engineering skills that cannot be easily replaced with artificial intelligence. Electrical engineering acts as a good example here, since due to its strong fundamental theory, the models of electrical engineering are rather precise in predicting electromagnetic phenomena. On the other hand, this consistency also helps to apply AI to electrical engineering tasks of industry.

Due to economical pressure and efficiency-driven development of universities during the recent decades, global worry about the state of higher learning in engineering education has risen. Typically the problem is closely related to overemphasising concrete engineering models at the expense of thorough learning of fundamentals. However, due to hierarchical structure of natural sciences, thorough learning of fundamentals is a necessity in gaining understanding about the assumptions and restrictions that validate engineering models. Such understanding represents long-term engineering skills that are not easily replaced with AI.

At Tampere University of Applied Sciences the method of cornerstones has been used in undergraduate studies of electrical engineering for about four academic year now. So far the learning results are mainly related to the principle of smallest set of fundamental rules, but the results have already been encouraging. In addition to promoting the different roles of immediate and long-term engineering skills, it seems that this kind of coherent and interconnected structure of substance also contributes to the realisation of individual learning.

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Teacher's Motivation for and experience with Using Flipped Classroom in a PBL-Environment

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Conference Key Areas: How Learning Spaces support innovative Teaching & Learning, Innovative Teaching and Learning Methods

Keywords: Flipped Classroom, Problem-Based Learning, Teacher Experiences, Engineering Education

INTRODUCTION

In higher educations awareness of, and experimenting with, technology-enhanced learning through the use of Flipped Classroom (FC) has increased during the last couple of years [1]. This is happening while educators involved in FC do not fully know the pedagogical concept of how to effectively translate the flipped classroom into practice [2][3]. At Aalborg University (AAU) a new research project: “Future directions for PBL in a digital age” is dealing with; how digital technologies can enhance problem- and project-based learning (PBL) at AAU [4]. Part of this project is researching the use of FC in a PBL environment as an example of using digitised aspects in existing curriculum. This paper has focus on why and how some teachers at AAU are working with FC. The following questions have leaded the research: What motivate some teachers at AAU to use the flipped classroom approach? Which opportunities and concerns have the teachers at AAU experienced when using FC in a PBL environment?

1 BACKGROUND

Since 1974 AAU has developed principles and models for Problem and Project Based Learning (The Aalborg PBL model), based on constructivist and social learning approaches emphasizing that learning is an active process, which take place through social relations. The PBL model highlights student-centered learning [5]. The AAU principles for problem-based and project-organized work [6] implies a structure for all educational programs where half of the semester is used on courses and the other half on student-organized project work (semester projects). Each semester is based on a curriculum and has a theme guiding the goals and content of the learning. In students semester projects there is a high emphasis of using the PBL competences related to working problem based and project- organized in groups (generic or transferable skills) [6]. Courses are meant to give students the necessary background knowledge for making their projects, and each course has their own exam. All teachers at AAU are working in a PBL environment based on active, social and student-centered teaching/learning approach is used, but there are different way of practising PBL. At courses a fully packed curriculum and course exams might cause that students have to prioritize where they will use their resources [3] which can cause less attention on e.g. students project-work and the important PBL competences. Some teachers have been challenged to change the traditional way of teaching their courses, and have seen FC as a new possibility for improving their courses. FC is in literature described as a pedagogical strategy used in courses [1] [2] and the research on FC in a PBL environment is in this paper therefore framed by PBL in a course-work setting.

1.1 FLIPPED CLASSROOM

From reviewing the literature on FC in higher education, it becomes apparent that there is a lacking consensus on what constitutes a flipped classroom approach. Lage et al. defined flipped (or inverted) classrooms as: “Inverting the classroom means that events that have traditionally taken place inside the classroom now are taking

place outside the classroom and vice versa” [7]. This definition presents a re-ordering of in-class and out-of-class activities and thereby presents a radical change from what is traditionally seen as teaching practice. However it is also claimed that ICT has to be an important part of FC because of the computer-based individual instruction outside the classroom, but also as a possibility for the interactive group learning activities inside the classroom [3]. FC is a rather new pedagogical concept for teachers to try out and newer studies tell more about both the teaching methodology and pedagogical approaches connected to FC.

The didactic method for FC is found in the technology-enhanced involvement that both students and teachers experience. Bliuc et al. describe it as a “systematic combination of co-present (face-to-face) interaction and technologically-mediated interactions between students, teachers and learning resources” [8]. The technology-based resources are often seen as videos [2][9]: small clips from YouTube or videos of teachers’ own presentations [10]. The video resources are often supplemented by quizzes or multiple-choice tests. This serves as a reassurance that the students are actually watching the videos and can be a monitoring of how well the material is used and understood [11].

Using videos for preparation purposes opens up new opportunities; like reaching students who prefer a more visual learning style or would like a greater flexibility to go through lecture presentations [12]. The pedagogical ideas and framework of the FC approach is built on encouraging students to get involved in interactive and high-order activities by giving more opportunities to engage in active learning [9]. By moving lecture time to out of class activities, the in-class learning activities can become more interactive and student-centered [11]. The pedagogical approach of both PBL and FC thereby seems to aim for similar learning approaches. A pilot study of the interaction between the two approaches is therefore carried out to find if FC could be part of the AAU pedagogical approach.

2 METHODS

The investigation presented in this paper was conducted, interviewing 10 PBL experienced AAU-teachers who are currently using, or has previously used FC in their course teaching. Their way of doing FC is diverse, but they have all introduced video material as preoperational material to their course teaching. The research presented is a part of the initial empirical data, which was acquired through the on-going exploratory case studies [13][14] at five study programmes within Engineering, Science and Humanities all using the FC approach. Semi-structured interviews [15], lasting approximately 30-45 minutes each with the 10 teachers using FC have given insight to the teachers’ personal experience of working with FC. The Interviews have been focused primarily on understanding 1) the teachers’ motivation for using FC, and 2) their individual experiences with using FC. The interviews have been coded in relation to the content and four of the central code themes will guide the analysis of this research: *i) Motivation for using FC, ii) Using the FC technology, iii) In-class activities when using FC, and iv) Knowledge production in FC.* The

phenomenological research method [16], has giving insight to the teachers' personal understandings. These data have been supplemented with observations of a few of the FC course lectures. These observations have given the research an outside look at the FC teaching practice. As it is a phenomenological research it is primarily the interviews that have been used for the data analyse but the observations have guided and reinsured that the change reported by the teachers are not presented as overly positive as self reporting is criticized for [17]. The teachers possessed a varying degree of experience with using FC and in the presentation of the empirical data it will be stated if the teacher is experienced (defined as: have used FC on several course sessions over more than a year) or as more novice teachers. This differentiating of the teachers has been made because earlier research has shown that a lot of start up problems when implementing FC can occur and therefore influence the experience of working with FC [12]. The teachers' names are anonymized, and presented as letters from A to J.

3 THE FLIPPED CLASSROOM

In the following sections, we present and discuss the teachers' motivation and experiences having organized and used the FC approach. We have structured the findings within the four above-mentioned analytically coded themes.

3.1 Teachers' motivation for using FC

The interviewed teachers have all by own initiative chosen to experiment with FC and this shows a great engagement and personal motivation because it takes a lot of resources for teachers to engage in FC. We found this motivation grounded primarily in three reasons: 1) *Problems getting students to reach the required academic level, following the learning goals of the course*. A motivation can thereby be related to insufficient previous teaching and outcome of former teaching practice. One of the experienced FC teacher's states that trying out FC was some kind of "damage control" (A) because her students missed a lot of basic skills. They were demotivated and found the class very difficult, therefore many students did not pass exam. Another motivational reason for using FC is framed as 2) *FC seems to be timesaving and more efficient*. A more novice teacher states "FC would give more time for discussions in class" (D). A general understanding between the teachers is that FC creates more time together with the students. All teachers agree, independently of their experience, that they need time for "hands on" interaction, supervision/facilitation and guidance in relation to the more abstract understanding of the academic content of the course. They want to cut down time spent on the traditional teacher-led activities in the classroom and create more time for the interactive and student-centred activities. This leads to the third motivational reason for using the FC approach: 3) *The pedagogical ideas of interactive and student-led teaching*. Pedagogical ideas based on interactive as well as social and student-centred learning has also been a motivating factor for changing the teaching practice. The motivation for changing to FC might implies that previous approaches in the course teaching may not have been satisfying and they see a need for change

which can create more time to interact with the students and establish a more active and student-centered learning approach.

3.2 The FC technology – Time saving or time consuming?

The AAU teachers' motivation in saving time becomes challenged as soon as the teachers start producing their own FC video presentations with sound and/or voice over, finding instructive clips from other media, quizzes, exercises etc. Furthermore the Moodle platform has caused problems for most of the teachers (A,B,C,D,G,I). The resources given to the teachers using FC have been inadequate, as the teachers have used many extra hours on the technology. One of the novice teachers have had a lot of problems recording the lectures. He had problems with the physical settings when recording and had technical problems with the sound (I). The self-produced FC material requires both technological skills and a lot of time. The motivation of FC to be time saving and efficient also has to be seen in the light of the time consuming process of producing the FC material.

3.3 Pedagogical opportunities - in-class activities

Most of the teachers using the approach are, despite difficulties working with the technology, very engaged in continuing using the FC approach. One of the novice FC teacher states that FC gives him half an hour more per lecture where he can do exercises together with the students (I). Other teachers state that they use less time going through text material that are given for out-of-class activities (A,B,C,G,I) and e.g. instead tells the students to ask questions if they don't understand the academic content (I). Observations of the FC courses and the teachers' experiences though tells us that implementing the interactive exercises is rather difficult. An experienced FC teacher states that "It is still the in-class exercises that we need to get working better" (A). The FC approach might thereby create more time for interactive learning in the classroom and the involved teachers have in some cases been able to find alternatives to the traditional lecture teaching, but it requires a lot of resources and when using a lot of time on producing the FC material, it can be difficult to find time and resources focusing on the exercises. The teachers though reports that it have had an effect on reflecting their own teaching strategies and methods (A,B,C,D,I,J). "The process connected to FC have started us to reflect our own pedagogical methods and being much more aware of new opportunities"(A,B)

3.4 Knowledge production in FC – Reaching a higher academic level

In the interviews we found an interesting understanding of how to reach a higher academic level when using the FC approach. It seems to some of the teachers that not all academic knowledge necessarily benefits from being flipped. One of the teacher's state: "The content has to be easy to understand when it is to be presented by video" (I). Another teacher also express this concern saying: "They [the students] need to read the text to reach a higher understanding. The text material, because it might be complex and abstract, can make students wonder and reflect... the video is another medium and it doesn't make you reflect in the same way" (H). These quotes indicate that the learning activities when using flipped classroom might change the

pedagogical learning approach. An experienced teacher evolves on why and how this change in practice is done: “The biggest problems we found, is that the students often find them [the videos] too long and they are not interactive – so they can just fall asleep watching them like TV. So we chopped them up so they are 6-8 minutes long and focusing on a specific topic”(C). The content of what the students are given is thereby changed, and this can affect the knowledge production. Quizzes are used by one of the teachers to make the videos interactive (C) through integrating the quizzes in the videos. This approach have had positive feedback from the students and they ask for more – especially focused on exams (C). Quizzes might have a great effect on creating more interactive learning, but the interaction level and reaching a higher learning level can still be discussed. An experienced teacher explains her use of quizzes (by her called exercises): “Those are just extremely simple things, almost just like: do you remember what you just heard? It's just to check whether the students follow the videos before the class.”(A). At an instructive level, quizzes may be used to facilitate factual knowledge, but quizzes may also be used to support reflection and higher-level learning, depending on the kind of questions (only one right answer or many possibly right answers?) and depending on the kind of detailed feedback given for the students to reflect upon [18].

4 SUMMARY OF RESULTS AND CONCLUDING REMARKS

Investigating the use of FC in PBL environments have in our study given insight into why teachers at AAU are experimenting with using FC in their course teaching. Pedagogical problems using the traditional lecturing structure and unsatisfying teaching results from previous courses have motivated teachers to change their practice. New and more interactive learning strategies are wished to improve the course teaching. The motivation to change teaching through FC in a course-work setting can thereby be seen as supportive in a PBL environment. The teachers experiences also show that the FC approach can create alternatives to the more traditional teacher- centered lectures. Some concerns are however important to encounter e.g. using FC approach in the PBL environment. Technology and product of FC material have shown to be difficult and very time consuming, and the resources used on this part of the FC approach can risk to become too overwhelming and time consuming, and can become a barrier for developing interactive and student-centered learning material. Furthermore we have seen some concerns about the ICT impact on the teaching content and the didactic approach to knowledge production. A risc of simplifying the curriculum content when producing good video presentations can have an unknown affect on students learning. This concern should be encountered when applying FC in a PBL environment where student- centered and problem based learning is essential.

5 ACKNOWLEDGEMENT

This paper haveen possible due to the research project “Future directions of PBL in a digital age” (PBL-Future), funded by Aalborg University and the Obel Family Foundation.

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Diversity and gender enrolment patterns in an undergraduate Engineering program

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Conference Key Areas: Gender Diversity

Keywords: Performance; Gender; Enrolment

INTRODUCTION

Gender diversity, along with other diversities, has recently been a significant issue in Engineering degree programs throughout the world. There are national variations, though and in many countries the number of females undertaking Engineering programs is significantly lower than the number of males and the drivers and reasons behind these trends are poorly understood. In Australia the proportion of females has remained at around 15% in recent years [1]. The University of Sydney, Faculty of Engineering and Information Technologies has made significant progress in improving its gender balance (with over 30% of the commencing engineering undergraduates being female - almost double the Australian national average).

The gender imbalance generally has the potential to skew professional workplace (engineering) cultures; to have narrower perspectives in technology related projects; to not produce effective outcomes from projects; and to result in the Engineering profession being less popular with females.

In reviewing the general trends in our enrolment and student performance data, alluded to above, it is easy to make untested assumptions which can lead to misinterpretation of the nature of the gender difference. This can potentially be addressed by undertaking fine-grained statistical analysis of our data. The aim is to use the resultant insights to drive admissions and curriculum decision making and through this to improve our gender balance and optimise the appropriate support provided to all students. A detailed analysis of a relatively large cohort of students (N=3906) who have been enrolled in our undergraduate Engineering degree

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programs over the last decade has been undertaken, where students' high school subject choices and results are correlated with their subsequent performances in their undergraduate engineering studies.

1 BACKGROUND

Exploration of gender issues in university Engineering programs has been undertaken by numerous researchers in different countries and cultures.

Early work was undertaken with a relatively small sample that showed that neither ethnicity nor gender differences had significantly influenced the success of students. Factors such as vocational interests and low stress levels were major influencing factors [2]. Interestingly, [3] did find that gender had an impact on student performance but it should be noted that this was a relatively small sample of only Chemical Engineering students.

In a much more recent study, an analysis of gender and ethnic enrolment patterns in a relatively large data set of electrical and computer engineering students illustrated a number of trends [4] but explanations of these were not attempted. In another substantial study, student success and attrition were examined through regression analyses where both cognitive and noncognitive variables were considered however gender differences were not found to be material [5].

Gender differences in student experiences and attitudes in a number of science majors, although not specifically engineering, are presented in [6] and it is suggested that significant gender differences in high school students regarding interest in different science majors with physical-related being more popular with males and biological-related being of more interest to females, and furthermore, males appear more interested in the financial rewards in careers while females were more connected with a "helping others" ethos.

Gender differences in grade point averages (GPA) among undergraduate students in biology, the physical sciences, and engineering were studied in [7], and a hypotheses was formed for the gender ecology of science/engineering and the advantages of support programs for women were noted.

An instrument to measure individuals' self-concepts toward engineering design tasks and identified motivation and anxiety were identified by [8]; and [9] identified the roles of gender and persistence in undergraduate computing majors' are related to various self-efficacies, however, these self-efficacy beliefs did not vary by gender.

These studies, and many others result in a relatively unclear picture of the ways in which gender may be a factor in student performance – though they do suggest that this is at least in part because the relationships are multi-factorial and hence a simplistic analysis is likely to lead to misleading or erroneous conclusions. We therefore aim to explore our data in a more nuanced fashion.

2 METHODOLOGY

We have collected a large data set containing all students who have been enrolled in an undergraduate Engineering degree program at the University of Sydney between 2006 and 2016 and who completed their secondary school studies in the state of New South Wales.

This includes students who enrolled in either a single Engineering degree program (e.g. a Bachelor of Engineering (Civil Engineering)) or a combined degree program where the student undertook an Engineering degree program concurrently with a different discipline (e.g. a Bachelor of Engineering (Electrical Engineering) / Bachelor of Commerce). The total data set contained N=3906 students as shown in Table 1.

For each student we recorded the following details:

Table 1. Total data set characteristics

<i>Gender</i>	<i>Single degrees</i>	<i>Combined degrees</i>	<i>Total</i>
Male	1717	1341	3058
Female	376	471	847
Unspecified	1	0	1
Total	2094	1812	3906

- gender;
- secondary schooling data:
 - the overall secondary school ATAR (Australian Tertiary Admission Rank). The ATAR is the ranking most commonly used as the primary basis for admission into University degree programs in NSW. It is calculated by the relevant state-based university admissions centres and is expressed as a percentile score that represents the students position within their overall cohort.
 - the subjects undertaken and result in each subject.
- university degree data:
 - enrolled undergraduate degree program (course code; course name);
 - the list of each University subject/unit of study attempted (unit code; unit name) and the result in each unit.

We also then derived:

- course type: i.e. whether the degree course was a single or a combined degree course.
- university overall results: The students' weighted average mark (WAM) across all attempted units in the degree course, as well as the WAM for all attempted first year units; the WAM for all attempted mathematics units; and the WAM for all technical units related to their Engineering discipline of study.

We then used this data set to assess a range of specific questions related to the relative performance of male and female students.

3 DATA ANALYSIS

3.1 Overall performance comparison

Question 1: How do females perform compared to males?

A reasonable starting point is to compare the overall performance (and standard deviation) of female and male students using their overall course WAM.

Females (N=847)	\overline{WAM}	$\mu = 64.45$	$\sigma = 12.87$
Males (N=3058)	\overline{WAM}	$\mu = 63.62$	$\sigma = 13.16$

Applying a 2 sample t-test to test if these means are different, gives a p value of 0.049, indicating that this difference in WAM for males and females is statistically significant at $\alpha=0.05$, and we can therefore conclude that it is likely that females are indeed performing at a higher academic level than males in this particular set of Engineering degree programs. A

common, but flawed, extension of this data would be to then conclude that this shows there is no significant academic disadvantage experienced by female students. This is supported by looking at the *output* performance (i.e. WAM) without considering the *input* performance (i.e. the ATAR) of the commencing students. If we look at the mean ATAR of the commencing cohort, then we see the following:

Females (N=847)	\overline{ATAR}	$\mu = 93.70$	$\sigma = 4.66$
Males (N=3058)	\overline{ATAR}	$\mu = 92.55$	$\sigma = 5.18$

Again, applying a 2-sample t-test, this time gives $p < 0.001$. This shows that the females enrolling in the engineering programs have a higher mean secondary school performance (\overline{ATAR}). It would therefore be surprising if they *did not* then have a higher overall performance in their degree program (\overline{WAM}). A worthwhile question to explore, though beyond the scope of this paper, is *why* we see this difference in the prior academic performance of males and females. It might be hypothesised that the nature of engineering programs (and their academic culture) is such that only females who are more confident in their academic abilities (relative to males) are choosing to undertake an engineering degree.

Irrespective of the reason for the above disparity in the commencing students, a natural subsequent question is whether this higher level of performance of females in the Engineering degree programs derives solely from this difference in their prior performance. This can be assessed by exploring the \overline{WAM} for sub-cohorts that sit within the same ATAR bands.

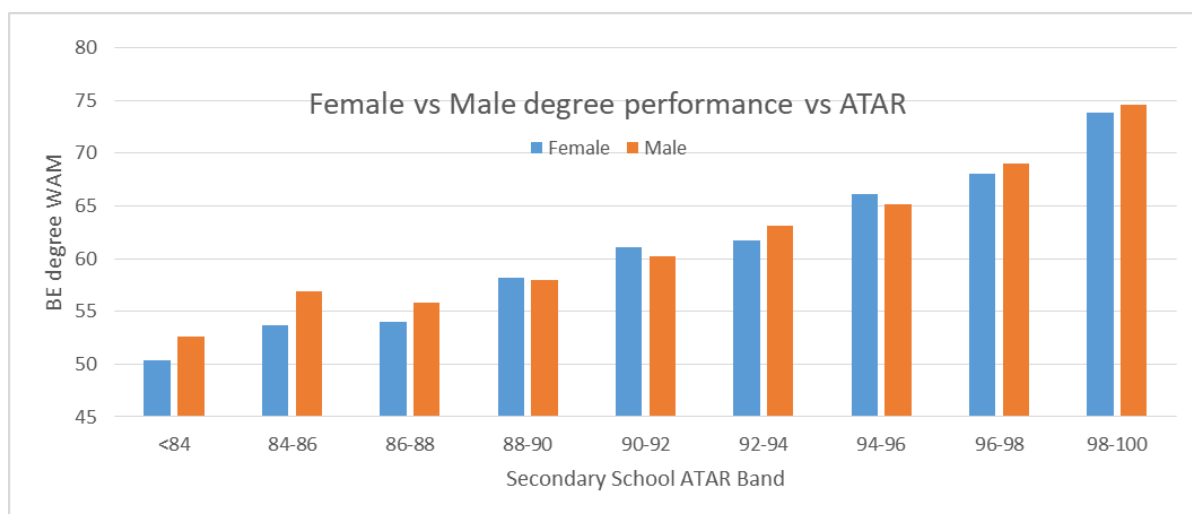


Fig 1. Degree performance by ATAR band.

Figure 1 shows the mean performance of males vs females for students in different high school performance bands. This shows that despite females having an overall degree performance that is better than males, they generally perform worse across most of the ATAR bands shown (six out of nine). This apparent anomaly is an example of Simpson's paradox, resulting from the commencing female students being skewed towards higher secondary school performance than males, and their degree performance therefore being higher than males, but the gap has reduced. This points towards two key avenues of further exploration: (1) Why are a higher proportion of female commencing students coming from higher ATAR students? (2) Once previous performance is factored out, why are female students on average performing slightly less strongly than male students?

3.2 Combined degree vs Single degree programs

It is common in Australian Universities for students to undertake a combined degree program where they complete two different undergraduate degree programs in parallel. Examples include a Bachelor of Engineering in conjunction with Commerce, Law, Science, Arts, Architecture, or Medical Science.

As high school performance increases students become more likely to choose a combined degree – see Table 2. Whilst below an ATAR of 95 this may partially be a consequence of the admission criteria, above 95 there is no difference in the admissions criteria.

Table 2. Proportion of students enrolling in combined degrees.

Type	90-92	92-94	94-96	96-98	98-100	Total
Single	64.29%	54.69%	38.50%	29.67%	27.03%	40.67%
Combined	35.71%	45.31%	61.50%	70.33%	72.97%	59.33%

Q: Is there a difference in the proportion of males compared with females undertaking combined degrees?

Table 3 compares data related to combined degree enrolments and shows that female students have a significant skew towards combined degrees when compared to males (55.4% compared to 43.8%). Given the above observation that higher ATAR females are more likely to choose to study Engineering than lower ATAR females, and higher ATAR students generally choose combined degrees, it is useful to consider the proportions only for high ATAR students. For those with an ATAR above 98, 75.0% of females choose a combined degree, and 72.1% of males – so the skew is much less pronounced than in the total group.

There is a noticeable difference in the choices being made by females and males regarding their second degree. Males are more likely to choose commerce whereas females are more likely to choose Architecture, Arts, and Medical Science. The reasons for this are worth further study.

Table 3. Comparison of combined degree performance

Values	Gender	Single	Combined							Total
		Archit	Arts	Commer	MedSci	ProjMan	Science			
Proportion	Female	44.55%	5.69%	6.99%	12.56%	8.89%	3.67%	17.65%	100.00%	
	Male	56.15%	1.96%	3.30%	15.66%	3.83%	3.76%	15.34%	100.00%	
ATAR	Female	91.37	97.64	94.63	96.50	95.47	93.56	94.99	93.68	
	Male	90.42	97.45	94.10	96.67	95.00	92.71	94.57	92.55	
WAM	Female	62.46	66.00	62.84	66.27	66.90	64.60	66.73	64.39	
	Male	60.98	68.99	62.70	67.61	66.26	66.25	67.45	63.62	
Total Proportion		53.64%	2.77%	4.10%	14.99%	4.92%	3.74%	15.84%	100.00%	
Total ATAR		90.59	97.53	94.29	96.64	95.18	92.89	94.67	92.80	
Total WAM		61.24	67.66	62.75	67.37	66.51	65.90	67.28	63.79	

3.3 Patterns of secondary school subject choice

The data set contained information on students' secondary school subject choices. It is worth considering whether there were gender differences in these choices, and whether this might be correlated to differences in engineering degree choices or performance.

Q: For students in a particular school ATAR band, do males and females make different subject choices?

Table 4 provides a comparison of females and males secondary school subject choices, including a comparison of their resultant overall ATAR band. There are few clear patterns in the data, though it is interesting to note that the level of Mathematics and Science studied was almost identical for males and females, whereas females tended to average a higher level of English and, possibly surprisingly, a lower level of HSIE (Human Society and Its Environment – which includes subjects such as Geography, History and Economics) and other languages.

The reasons for these variations are unclear but one hypothesis worth further exploration is the possibility of self-selection – i.e. only female students who are more focused on core subjects (English, Maths, Sciences) choose Engineering, and those who have wider interests are more likely than their male counterparts to not choose Engineering.

Table 4. Secondary school subject choices for male and female students. (The values shown are the mean number of subjects taken in the given category. For example, a student who studied English, Extension English, Standard Mathematics, Physics and Chemistry would have a value of 2 for English and Science, and 1 for Mathematics).

ATAR	Female					Male				
	English	Maths	Science	HSIE	Langs	English	Maths	Science	HSIE	Langs
88-90	1.05	1.72	1.63	1.68	1.25	1.10	1.73	1.76	1.48	1.40
90-92	1.16	1.76	1.72	1.45	1.47	1.09	1.75	1.68	1.50	1.31
92-94	1.19	1.78	1.80	1.29	1.26	1.10	1.83	1.67	1.46	1.29
94-96	1.21	1.88	1.66	1.31	1.11	1.15	1.87	1.74	1.45	1.33
96-98	1.15	1.97	1.76	1.31	1.33	1.14	1.95	1.75	1.36	1.47
98-100	1.32	1.97	1.82	1.25	1.53	1.18	1.98	1.77	1.21	1.68
Total	1.20	1.87	1.75	1.34	1.33	1.13	1.87	1.73	1.41	1.47

We can extend the above analysis to consider students once they are enrolled in the engineering degree program.

Q: For students in a given WAM band, do males vs females have different Foundational vs Technical vs Professional subject results?

Table 5 compares the subject choices and how this correlates with the mean WAM for students. No clear pattern is discernible, though it does appear that higher performing male students are more likely to have studied science, whereas this pattern is not true for female students.

Table 5. University results (WAM) and correlation with secondary school subject choices.

WAM	Female					Male				
	English	Maths	Science	HSIE	Langs	English	Maths	Science	HSIE	Langs
50-60	1.18	1.79	1.85	1.33	1.28	1.11	1.78	1.72	1.50	1.38
60-70	1.17	1.83	1.71	1.38	1.32	1.10	1.82	1.66	1.42	1.39
70-80	1.20	1.96	1.80	1.23	1.24	1.14	1.92	1.75	1.32	1.48
80-90	1.24	2.00	1.64	1.22	1.64	1.10	1.97	1.86	1.18	1.52

3.4 Progression through the degree program

The above performance measures show variances between male and female students. These results do not however address how this might relate to variation in performance through the degree program, and in particular whether there is a gender influence.

Q: Is the trend in results from year to year different for males and females?

As can be seen in Table 6a, female students' overall performance in the first two years of the program is marginally lower than male students' ($\Delta=-0.69$ in year 1, $\Delta=-0.42$ in year 2). However by years 3 and 4, females are performing better than their male counterparts ($\Delta=+0.24$ in year 3, $\Delta=+1.11$ in year 4). Interestingly, the performance differential is greatest in Mathematics, and lowest in the technical disciplinary subjects.

Table 6b shows the same analysis for the narrower cohort of Engineering students who had an ATAR of 98 or higher in their secondary school studies. This provides an even more interesting pattern. For these students, who achieved comparable secondary school results, the negative disparity in first year ($\Delta=-4.14$) and second year ($\Delta=-1.19$), and the positive disparity in third year ($\Delta=+1.72$) and fourth year ($\Delta=+4.22$) is much more pronounced than the general group. Possible hypotheses for these outcomes include:

- There is a bias in the data insofar as male students in this 98-100 ATAR cohort have benefited from prior advantage, which is progressively dissipated through the degree, allowing the more capable female students to excel.
- The commencing male and female cohorts are equivalent, but the females suffer a disadvantage in the early stages of their engineering studies (e.g. some form of bias inherent in the design or delivery of the program) which is either not present, or which the female students have learnt to manage, later in the degree program.

The current data is insufficient to explore this issue further, but it does point at a critical issue that warrants further exploration.

Table 6. Comparison of results longitudinally through the degree, and in different subsets of subjects (Note: Engin. refers broad professional or generic Engineering subjects; Discipl. refers to subjects specific to a particular Engineering discipline, such as Civil Engineering).

(a) All Engineering students

Gender	WAM	Year 1	Year 2	Year 3	Year 4	Maths	Engin.	Discipl.
Female	65.63	60.10	55.76	58.71	60.69	63.50	63.99	63.43
Male	64.16	60.79	56.18	58.47	59.58	61.75	62.80	62.89
Total	64.46	60.65	56.09	58.51	59.77	62.11	63.04	63.00

(b) Engineering students with an ATAR>96

Gender	WAM	Year 1	Year 2	Year 3	Year 4	Maths	Engin.	Discipl.
Female	75.21	67.55	64.29	68.89	68.07	73.81	70.37	73.81
Male	74.64	71.69	65.48	66.17	63.85	75.17	74.21	73.13
Total	74.79	70.65	65.19	66.76	64.70	74.83	73.24	73.30

4 CONCLUSIONS

There are a number of key findings that emerge from the above analysis. Firstly, it is clear that gender diversity is a significant issue in Engineering degree programs throughout the world and that gender imbalance can skew professional cultures, lead to less effective outcomes from projects, and result in Engineering being less popular with females.

Existing literature presents mixed findings regarding whether gender is an important influencing factor in student performance. Our detailed statistical analysis of a relatively large cohort of students over the last decade has however provided a number of interesting insights:

1. Females are performing at a higher overall academic level than males in our Engineering degree programs. This result could easily be misinterpreted as suggesting that the females are coping with the program better than their male counterparts, and hence mask the existence of deeper issues.
2. Females enrolling in the Engineering programs have a higher mean secondary school performance than males. Given this observation, when we look just at a cohort with comparable secondary school performance, the females generally are performing worse in the University degree program, suggesting that there may be factors that are being overlooked.
3. Female students' overall performance in the first two years is marginally lower than male students, but in years three and four they are performing above their male counterparts. This suggests either that the factors leading to lower female performance is focused on the earlier years, or that females develop an ability to overcome these factors.
4. Highly performing female high school students are more likely to choose to study engineering than lower performing females, and these higher performing students generally choose combined degrees. Of those who do undertake combined degrees, males are more likely to choose Commerce as a second degree, whereas females are more likely to choose Architecture, Arts, and Medical Science.
5. The level of Mathematics and Science studied at high school was almost identical for males and females, whereas females tended to study higher level English. Higher performing (high school) male students are more likely to have studied Science, whereas this is not the case for female students.
6. Very high performing high school students show a negative disparity in first year and second year, compared with other students, but a positive disparity in third year and fourth year.

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How to foster entrepreneurial mind-set in a compulsory course with many students?

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Conference Key Areas: Teaching creativity and innovation, Fostering innovation, Innovation as the context for EE

Keywords: Entrepreneurial mindset, multidisciplinary teams, innovation, scaffolding

INTRODUCTION

A clear trend in today's society and work life is a growing need for skills in interdisciplinary collaboration and innovation. Industry requires engineers with good communication and teamwork skills and a broader understanding of how to solve real-world problems and create value in the marketplace by competing on innovation [1]. Therefore, many universities are developing educational programs to foster competences within innovation and entrepreneurship and these educational programs have grown in pace and scale worldwide also in engineering education, with the aim to develop engineers who have entrepreneurial ways of thinking and working, which they can apply within existing organizations of different sizes and types [1].

Entrepreneurship education is about developing attributes and competences in students, developing personal attributes and skills that form the basis of an entrepreneurial mind-set and behaviour including creativity, initiative, risk-taking, autonomy, self-confidence,

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leadership, realisation of values and team spirit [2]. It is also about raising awareness amongst students of self-employment and new venturing as possible career choices.

In terms of learning style, the development of an entrepreneurial mindset, calls for use of pedagogical tools like problem solving, problem-based learning and active engagement of the students [1], [2]

Another trend to take in to consideration is the growing class size at many universities and the need to rethink the teaching style and learning design by supporting authentic and self-directed learning on courses with many students. With larger classes and especially with compulsory courses, the student group often becomes more diverse regarding motivation, commitment, professional prerequisites and experience with project work and working with open challenges.

In this study, we explore how a framework for a course in innovation and entrepreneurship can be designed when aiming at a course set up for large classes that can both inspire and motivate the students and foster an entrepreneurial mind-set.

1 TRAINING BACHELOR OF ENGINEERING IN INNOVATION AND MULTI-DISCIPLINARY TEAM WORK

Innovation Pilot is a multi-disciplinarily course (10 ECTS point) on innovation and entrepreneurship for 3rd year students in the bachelor of engineering program at The Technical University of Denmark (DTU). The course is compulsory for all students in the named programmes. Approximately 350 students from 17 study programmes attend the course during each spring and winter semester and approximately 100 students attend the summer course. At the beginning of the course, the students are grouped into multidisciplinary groups of 5-6 students with maximum two students from the same study line.

Innovation Pilot is a practice-oriented course with the overall aim to promote an innovative mind-set and enable students to participate in innovation processes as well as to organize and implement a multi-disciplinary innovation process using relevant innovation models and methods. The students work in multidisciplinary teams with specific real-life challenges offered by the involved companies. The companies provide open-ended projects, which take a starting point in actual challenges observed by the company. The company is the problem owner and the students should involve the context reality of the company in solving the challenges. The students are responsible for finding ways to apply their professional skills and knowledge to create value in the projects.

1.1 Course design and learning processes

The overall course design aims at challenging the students and bringing them out of their regular comfort zone. To structure and support the student's innovation process the Double Diamond model created by [3] is used. The model presents four main stages across two adjacent diamonds, where the first diamond concerns exploring and understanding of the problem and the second diamond concerns problem-solving. The model is building on the four phases 1) Discover (divergent phase), 2) Define (convergent phase), 3) develop

(divergent phase) and 4) deliver (convergent phase), where the divergent and the convergent phases comprising of explorative and synthesis works, respectively. In addition, a set of supporting innovation models and tools to be used in the different phases of the double diamond process is available to the students. The course introduces the model to the students in the very beginning of the course and it works as a guide for the students during the rest of the course. To gain reflective experience the course is designed in two learning loops where the students go through the “double diamond” process twice. Both loops involve real life company challenges.

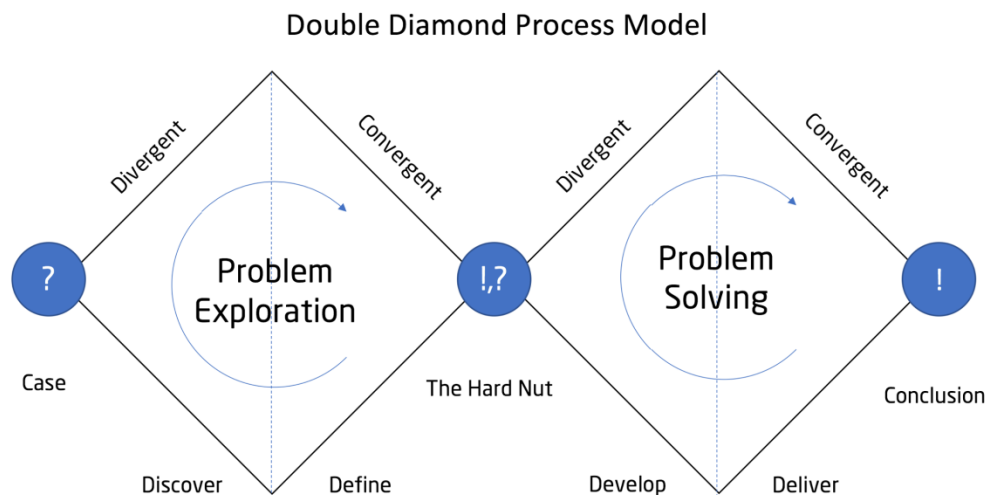


Fig. 1. Made by inspiration from the double diamond process model [3]

In both loops, the students conduct an innovation process structured according to the double diamond model (*Fig. 1*). The first loop takes four weeks and it is a training loop where the students get to know how to work with the double diamond process model with additional methods and tools. In the second loop, students work on a new challenge provided by a company and the process is structured as in the first loop, but now more independency and to be self-driven are expected from the student groups. The second loop takes 8 week with 3 weeks dedicated to exploring and defining the problem (the first diamond in Double Diamond) and 5 weeks dedicated to problem-solving and prototyping (the second diamond in Double Diamond). In each semester, about 20 companies are involved in the course.

The teaching styles is based on student centered learning where teaching methods such as active learning, teamwork, project based and real life problem solving are important “corner stones”. Furthermore, blended learning, peer-feedback and pitches are used as part of the teaching model.

At the end of the course, the students pitch their ideas and solutions at a big event involving both companies and innovation experts. For the evaluation, the students hand-in two group reports, one innovation report mainly targeting the company the group have worked with.

The other report is a reflection and learning report addressing the innovation process, team processes as well as learning outcome as both a group as well as individual. Each student receives an individual grade based on an overall evaluation of the two reports.

With this course design, we aim at adapting the qualities of learning processes in small class settings with dialogue and student-centered focus to a large class setting.

2 INVESTIGATING THE DEVELOPMENT OF ENTREPRENEURIAL MINDSET

One of the course aims is to enhance entrepreneurial and multidisciplinary competences of the students. The student's progression towards an entrepreneurial mind-set were evaluated using a questionnaire consisting of 28 statements and the students were asked their level of agreement.

2.1 Student survey

The survey "entrepreneurial mind-set self-assessment" [4] was used in the course to investigate how well the course meets its objective with respect to development of an entrepreneurial mind-set among the students. In the survey, the students rate themselves on 28 statements about topics central in an entrepreneurial mind-set. For all questions, the answers were given on a 5 point Likert scale where 1 indicates "strongly disagree" and 5 indicates "strongly agree". The survey was done once at the beginning of the course (pre-test) and again at the end of the course (post-test). Due to anonymity, it is not possible to pair the two tests.

3 RESULTS

3.1 Data from student survey

Data were collected in fall 2017 and spring 2018. Data consists of 210 and 141 respondents from the pre-test in fall 2017 and spring 2018, respectively and 67 and 135 respondents from the post-test in fall 2017 and spring 2018, respectively.

The questionnaire consists of 28 questions which are grouped into four topics concerning "Problem solving and critical thinking" (8 questions), "Teamwork" (7 questions), "Business acumen" (8 questions) and "Societal issues" (5 questions). The mean score for each question was calculated. In Figures 2-5, there is a visual presentation of the results for the four groups of questions. The left figure is data from fall 2017 and the right figure is data from spring 2018.



Fig. 2. **Problem solving and critical thinking** from fall 2017 (left side) and spring 2018 (right side). Pre-test = blue, Post-test = reddish , 1= “I am able to recognize problems that exist in the world around me”, 2 = I am good at devising multiple solutions when solving problems”, 3 = “I continue trying even after I have failed”, 4 = “I ask relevant questions to clarify situations and gain new knowledge”, 5 = “I am able to independently gain new information from various sources”, 6 = “I accept responsibility for my personal actions”, 7 = “I accept responsibility for the work I produce including mistakes”, and 8 = “I think outside the box and am creative”.

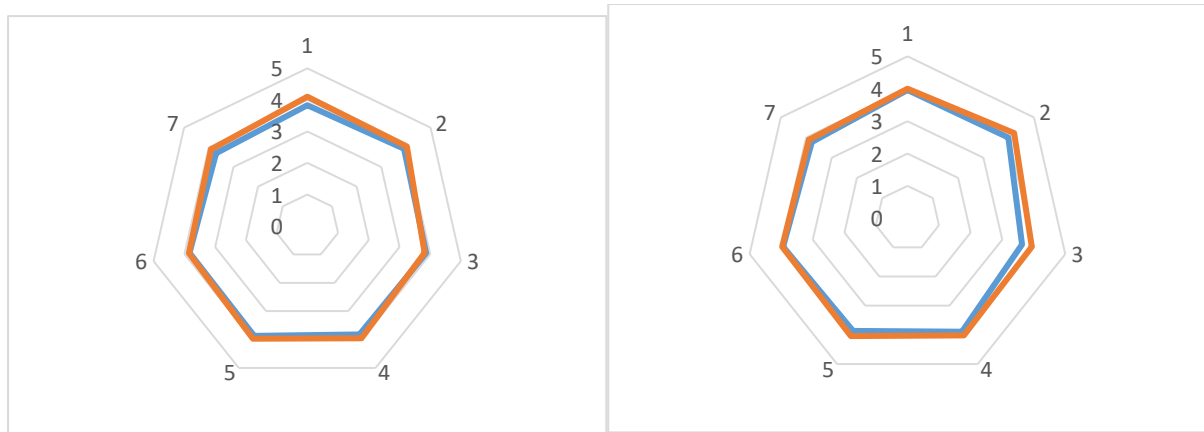


Fig.3. **Teamwork**. Data from fall 2017 (left side) and spring 2018 (right side). Pre-test = blue, Post-test = reddish, , 1 = “I understand and identify with the feelings, experiences and motives of others”, 2 = “I am aware of my personal strengths and weakness”, 3 = “I can identify strengths and weaknesses in others”, 4 = “I am able to determine whether I should lead or follow in different situations”, 5 = “I can develop and maintain working relationships with peers”, 6 = “I can develop and maintain working relationships with supervisors or superiors, and 7 = “I am capable of resolving conflicts”.

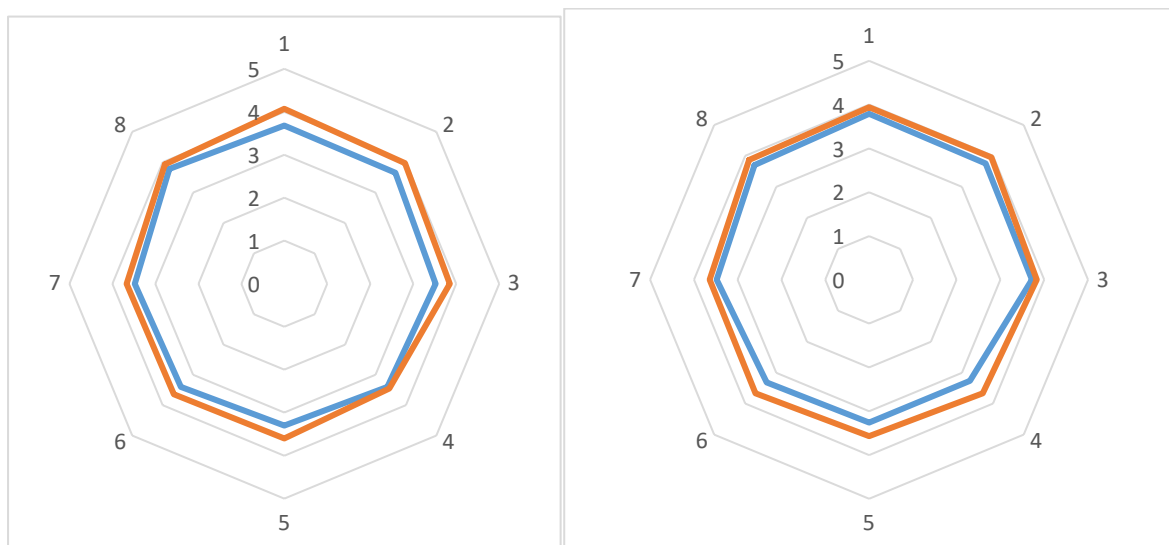


Fig. 4. **Business acumen** from fall 2017 and spring 2018 Pre-test = blue, Post-test = reddish. 1 = “I am able to verbally organize and communicate ideas appropriate to the situation”, 2 = “I am able to organize and communicate ideas in writing appropriate to the situation”, 3 = “I understand basic principles of business”, 4 = “I understand how marketing is used effectively within an organization”, 5 = “I understand the concepts of finance in a business setting”, 6 = “I access opportunity and recognize unmet needs”, 7 = “I access and undertake reasonable risks”, and 8 = “I can develop my own vision”.

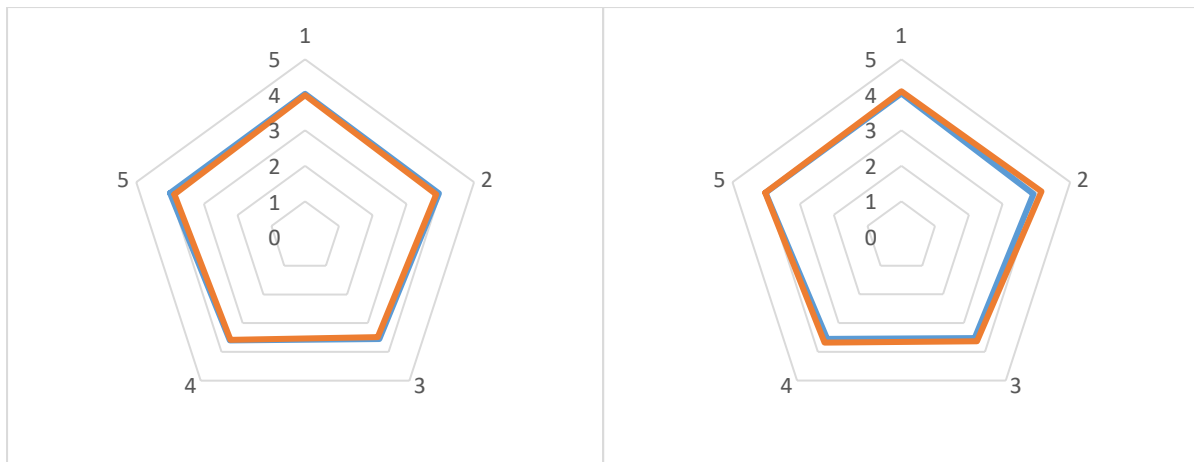


Figure 5. **Societal issues.** Fall 2017 and spring 2018. Pre-test = blue, Post-test = reddish. 1 = “I think and behave ethically”, 2 = “I am aware of how global issues influence society”, 3 = “I serve the needs of others”, 4 = “I try to make environmentally sensitive decisions” and 5 = “I aim to make a positive impact on society”.

3.2 Discussion

In general only small differences are observed between the pre-test and post-test for both data from 2017 and spring 2018. There is a tendency that the results from the post-test are slightly higher than seen for the pre-test. For the “Business cumen” there was a slight movement from the pre-test to the post-test. As part of the course curriculum, we provide the students with material about business issues. The course curriculum does not clearly relate to the other groups of questions.

Rootzen et al. [5] did the same survey with bachelor students from a course concerning “High-tech entrepreneurship”. They found that students move in a positive direction in all four groups of questions and they concluded that the students learn from the process in the course. But they saw the biggest difference in the students rating for “Societal issues” which is not clear in the present study. Rootzen et al [5] concluded that the students had seen the relevance in working multidisciplinary. This tendency is not clear in the present study.

4 DISCUSSION AND SUM UP

To sum up, in this paper we have described a framework for a course in innovation and entrepreneurship for large classes. We have looked into the impact of students entrepreneurial mindset using the “entrepreneurial mindset” questionnaire. However, the results from the questionnaire did not show any clear impact of the students entrepreneurial skills.

Compared with the students own learning and reflection reports (part of the evaluation) the survey results are to some extent surprising as the learning and reflection reports leave an impression of a higher learning outcome and more progression on the dimensions related to process understanding (problem solving/critical thinking and team work).

An explanation for this could be that the students lack a clear picture of what is learning and progression in this field and therefore have difficulties recognizing it. Further development

steps are therefore to include scaffolding elements [6], as a strategy to actively stage the content complexity of different teaching and learning activities in a way where student's learning abilities are met. This approach can also be used to promote and support the students taking a more active role for their own learning and sharing responsibility for learning with their fellow students. Attributes which are also central in developing an entrepreneurial mind-set.

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The student as facilitator

A qualitative exploration of monitoring strategies used by 'dominant' team members in PBL groups.

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Conference Key Areas: Engineering Skills, Innovative Teaching and Learning
Methods, Fostering entrepreneurship

Keywords: Problem-based learning, Student-led Learning, Entrepreneurial
Competencies, Problem-solving

INTRODUCTION

At present there is a concern that modern engineering graduates are beginning professional work without the necessary preparation; current educational practices are so far removed from the reality of industrial work that graduates have difficulty adapting [1]. Educational and industrial professionals have different opinions on what is important for working life, with academics focusing mainly on technical knowledge and often overlooking the need to develop students' professional skills [2]. There are currently few opportunities for students to improve their entrepreneurial skills which

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are necessary to help solve the global challenges facing industry in the twenty first century [3].

Problem-based learning (PBL) has been adopted by engineering education as one method to improve students' performance and engagement while providing an environment for them to develop entrepreneurial competencies, e.g. problem-solving, teamwork and leadership. PBL for 'professional action' is an authentic pedagogy which imitates a real-life working environment and gives students the responsibility for their own learning [4]. The existing body of research on PBL for skill development has so far utilised quantitative methodologies, investigating mainly the perceptions of students or the products of learning (e.g. assignments, reports or grades) rather than the processes involved in learning itself. In the last decade there has been a greater focus placed upon the interactions and group processes which occur during PBL or small group tutorials [5-7]. The work presented here adopts a novel approach using a qualitative method to analyse the behavioural characteristics of students when doing problem-solving to understand 'what works' in PBL. This aims to inform educational practices on methods that can promote the development of professional skills in graduates.

The theoretical background to this study is based on the social constructivist view of learning [8, 9]. Where learning is grounded in an individual's experience, knowledge is uniquely constructed based upon these experiences and is influenced by the social environment. This is further built on through the concept of situated cognition which believes that learning is influenced not only from interactions with peers but it is also dependent on the context where it occurs [10]. This gives argument for learning environments to be closely linked to the situation in which the knowledge might need to be applied, e.g. problem-based learning. Focus on the social aspect of learning is something which has not been emphasised by previous researchers. Thus, this paper presents an investigation into 'how' students solve problems in a group and 'how' their interactions impact on their learning process when the guidance of a tutor is limited. Specifically, in this paper we investigate instances when dominant students take on a leadership role in their PBL tutorials and further analyse the response this behaviour receives by peers.

1 METHODS AND RESEARCH DESIGN

1.1 Data Collection and Participant Recruitment

The data reported on in this paper are from video recordings of third year undergraduate PBL sessions, collected from a core Chemical Engineering Design module, taught over two semesters, at a UK university from September 2016 - March 2018. The purpose of collecting video footage is to gain close insight to the naturalistic interactions which take place in PBL tutorials with the intermittent presence of a tutor (a floating facilitator). This means that the researcher can continuously go back to the raw data and unlike traditional observations the data can be revisited to validate the analysis. Approximately fifty hours of data has been gathered and analysed for this ongoing study but only a portion of the results and analysis will be presented in this paper. The first stage in the process of PBL, when teams brainstorm a problem definition and decide on learning objectives, was analysed for this work.

Ethical approval was obtained from the departmental committee before participants were recruited and filming commenced. Overall twenty-five third-year undergraduate

students, taking part in the design module, volunteered to participate in the study making up four small tutorial groups of 5-7 students (see *Table 1*). This is the first time students in these cohorts experience PBL. To provide anonymity all participants were given pseudonyms for the analysis.

Table 1. Characteristics of participant student groups by academic year and formation method.

Group	No. of Students	Academic Year	Cohort Size	Group formation
1	7	2016-2017	136	Random
2	7			
3	5	2017-2018	150	Belbin Scores
4	6			

1.2 Data Analysis

Studies which assess the success of PBL, for skill development, have traditionally employed a quantitative approach. Warnock and Mohammadi-Aragh (2015) conducted a case study based on student perceptions before and after taking part in a PBL led module [2]. However, the current study focuses on ‘how’ students work collaboratively in order to describe the processes taking place during problem-solving which requires a qualitative approach. The advantage of this approach, using video recorded data, is that the behaviour and interactions which occur throughout this process can be examined in detail to gain insight into the techniques that students use. Imafuku and Bridges (2016) point out that there is a need for qualitative interactional investigations of PBL to strengthen the current corpus of research [5].

The data was examined using qualitative content analysis (QCA) to describe patterns which emerge in the students’ discussions [11]. This method requires the data to be transcribed verbatim so that the textual data can be coded. The transcripts were then collated and coded following a process outlined by Schreier (2012). The analysis for this work has been mostly data-driven, with codes emerging from the transcripts rather than being predetermined. The initial coding pass identified several techniques used by the students to help the team when formulating ideas and creating learning objectives during the initial phase of the PBL cycle (i.e. from brainstorming to formulation of learning objectives). Following this, a meta-analysis was completed to investigate relationships between the codes and the participants. This secondary analysis has allowed the researchers to look further into ‘how’ these identified techniques are used in problem-based learning tutorials. One key discovery from this secondary analysis is outlined and thoroughly examined in this paper.

2 RESULTS

The purpose of this original study was to gain some understanding of ‘how’ students approach problem solving as a group through analysis of the discussions which occur in their PBL sessions. A coding frame was reached using QCA to establish the conversational techniques used by students in the problem definition stage of PBL to create an action plan moving forward. Examples of these codes/techniques include implementing order to the session and making use of different resources such as the case material or the tutor. Further analysis was carried out to shed light on the interrelation of the codes with each other and the participants. This paper presents and discusses one phenomenon apparent in the secondary analysis and seen throughout the data corpus considering different student groups.

One of the strategies for problem-solving, derived in the initial analysis (as per section

1.2), was the use of a 'structure'; by identifying stages in the problem-solving process for which expectations of what needed to be achieved at each stage were clear. This was a method by which the groups monitored progress and prompted productivity. It often was implemented using specific words, from the PBL cycle (e.g. brainstorm, issues, problem definition etc.) which directed the discussion and reminded the team to reach a conclusion. Further investigation delving into the coding frame and focusing on individuals' interactions within the team, made it clear that this structure, which is used to facilitate the PBL sessions, is primarily and continuously used by specific individuals within the team. These individuals often happen to be the most dominant team members as seen through high participation in the discourse. They appear to be acting as a substitute tutor or facilitator throughout the PBL sessions in the semester and not only in specific meetings. Even when groups had made a role rotation the dominant team members appear to take up the leadership role regularly.

To illustrate this phenomenon, three examples where 'dominant' students have exhibited this particular behaviour as shown below. The extracts selected illustrate how group members react to these attempts at facilitation. The first extract has been taken from group 3 when working on a case focused on the design of a heat exchanger which took place at the beginning of the module when the students were very new to the PBL process.

Extract 1. Group 3 – Heat exchanger -case number 3, Week 1.

A-Aaron, R-Richard, C-Conor, E-Eva and J-Jamal

1. A: right so the big big situ- (0.3) the big picture is that
2. we're designing a heat exchanger
3. R: yeah
4. A: thats the problem
5. C: thats the problem
6. (5.0)
7. A: so they'll be a load of
8. E: so is this
9. A: problems underneath that which stop us doing that but the
10. main problem is
11. J: what does it mean by the 'temperature of the ammonia
12. dictated by the process side' does that mean is it
13. supposed to be size is that a typo or what is
14. E: 'the inlet and outlet temperatures' ah I think it means
15. whether or not its inlet or outlet cause if its inlet it
16. will be a different temperature
17. J: oh its talking about the side of the heat exchanger
18. E: I think so

Extract 1 shows how Aaron has tried to instigate the conversation about the case at hand. The group have had the new material for twenty minutes but so far have had extensive discussions about the module organisation and upcoming deadlines but have not addressed the case itself. Approximately thirty seconds prior to this excerpt Aaron asks the group "so whats the problem lets do that first" but there is no uptake by the other team members who continue their off-topic discussions. In line 1 (*Extract 1*) we see Aaron proposing an answer to his earlier question with both Richard and Conor acknowledging him in lines 3 and 5 respectively. It seems that Aaron is not just prompting the group to consider the meaning of the case, but he is determined to establish a decision for the problem definition. He is not satisfied by the agreement of Richard and Conor as he continues to justify his thoughts in lines 7, 9 and 10

interrupting Eva (line 8) in the process. This extract provides evidence to suggest that this facilitation is not having the desired effect because the team is unresponsive to Aaron's prompts.

It is also noticeable that Jamal does not appear to have the same priorities as Aaron, in line 11-13 we see that Jamal swiftly moves the conversation to more specific details about the case itself. The need to follow the PBL cycle – the seven steps – is not reciprocated. Thus showing that there are two ways of approaching these cases, the first by following the PBL steps to establish an action plan and the second through delving deep into the content immediately attempting to solve the problem. This may suggest that Jamal is not only ignoring Aaron's prompts because he is not the prototypical leader but because they are working towards different goals.

Similarly in *Extract 2*, an excerpt from group 1, shows them working on a case based on the design of a phase separator completed over half way through the module. It is interesting to notice the same behaviours occurring once the group have had some time to familiarise themselves with the PBL process as well as team members.

Extract 2. Group 1 – Separator case number 13, Week 14.

A-Annie, C-Craig, La-Laura, S-Sharon, M-Molly and Li-Linzi

1. A: oh we have a new case (0.2) we should do that first
2. La: mmhm
3. (6.0) ((A yawns))
4. A: what do we need to know about separators
5. (3.0)
6. A: oh whos writing
7. S: I think I'm writing but I'll check
8. A: oh yeah Linzi do you (.) want to be leader
9. C: we don't use our mass erm sorry mass separations stuff for this
10. (5.0)
11. A: oh
12. S: I'm writing Laura is leader

Extract 2 begins with Annie's statement starting the new case six minutes after the team have received the case material but she receives no uptake from the team, see line 3. Annie again tries to instigate discussion in line 4 where she asks a more detailed question but is met with the same silence. Annie only achieves uptake from the group when she back tracks to different topic (i.e. roles) which does elicit a response from Sharon in line 7. It appears that the topic of role assignment is more acceptable than discussion of the case at this point in time. This is further confirmed when Craig poses another question in line 9 but Sharon responds, in line 12, to Annie instead. This shows that members of group 1 react similarly to Annie's prompts as group 3 did to Aaron despite the group in this second extract being more familiar with the PBL process. In fact there are two team members who remain completely silent throughout the second extract, indicating their reluctance to join the conversation. It is interesting to note that in this instance Annie does prompt the team but she is less direct than Aaron, possibly because Aaron (in *Extract 1*) appears to be pushing the group to reach a decision whereas Annie (in *Extract 2*) is initiating a discussion. This suggests that it is not the way in which 'dominant' students facilitate that makes team members resistant to it.

*Extract 3. Group 2 – Material balances case number 9, Week 8.**K-Katie, M-Matt, J-Josh, R-Ryan, O-Oliver, H-Hannah and Y-Yasmin*

1. K: right can we do this
2. ((group laughter))
3. M: yeah sorry (man)
4. ((unclear speech))
5. J: give problems
6. (0.2)
7. K: right (.) let's actually write something - ((addressing Matt))
8. M: me
9. K: aha
10. M: yeah sure su-that's what I was doing right now was
11. writing down stuff
12. K: okay
13. M: so emm I said that (1.0) for the (.) basic calculation sheet
14. (0.2) so this project's based on ammonia so I said the mass
15. balance (.) so I done the stoichiometry...
16. ((Matt continues to read out what he has written down))
17. K: well it's nice of you to do that but now I think we should
18. fill in the sheet
19. M: oh ok (.) oh this sheet
20. K: yeah
21. M: oh ok

Extract 3 is an example where this facilitation is in fact accepted and taken up by the rest of the team. It is from a video of group 2 midway through the module and is focused on material and energy balances, which are familiar concepts that have not been applied in this context previously. *Extract 3* occurs 23 minutes after the case material has been given to the group and it immediately follows on from an off-topic conversation between two team members (Matt and Ryan). Katie is the 'dominant' student and again she is encouraging the group to make progress. In line 1 she says "right can we do this" which is an explicit statement trying to get the group on track but is met with laughter from the group suggesting they are not taking her seriously. She persists with this line of thought repeating "right lets actually write something" in line 7 specifically addressed to another team member, Matt. This is taken up by Matt in line 8 and he then begins a long monologue, which has been cut short in this paper for the purpose of succinctness and explains what he had already been "writing down". Despite this extensive response to Katie's request she again tells Matt that was not actually what she had meant in the beginning. Eventually they reach a mutual understanding and Matt acknowledges Katie's prompts in line 19 and 21.

This is a long sequence with persistent intervention from Katie to get Matt to fulfil his assigned role. This shows a deviant case compared to those in *Extract 1* and *Extract 2* where Katie's facilitation and policing of Matt appears to be necessary and acceptable, this is seen by his continued uptake and also by the rest of the group remaining quiet. None of the other group members either affiliate or disagree with Katie but remain neutral instead. At the beginning of the tutorial Katie identified Ryan as the leader for the upcoming session but then continually demonstrated leadership behaviour herself. This phenomenon has frequently been noticed to occur throughout the data corpus despite other team members having been assigned to assume the leadership role.

3 DISCUSSION AND CONCLUSION

3.1 Analytical Summary

Through the investigation into 'how' students solve unfamiliar problems in a PBL group, it is seen that students utilise the given PBL cycle to structure the session. The results shown here focused on exploring the fact that this 'structure' is put in place by only one or two students who are also most dominant within the team discussions but not necessarily appointed by the team or by an established rotation as leaders. We see that generally team members are resistant to this facilitation because it is often ignored. This might be because team members do not believe that only one person has the authority to take on only this leading role but should instead be contributing and joining in as part of the team. However there might be instances (i.e. *Extract 3*) when this type of leadership is necessary, for example when one student is not meeting the expectations of the group. This situation is much less frequently seen in the data corpus.

It is known that having an order to the discussion can be useful because it allows the group to monitor progress, keep on track and gives them an immediate task to complete [12]. However, having only one student pushing the team to follow this structure can be counterproductive as the 'dominant' student seems to be taking an authoritative role suggesting perhaps that they are 'more capable' than the other team members. For this type of behaviour to be successful it would need to have group consensus.

3.2 Practical Recommendations

Leadership is important for students to develop but a shared leadership would be more productive and have a positive effect on group processes in PBL [13]. In this PBL context, where students are at the same level in knowledge and experience, the group members should have shared ownership of the team's progress, performance and leadership. By only one student taking on the facilitator role the other team members are missing out on valuable opportunities to develop their own leadership skills.

Therefore in PBL practice more effort should be made to ensure that groups rotate leadership as to give each student the chance to practise managing a team. This could create a more comfortable atmosphere to encourage equal participation rather than having certain individuals dominate discussions. Similarly, students would benefit from support about managing participation when working in teams so that everyone can have a positive influence in the problem solving process.

3.3 Limitations

This study has only focused on one specific module that uses PBL where the students taking part have no previous experience with the pedagogy. One concern is that this does not give enough time and practice for learners to truly understand the process and fulfil their potential with PBL. This is particularly important as the PBL model used here is based on the tutor being present only intermittently consequently placing more emphasis in the group to manage their learning process from the beginning. Therefore it would also be useful to investigate students at other institutions and at different levels of their study.

4 ACKNOWLEDGEMENTS

The authors would like to gratefully acknowledge the students who volunteered to participate in the research. This ongoing study is supported with funding from the University of Strathclyde John Anderson Research Award.

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Teaching and Learning Competencies

Valued by Engineering Educators: A Pilot Study

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Conference Key Areas: Continuing EE and Lifelong Learning, Discipline-specific Teaching & Learning, Engineering Skills

Keywords: Engineering Educators, Identity, Professional Development, Teaching & Learning Competences.

INTRODUCTION

At the onset of this paper, it is important to provide context by highlighting two backdrop narratives, which have prompted and guided this research project:

- (i) Since 2015, The National Forum for the Enhancement of Teaching & Learning in Ireland has undergone an extensive consultation process on professional development, resulting in a guiding document entitled the National Professional Development Framework (NPDF) for Staff Who Teach in Higher Education [1].
- (ii) The Technological University Alliance for Dublin has placed Dublin Institute of Technology (DIT), Institute of Technology Blanchardstown (ITB) and Institute of Technology Tallaght (ITT) on a merger trajectory towards technological university designation [2] under the Technological Universities Act 2018.

Project Levitus is a cross-institute initiative tasked to develop and pilot a disciplinary-specific (engineering) version of the NPDF, transferrable to other academic disciplines. A steering committee, comprising of engineering educators, teaching and learning specialists, academic managers and HR representatives, has guided the project.

1 OBJECTIVES OF THE STUDY

The project follows three stages: [i] research, [ii] development, [iii] pilot and evaluation. This paper outlines the findings from the research phase, which identifies core and discipline-specific teaching and learning competencies valued by engineering educators, which will inform the later development of a competency framework.

RQ1- What are the perceived core and discipline-specific competencies to be an effective engineering educator?

RQ2- How can these competencies be best addressed by professional development (PD) activities in teaching and learning (T&L)?

2 LITERATURE REVIEW

Three strands of literature inform this review: [i] professional development in higher education [ii] reform in engineering education, and [iii] teaching and learning training.

2.1 Core Teaching & Learning Competencies

Several definitions of competency prevail, with lexes such as skills, knowledge and behaviour to the fore. Competencies can be defined as demand-orientated skills for solving problems [3] or as collaborative skills to engage with students and colleagues [4]. Other competency domains include the learning-scholar, knowledge-expert, learning-facilitator and individual-teacher [5]. The student perspective on what it is to be an effective teacher offers a worthy insight and further enhances these definitions. Teachers' wealth of knowledge and ability to communicate their expertise is important, as is their enthusiasm and passion. Valued behaviours include teachers' openness, approachability, friendliness and an ability to challenge, motivate and stimulate [6]. The NPDF outlines five domains: [i] self, [ii] professional identity, [iii] personal and professional digital capacity, [iv] knowledge [v] professional communication and dialogue. Yet, it is important not to lose sight that teaching and learning competencies must accommodate diverse contexts in which teaching takes place. The challenge is to create a competency framework, which can be continuously adapted.

2.2 Engineering Teaching & Learning Competencies

Engineering today is characterised by a diversity of demands made on professional engineers. Contemporary challenges in their education include: student recruitment and retention, low female participation and a gap between professional engineering practice, based on interdisciplinary problem-solving, and an education model rooted in the sciences. There has been concern for some time now that the education system for producing new generations of engineers is failing to keep pace [7]. Engineering teaching and learning competencies should, therefore, reflect these challenges.

Desired characteristics for PD in engineering education, suggest that it should articulate a clear metaphor for effective classroom learning [8], provide educators with opportunities to broaden their experience, be congruent with andragogic principles [9], build community of practices [10] and prepare educators for leadership roles. Fink et al. [11] explore the challenges of becoming a professional engineering educator, citing reports calling reform [12, 13, 14]. They advocate for integrated curricula, addressing multiple learning styles, a focus on employability skills and socio-economic responsibility. Calling for reforms to be rooted in educational research and cognitive science [15], they remind us that students remain the focus [16, 17].

To identify the competencies required of engineering educators, it is important to understand the knowledge, skills and values they seek to develop in their students. Passow [18] highlighted several ABET competencies important to engineering graduates in their professional work, such as teamwork, data analysis, communication and problem solving. Synthesising a large evidence base, Passow and Passow [19] identified 16 engineering competencies including initiative and creative thinking. Of course, not every engineering educator will possess all these competencies equally; some may be technical specialists, others better able to integrate knowledge and operate across boundaries in complex environments.

The ideal engineering educator can be considered: competent in their own engineering discipline; active in research and maintaining currency; an effective teacher; understanding the role of the engineering education in society; and a role-model engineer for students [20]. Hence, although teaching and learning is only one aspect of engineering educator competence, it remains inextricably linked to a wider role encompassing research, professional practice and community engagement.

2.3 Training Provisions in Teaching & Learning

A snapshot of accredited professional development in Ireland [21] identified 68 teaching and learning programmes from 23 institutions, the majority at NQF Level 9. A snapshot of non-accredited provision identifies four categories [22]: pedagogy, assessment, academic development and digital capacity. Even within the three merging Institutes, there are known provisions. For example, Dublin Institute of Technology's LTTC offers an MA in Higher Education, an MSc in Applied eLearning, a PG Diploma and modules for continuous professional development. These offerings are also available to staff at ITT and ITB.

3 THEORETICAL FRAMEWORK

Implicit for engineering educators is a dual professional identity. Some argue that they are educators and the adjective 'engineering' describes what type. Others point out that they are educating for entry into a profession and are, hence, engineers who happen to be educating. Irrespective of which lens, engineering educators inevitably seek to develop inextricably linked competencies as an engineer and educator.

Hence, two streams of theoretical work inform the study. The first recognises the need for engineering educators to translate their engineering knowledge into pedagogically powerful structures that are adaptive to varying student learning needs [23]. The second recognises a need for engineering educators to remain professionally current through research, consultancy and engagement in communities of practice that seek to solve engineering and engineering education problems [11].

4 METHODOLOGY

4.1 Research Design

Given the quest to establish a middle ground between different stakeholder groups, the study leans towards a qualitative-interpretive approach [24]. The project was introduced to staff at the three Institutes at the start the academic year 2017/2018. A survey was then designed through a process of extensive consultation. Using a mixed methods approach, the survey was used to maximise insights from engineering educators, focus groups explored views of students and in-depth interviews sought academic managers' perspectives. The survey data was analysed in MS Excel and a thematic analysis [25] of the interview and focus group transcripts was undertaken in Nvivo. Both the literature review and empirical findings are currently being used to inform the development of the competency framework.

4.2 Population and Sample

Using a voluntary sampling method, the survey link was emailed by champions to participants who could self-select into the survey. Across the three Institutes engineering students were invited to participate in focus groups, and Heads of School and Heads of Department were contacted to request an interview.

4.3 Data Collection and Analysis

An electronic survey elicited responses regarding competence, and PD activities, both valued and needed by engineering educators. Divided into three sections: [i] background information, [ii] professional experience and [iii] professional development in teaching and learning, respondents were asked to rate their values and needs according to a 4-point Likert-type scale. Forwarded to over 300 colleagues, data was elicited from 121 respondents ($\approx 40\%$ participation rate).

A focus group guide was developed, whereby students were asked to identify competencies across three domains: educator, engineer and engineering educator. Across the three Institutes 27 students shared insights. Responses were mapped to three competency domains: [i] pedagogical: teaching practice, [ii] content: engineering knowledge and [iii] pedagogical-content: relating engineering practices to T&L.

An interview guide was designed and sent to academic managers. All interviews were recorded. Transcripts were sent to participants for review. Interviews with academic managers ($n=8$) sought to understand how the current PD in T&L system functions and to identify gaps and improvements. Each transcript was reviewed under three a priori themes [i] support for PD in T&L, [ii] managing PD and [iii] cultural change. All transcripts were read thoroughly by the researchers to familiarise themselves with the data. An initial coding of the transcripts identified nine emerging sub-themes, which were then categorised under three a priori themes (Fig. 4). Interpretation of meaning attributed to coded text extracts was calibrated to further validate the emerging themes.

5 SUMMARY OF FINDINGS

5.1 Results for Research Question One

Question 13 of the survey asked: *What makes a great engineering educator? Rank all the statements from 1 - 6 in order of importance.*

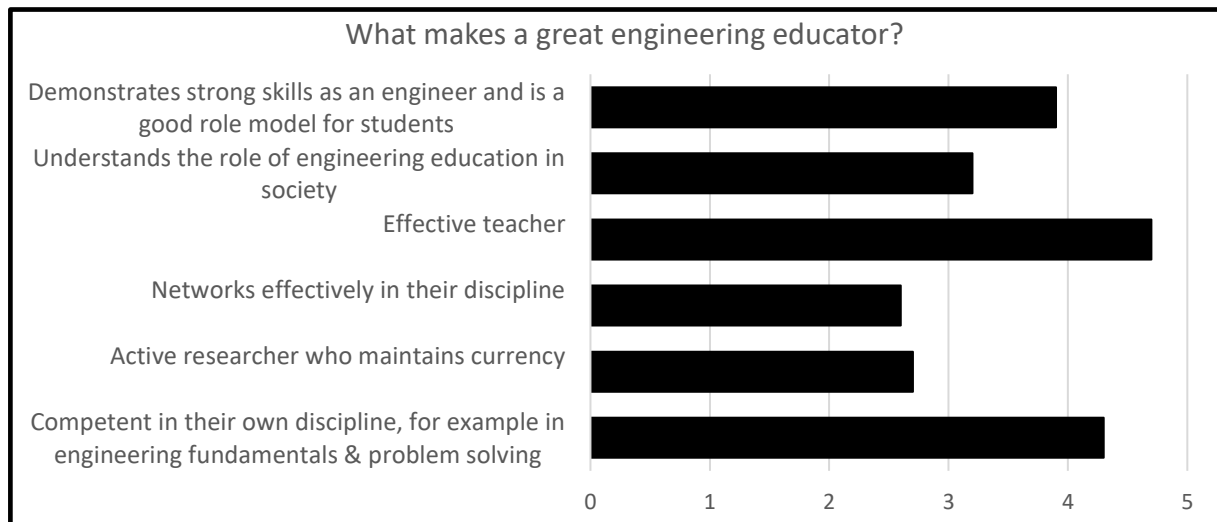


Fig. 1. Relative scores for key attributes of a 'great engineering educator'

The focus group responses were mapped to the draft competency domains. Table 1 provides sample statements with the total number of coded responses for top domains.

Table 1. Sample student responses in respective competency domains

	Domain 1	Sample responses from students.	N
Pedagogical	Teaching Practice	"Interacting with students in different ways; Makes an effort to be on a one-to-one basis; Up to date notes and not notes that they prepared when they first became a teacher 20 years ago."	60
	Knowledge & Skills	"Provide context rather than only reading from slides; Good knowledge in their field; Able to explain things in more than one ways."	40
	Domain 2	Sample responses	N
Content	Communication	"Interpersonal skills; Ability to simplify concepts for non-engineers; Ability to work in a team."	30
	Engineering Fundamentals	"Strong fundamental knowledge; Great maths skills; Creative thinker."	22
	Domain 3	Sample responses	N
Content-Pedagogical	Role Model as Engineer	"Knowledge and experience in the field; Engages in professional development; They are what we students want to become; We want to be engineers and they are the only examples we have as engineers."	16
	Design as Fundamental Engineering Pedagogy	"Ability to apply theory to the practical environment; Technical knowledge of the course they are teaching; Ability to break down complex theories into simple/manageable understanding for the students."	7

N = Number of coded extracts from student responses categorised in each domain.

Question 20 of the survey asked: *What value do you place on the following activities to your professional development teaching and learning? Please mark one choice in*

each row. Table 2 shows the % responses and mean Likert-type score for the top three responses.

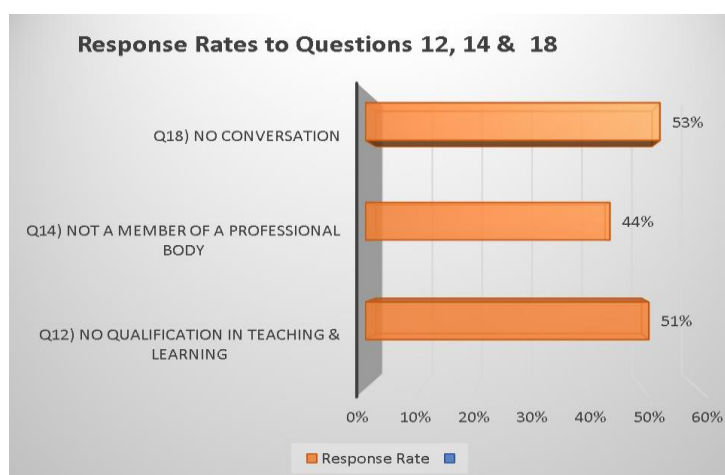
Table 2. Most valued professional development activities

Responses	No	Low	Mod.	High	Average
Engaging in informal dialogue with your colleagues on how to enhance your teaching	0%	10%	33%	57%	3.5
Engaging in self-study	1%	14%	36%	49%	3.3
Mentoring students	1%	13%	38%	48%	3.3

5.2 Results for Research Question Two

RQ2- How can these competencies be best addressed by professional development activities in teaching and learning?

Several questions in the survey were designed to explore how professional development activities are currently addressed. Specifically:



Q12- Do you hold any qualifications in teaching and learning? Please mark multiple choices.

Q14- Your professional body membership. Please mark multiple choices.

Q18- Have you engaged in a conversation with your Head of School/ Department about your professional development in teaching and learning?

Fig. 2. % Responses to Q12, Q14 and Q18

Question 21: Select your needs in professional development in teaching and learning.

Question 23: Select your current needs in professional development in teaching and learning specific to engineering.

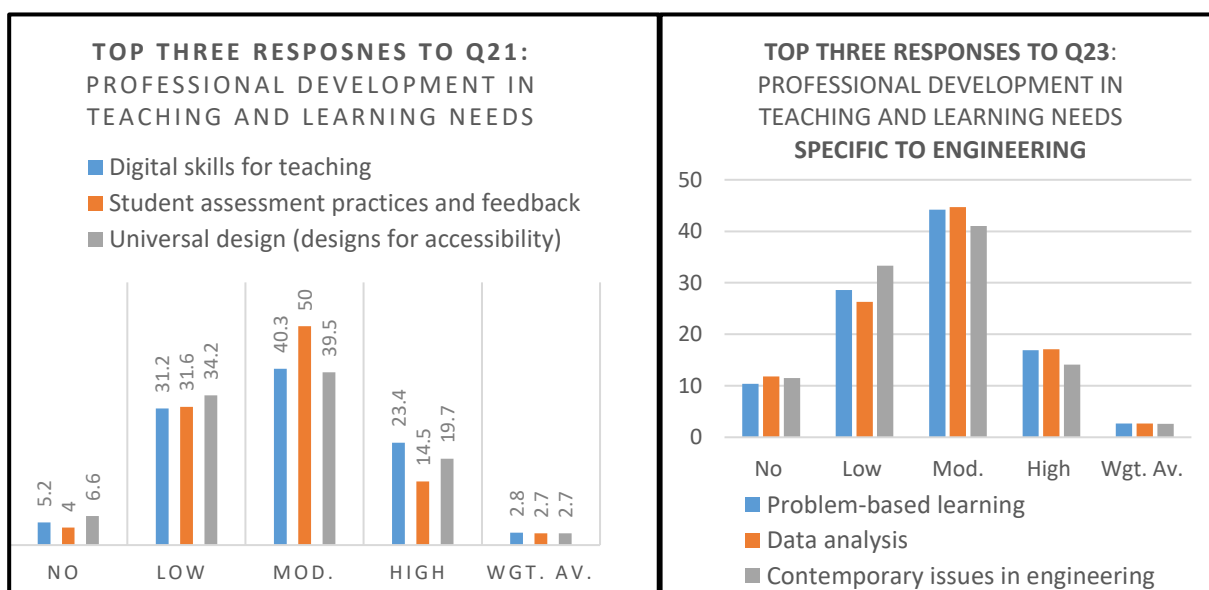


Fig. 3. Top three responses to Q21 and Q23 respectively (Y-Axis shows % response).

Interviews with academic managers revealed nine sub-themes regarding professional development in teaching and learning (Fig. 4):



Fig. 4. Sub-themes emerging from interviews with academic managers

6 DISCUSSION

Although there was accord with the competencies identified in the literature review, priorities at times differed, which may reflect institutional culture. The research findings offered several insights into which teaching and learning PD activities engineering educators value most. Student perspectives concurred, validating why these competencies are important. Academic managers highlighted current challenges to support the needs of staff and the conflict between teaching and research.

6.1 What the survey revealed?

The hybrid identity of engineering educators is clearly evidenced in the findings. Echoed by Morell and DeBoer [20], highest ranked responses to what makes a great engineering educator were [i] an effective teacher, closely followed by [ii] discipline competency. The wider role encompassing research, professional practice and community engagement was not considered as important. With the results revealing low levels of engineering professional body membership and an equivalent teaching body membership, an opportunity arises to bridge academic and disciplinary identities.

As teaching and learning is perceived as a central function, this identity vacuum demonstrates a need for funding, support and policy for PD in T&L. Low levels of discussion between educators and academic managers could be addressed through the adaptation of a competency framework as a catalyst for dialogue. An interesting challenge as the Technological University Alliance for Dublin moves forward is where will priorities lie within the teaching and learning versus research space?

Regarding the most valued PD activities in T&L, they were broad and diverse, highlighting the importance of individual values and needs as recognised by the NPDP domain of the self. The activities most valued were non-accredited: collaborative, (e.g. conversations with colleagues); unstructured (e.g. reading articles); and structured (e.g. attending workshops). Receiving an accredited, formal qualification was least valued, so the implications for those involved in developing and delivering PD activities is that short, unaccredited and collaborative workshops should be prioritised.

Regarding teaching and learning PD needs, digital skills for teaching ranked highest followed closely by student assessment and feedback practices. These go hand in hand, as the digital space can offer solutions to assist with more efficient ways to assess and give feedback. The biggest challenge of all though relates to the PD needs of engineering educators specific to their field due to the ever-evolving nature of the discipline. Competencies such as problem-based learning and data analysis were most needed, which Passow [18] also identified. This highlights the importance of seeking regular and systematic feedback from engineering educators regarding their PD needs.

6.2 Focus groups

Students had little difficulty identifying general teaching competency domains. Approachability and flexibility of their lecturers was highly valued as encountered in the literature [6], mirrored by engineering educators as they ranked mentoring students as the third most valued PD activity. As students are already very familiar with the role of an educator, the more allusive and less familiar domains of engineer and engineering educator proved somewhat challenging to define.

As the students grappled to describe what makes a great engineer, it could be argued that there is a need for programmes to include guest speakers who are experts in the engineering field. Embedding a work-based learning component or internship into programmes, may help students to identify clearly with the field of engineering and envisage the types of roles that they may work in.

In the domain of engineering educator, the students found it difficult to pinpoint competencies, but they highlighted the importance of authenticity, i.e. that educators are also experts in their own field, so they can relate real-world examples to classroom problems. This once again strengthens the argument that maintaining professional currency as an engineer is a vital component of teaching excellence. Digital capacity was identified as important by students, also recognised as the highest need by educators, as students discussed the need for engineering educators to be comfortable in the digital learning space, such as recording lectures for further reference and using screencasts to recap on key themes.

6.3 Academic Manager Interviews

A differing landscape exists across the three Institutes regarding PD in T&L in terms of mechanisms to support it, funding and policy. Some departments had designated budgets, whilst others used funds from departmental resources on an ad hoc basis, wary to ask educators about their PD needs. Teaching and learning is considered an intrinsic part of the character of institutes of technology, confirmed by academic managers, further echoed by engineering educators in the survey and by students in the focus groups. Given the failing public sector performance management development system (PMDS) as a model for supporting PD in higher education, academic managers highlighted the need for an alternative system of promoting, recording and recognising PD activities of their staff outside of the HR domain. The emerging technology university will need to not only identify clearly where the balance lies between teaching and learning and research in the future but articulate an alternative model for incentivising and recognising professional development.

7 LIMITATION OF THE STUDY

This research has focused on one small segment of the higher education sector in Ireland. As a qualitative study, it is less concerned with statistical generalisability as it is with the emic perspectives of its participants. The authors make no claims about the transferability of the findings. It is proposed to scale the survey nationally to further investigate the teaching and learning competencies most valued by engineering educators in the broad higher education landscape.

8 CONCLUSION

A wide range of teaching and learning competencies were valued and needed by the engineering educators who participated in this research. In particular, digital skills for teaching, assessment and feedback and universal design suggest as genuine desire amongst educators to maximise access to education. Students reinforced the

importance for their educators to be authentic role models as engineers and effective teachers, confirming the significance of the hybrid identity recognised by engineering educator themselves. Also valued by students were traits such as approachability and the ability to explain complex concepts using real-world examples. Engineering as a discipline, is subject to ongoing change and it is these changes that present the challenge in keeping abreast of PD in T&L. The evolving landscape of higher education and the increased demand for competency in digital capacity, as evidenced in this research, serves to highlight the challenge of balancing the professional development of the educator and the engineer. What is clear, however, is that collaboration is most valued, flexibility is required, and a culture of intrinsically motivated lifelong learning should be fostered as we continue to seek to professionalise in our roles.

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Interdisciplinary Learning in Engineering Practice

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Conference Key Areas: Engineering Skills, Continuing EE and Lifelong Learning, Philosophy and Purpose of Engineering Education

Keywords: Skills & Knowledge, Interdisciplinary Knowledge, Engineering Practice, Employability

INTRODUCTION

Over the past 100 years from the Mann Report (1918) [1] to current day IET (2017) [2] there has been criticism of the state of preparedness of newly graduated engineers for their initial engineering practice. Most attention has been paid to the perceived skills gaps but little attention towards the perceived knowledge gaps. These gaps exist because of the necessarily generic nature of university education and the specific requirements of individual job roles. Also the majority of engineering courses are in single disciplines while much of engineering practice is interdisciplinary. This study seeks to understand how students could be better prepared to overcome those knowledge gaps by examining how practicing engineers acquire their interdisciplinary knowledge. It looks at the epistemic practices they engage with, why they choose particular practices, the barriers they encounter, and what are the resulting knowledge outcomes.

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1 BACKGROUND

1.1 Knowledge Acquisition for Early Career Engineers

There is limited research on engineering knowledge; Vincenti (1990) [3] synthesised six categories of engineering design knowledge and Dowling & Hadgraft (2013) [4] developed methodology to identify discipline-based capabilities including the knowledge component. Nonaka (1994) [5] identified an additional challenge in knowledge research where knowledge changes from explicit to tacit and back to explicit, therefore data subjects find it hard to identify what knowledge they have and how they are using it.

Trevelyan (2009) [6] quantifies how early career engineers spend their time overcoming the capability gaps from their engineering education and suggests that a better model of engineering practice is required to help design more effective engineering education. The gap has been confirmed in other studies such as Ridgman and Liu (2014) [7] in China and Ridgman (2013) [8] for India. The importance of understanding how to acquire interdisciplinary knowledge is illustrated by Dixon (2015) [9] that shows that the coherence between degree title and area of practice of employment is between 15% and 60%.

1.2 Challenges for Engineering Education

The default engineering education paradigm is that students are taught useful engineering knowledge that they 'apply' in practice. This has to be defended against criticism from employers that University teaches out of date, single discipline material at a low technical level. Early career engineers find they have to work hard to cover the gap between what they have been taught and the knowledge needed to do their jobs. While these criticisms/arguments are longstanding as the employability agenda develops, and the view of the student as a consumer is developing, they will come under much greater scrutiny.

If the specific knowledge that any particular graduating engineer will need at the start of their career is not predictable then educators need to focus on helping students understand and improve their personal knowledge acquisition skills. The knowledge acquisition process consists of several components - realising what needs to be known, finding knowledge and deciding whether and how to use it. This research looks at the final stage of that process.

2 RESEARCH DESIGN AND METHODOLOGY

The research started with a single case that was analysed to produce a simple model. The model was then evaluated using a range of methods to compare its variables with a range of issues identified from the literature. This resulted in a refined model which was then tested on two further cases chosen using the criteria of 'most-likely' and 'least-likely' scenarios.

2.1 Initial Case Selection

To be able to clearly identify the "new" knowledge acquired and avoid the tacit/explicit issues it was decided to research practicing engineers carrying out interdisciplinary life science projects. The case selected was based on a team of engineers and a biochemist who worked on a project at a leading biotech company to increase the production of a therapeutic hormone. To achieve a successful outcome to the project the engineers needed to acquire life science knowledge of 'craft' processes and convert them to engineering knowledge and deliver a successful robotic solution. Two engineers and one biochemist were chosen as research subjects.

2.2 Analysis Methods

The research analysis was designed to adhere to the five principles of data analysis according to the critical realism philosophy outlined by Wynn and Williams (2012) [10]. These are: explication of events, explication of structure and content, retroduction of mechanisms, empirical corroboration and triangulation of methods. The reliance on a single exploratory case calls for a range of coding techniques and action coding, causation coding and pattern coding were carried out as suggested by Saldaña (2012) [11]. Since the research was carried out using a social material perspective this suggested the use of an actor network theory analytical framework, Callon (1986) [12]. The typology and the identification of inferences and their relationships were derived using the techniques outlined in the non-statistical analysis of a small number of instances, George and Bennett (2005) [13].

Procedure	Method	Outcome
Coding the interview data	Coding Techniques	Codes and conceptual categories
Framing and re-describing key aspects	Actor Network Theory Framework	Patterns of Causal Relationships
Characterising Causal Patterns	Typology	Types of causal relationships
Generating causal inferences	Comparative Method	Causal inferences
Evaluating causal inferences	Congruence Method	Established and unresolved causal relationships
Validating causal relationships	Casual Process Tracing Methodology	Tentative Theoretical framework
Refining and generalising theoretical framework	Cross Case analysis	Proposed Theoretical Framework

Table 1. Summary of Research Methods

3 RESULTS AND DISCUSSION

3.1 Simple Model

The first stages of the analysis used action codes and causation codes from the interview transcripts to develop conceptual categories for the actions engineers took to develop their knowledge (epistemic practices) and the outcomes of those actions (knowledge outcomes).

3.1.1 Epistemic Practices

Initially three epistemic practices were identified

CEP - Consultational Epistemic Practice: A set of related activities taken to gain further understanding about the life science knowledge they encountered. For example the life scientist have to explain why they need to heat a sample to a given temperature in a way that is understandable both in a life science and an engineering context.

TEP - Translational Epistemic Practice: A set of related activities taken on the content and forms of the life science knowledge in order to arrive at the knowledge contents and forms that can be used to develop solutions – For examples the life scientist may regularly stir something but to useful in the project the ‘stirring’ has to be converted into a set of engineering parameters such as vessel size, paddle speed, fluid shear forces, duration, etc.

EEP - Evidential Epistemic Practice: A set of related activities taken to gain and show confirmation of the usefulness of the different contents and forms of knowledge. For example in order to fit some parameters to a life science craft activity it may be necessary to carry out some experiments.

3.1.2 Knowledge Outcomes

Adoption – Able to understand, appreciate and reuse the relevant knowledge while retaining the content and meaning. This was the case when the life science knowledge fitted easily into the physical science knowledge of engineering and could be considered as any other engineering rule.

Translation – Able to develop and use knowledge whose terms and forms usefully differ from, but correspond to, those used in, or provided by, the other discipline. In this case the life science knowledge can be translated into an engineering equivalent where the engineering rules for the equivalent are satisfactory for the project context.

Avoidance – Able to avoid pursuing the learning and using the knowledge contents and forms that do not contribute to the successful development of the solution. In this outcome the life science knowledge is not immediately relevant to the project and therefore doesn't need to be considered further.

Addition – Able to add knowledge that is new to the collaborators from other disciplines and evidently useful for improving their practices. In this case through discussion with the engineers the life scientist develop a new understanding of how their process works.

3.1.3 Preliminary Model from Case Study 1

Having identified practices and outcomes the next stage of the model development is to understand how they are linked together. From the transcripts it is possible to identify action codes where a practice is linked to a satisfactory knowledge outcome and 'predicament' codes where the outcome of a practice is not satisfactory and therefore a different practice is considered. This resulted in the initial model shown in Fig 1.

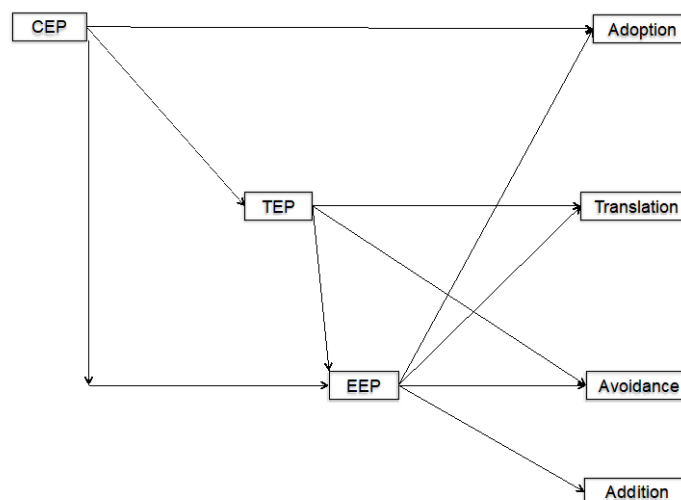


Fig. 1. Initial model

3.2 Developing the Model

The model above is very simple but does not help in understanding why engineers were able to undertake those practices and be successful in overcoming the predicaments rather than abandoning their learning prematurely.

3.2.1 *Modes of Epistemic Engagement*

Actor Network Theory (ANT) was used to identify three modes of epistemic engagement and three barriers to accepting knowledge.

Perspectival Mode – This occurs in the ‘problematization’ moment in ANT theory where different actors are attempting to render themselves indispensable to others by framing the nature of the problem according to what they know. By looking at the life scientist perspective they were able to recognise social-material elements on which they could consult and interact further. They could adopt the knowledge, if it was useful, or attempt to translate it into engineering terms.

Justificational Mode – In ANT’s ‘moment of enrolment’ the actors try to overcome their disagreements by justifying their positions. This justification mode is where the engineers seek justification for seemingly ambiguous knowledge.

Complemental Mode – This also occurs in the ‘moment of enrolment’ and is where engineers think about improvements that could be made to their understanding by developing new knowledge.

3.2.2 *Evaluating Causal Inferences*

In the evaluation of casual inferences congruence analysis is used to determine if there might be other variables suggest by literature that could be influencing the outcomes. Three of these were identified as being an important addition to the model.

Communication Barrier – During the consultation phase a lack of understanding of the life science perspective was a causal factor in the engineers’ decision to attempt to make a translation into an engineering paradigm.

Contradictory Barrier – Professional practices exhibit ‘discordant practices’ where espoused values and enacted practices differ. When faced with a perception that what the life scientist said, and what they did, differed the engineers would seek additional evidence to resolve the contradiction.

Contributory Barrier – Although the engineers may have developed an understanding in engineering terms of a project it could be difficult to persuade the life scientists of this without producing ‘hard’ evidence. This became a driver of engagement in EEP.

3.3 Refinements from Supporting Case Studies

3.3.1 *Nature of Case Studies*

The second case study interviewed 3 engineers from different engineering disciplines who had been involved in a project to develop an automated micro-scale bioreactor. This required knowledge development from the whole team because the engineers were unfamiliar with the biological processes and the life scientists had never used, or seen, any representation of ‘scale down’ from lab equipment to micro-bioreactors.

The third case study interviewed two engineers who were developing a device to test lung function. The engineers needed to gain medical knowledge of lung function and diagnosis but also the safety and usability requirements for hospital equipment.

3.3.2 Additional Variables from the Cross Case Analysis

CPEP - Comparative Epistemic Practice. Comparing knowledge suggested or practiced by others against a set of criteria that are underpinned by the engineers' prior knowledge. For example the design engineer compared the requirements for micro-bioreactor with the existing knowledge of conventional scale bioreactors.

Implication Barrier – This occurred when the life scientists were unclear of the implications of the engineering solution. For example the life scientists did not know how cells might behave when subjected to the micro-reaction process. To understand this some form of experimentation was required. This led to an additional engagement mode, the implication mode, to determine whether the knowledge encountered has implications for the solution under development.

A further refinement to the model was to better understand that the linkage between the consultational epistemic practice and knowledge adoption was based on analogous perception. Faced with the new knowledge if the engineers thought there was a good analogy to their existing understanding and if they did not perceive any discordant practice or ambiguity they were satisfied that they could adopt the knowledge.

3.4 Final Model

These findings have been brought together in a generalised theoretical framework (Fig 2). The framework has been developed in the context of a team of interdisciplinary engineers working with life scientists to produce an engineered product. The engineers respond to knowledge suggestions from their life science collaborators based on their perception of whether they have sufficient knowledge to engage with the suggestion. Then they either feel confident in engaging in consultation or seek an engineering analogy as a start point in developing their understanding.

They can then accept the lifescience knowledge and add it to their own knowledge base, translate it from a life science perspective into an engineering perspective or carry out some experimentation to validate the knowledge. This leads to a range of outcomes of adopting the knowledge as expressed by life scientists, translated engineering knowledge, avoiding the knowledge because it is not perceived as useful for the project. The final outcome is creating new knowledge by combining engineering and life science knowledge.

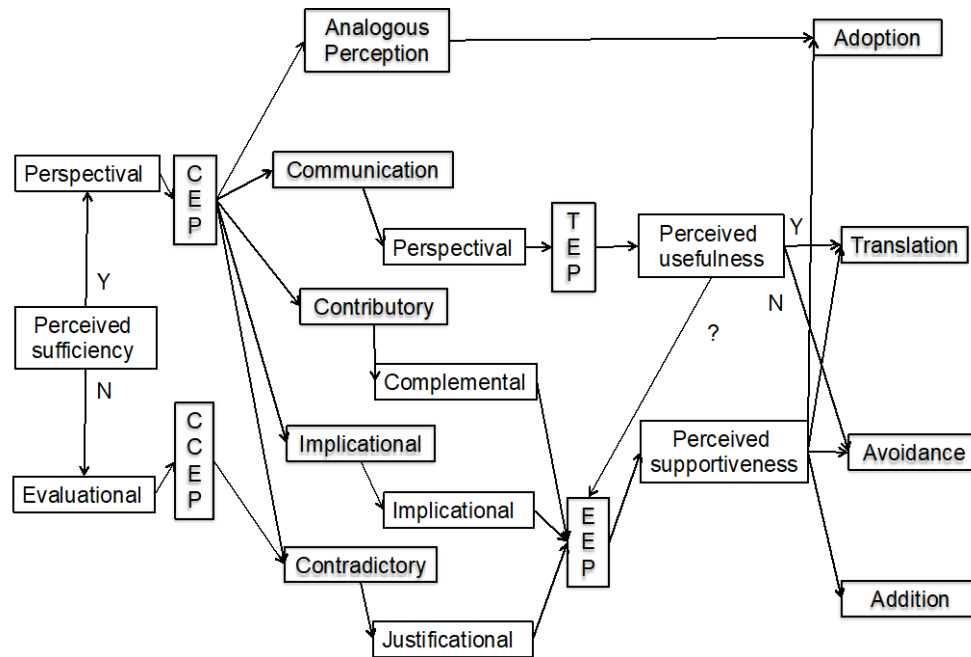


Fig. 2. Generalised Theoretical Framework

4 INSIGHTS FOR ENGINEERING EDUCATION

As discussed earlier the gap between engineering as taught at Universities and as practiced in industry has been extensively researched over many years. Changes, such as project based learning, to narrow the gap being limited and very slow to permeate through the sector.

Some of the pressures on the sector, driven by student consumerism, 'teach to the test', collective disengagement etc., are likely to widen the gap by producing highly credentialed students with limited ability to practice and limited intellectual development. Using Perry's 9 stage framework of intellectual development Felder and Brent (2004) [14] discovered that engineering students were generally between 2.5 and 3.5 with less than a third making it to level 5. As this level of intellectual development students are only equipped to deal with well-defined problems and complete data as opposed to the uncertainty and ambiguity that characterises day-to-day engineering problem solving.

This initial work is very exploratory but has provided a framework to help students deal with the challenges of understanding the learning process they will need to adopt early in their career.

4.1 Development of Professional Identity

More work has to be done to help students develop their identity as engineers to smooth their transition from new graduate to early career engineers. While plugging the gap in practice will take a long time with the slow rate of change in engineering education at least being able to explain the issue will help remove discontent. A framework is needed to explain how learning takes place in practice and how to manage the transition from discipline based study to inter-disciplinary project work. Interdisciplinary work has to be founded on solid disciplinary competence but most projects and products are realised by interdisciplinary

teams. Much of the work on helping students think about these transitions has focussed on developing team and other interpersonal skills there is little support for them to either understand that they will have to increase their level of intellectual development and learn how to manage their own knowledge acquisition.

4.2 Developing Pedagogic Strategies

The first step in developing strategies to improve personal knowledge acquisition is to introduce students to interdisciplinary projects and ambiguous information. However while many courses have adopted projects in some form the assessment of knowledge gained by the students or, even better, the students' ability to self assess the knowledge acquired is very limited. Students tend to focus on the project outcome, with some limited reflection of the team/transferable skills development.

The first stages would be to combine knowledge acquisition development with existing teaching of critical thinking and project reflection journals enabling the students to identify what knowledge they identified for the project, the barriers they faced in understanding it, how they tested its applicability and its relevance. Once some expertise had been developed in this mode of teaching it could be introduced earlier in the curriculum particularly in a flipped classroom methodology since both flipped class and engineering projects are both aimed at developing self directed learning.

5 CONCLUSIONS

To advance the knowledge of our students, to help them develop their professional identities as engineers and to reduce the stress of their early career learning we need to help them understand how to use ambiguous knowledge in complex problem solving. This involves developing a personal knowledge acquisition competence that includes how to find knowledge, evaluate it for its usefulness to the problem in hand, recognise, and overcome the barriers to use and test when necessary. In a world where knowledge is available at a press of a key the competitive advantage lies in understand when, where and whether to use it. The exploratory research has developed a preliminary framework to help understand the knowledge acquisition process.

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The role of institutional power in tutorless problem-based learning. Students' interactional strategies for self-managing conflict in teamwork.

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Conference Key Areas: engineering skills; innovative teaching and learning methods; how learning spaces support innovative teaching and learning

Keywords: problem-based learning; teamwork; conflict; conversation analysis

INTRODUCTION

The capacity to work effectively in teams is fundamental within all fields of engineering employment. In 21st century engineering, technical subject knowledge is of limited value on its own and must be accompanied with these interpersonal skills as part of the full graduate package. Teamwork is particularly important where innovation and entrepreneurial knowledge are highly valued, and therefore, one of the primary duties of current university institutions is to fulfil these prime industry demands [1].

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Entrepreneurial competencies entail having knowledge of how teams work, as well as how they are managed, in order to be successful; whether in virtual or face-to-face environments [1]. Consequently, it is essential that students learn to work in alignment with their peers if they are to deal with the complex and unpredictable problems presented by the engineering world.

Problem-based learning (PBL) is a collaborative pedagogy said to enable the development of 'soft' communicative skills such as teamwork [2]. PBL provides the means to learn relevant disciplinary knowledge through the use of ill-defined and real-world problems, while supporting the development of problem-solving skills in different contexts; in turn, bringing about innovation [2]. Although, *how* PBL actually enables the development of these skills is not fully understood, as little research has examined PBL interactions at close range [3]. This is problematic, as it is critical that we gain insight into the true dynamics of student-centred learning if we are to determine pedagogical best practice. Interpersonal complications resulting from negative behaviours within teamwork, for instance, can undermine the success of PBL, so we must understand how students self-manage social problems (if at all).

Given its theoretical principles which hold that students must work collaboratively if they are to sufficiently develop solutions to the problem tasks at hand, it is important to examine the working patterns involved in PBL [3]. The present work specifically investigates how students deal with difficult – and often inevitable – situations arising in PBL tutorials. For instance, social loafing – one of the major complaints associated with PBL – can be extremely detrimental to team productivity if it is not managed effectively by group members [4]. Similarly, repeated disagreements can detract from the purpose of the PBL sessions themselves [5]. These negative teamwork behaviours are especially prominent issues here, given the focus on floating facilitator/tutorless PBL, where the self-regulatory skills of the students are more explicitly called upon [5]. Floating facilitator PBL is commonly used to overcome resource restrictions in educational institutions involving larger cohort sizes, and limited numbers of tutors. That is, where it is not feasible to have one 'dedicated' tutor per group, students are expected to function predominantly within a tutorless PBL tutorial environment.

In light of these aforementioned issues therefore, by exploring the PBL experience, the aims of this paper are to develop empirical research which illuminates how students self-manage group responsibilities and arising conflicts *without* the tutor being on hand to guide each stage of the process on their behalf. Detailed analyses be presented and their implications for teaching practice discussed, with the aim to establish mechanisms by which students can be supported better in future teamwork situations.

1 METHOD

1.1 Participants and data collection

33 students – comprising six groups – within a third year Chemical Process Design module at a UK university were video-recorded (60 hours footage overall) during PBL tutorials (three meetings per week for 10 weeks in total). Following informed consent, students were filmed in private university rooms, where non-intrusive cameras and microphones were situated around the workspace. As this was their first experience of PBL, students received a one-day training workshop in conflict resolution/group processes, prior to the commencement of tutorials.

1.2 Problem-based learning (PBL) approach

As part of the floating facilitator PBL model, tutor participation was significantly reduced. Instead, educational accountability was placed upon the students themselves, forcing them to adapt to different learning styles amongst the group, and to manage arising social conflicts; as they would in real-life [6]. For example, at the start of each PBL session, students had brief contact with a 'floating' tutor who provided them with instructional materials and answered any prominent queries. The tutor would then leave the room, only revisiting the group around the mid-point of the session to ensure students were on-track with their collective goals for the specific PBL case.

The groups received two new problem cases each week. Students were presented with authentic industry problems (e.g. a client brief requesting their expertise in the conceptual design of a power plant, alongside efficient environmental management). Although contextually unfamiliar, these problems were laced with subtle prompts to students' previous learning, and were open-ended to encourage creative thinking, as in conventional PBL [6]. As part of monitoring group progress – a primary concern, given the tutorless environment – students submitted reflective reports to the class leader on a weekly basis.

1.3 Analytical procedure

Through Conversation Analysis (CA) and the accompanying Jefferson transcription system (1.4), we were able to examine the naturalistic student talk at a fine-grained level [7]. In this way, the interactions could be considered from the necessary institutional lens (i.e. functioning within the educational environment) where student discussions were meticulously organised in line with implicit group norms (i.e. within the PBL community) [7]. In the present case of student-led PBL, we sought to elucidate how students managed their newfound learner autonomy, and how this impacted the mechanics of dealing with arising conflicts. The following extracts, therefore, were included in this paper as striking representations of the data corpus as a whole, in that students negotiated social challenges through intricate discursive strategies.

1.4 Jefferson transcription system [8]

(0.2) – Pauses in tenths of a second

CAPITALS – Louder than the surrounding speech

Underline – Indicates emphasis on speech

↑ – Indicates a marked rising in speech intonation

£ – Talk produced in a laughing voice

: – Extension of the preceding (vowel) sound

[– Square brackets indicate overlapping speech

2 RESULTS

One of the core expectancies of PBL is that its learners will arrive at tasks with diverse knowledge stances. Some level of disagreement, therefore, is necessary if the cognitive rewards of PBL are to be reaped, and if learners are to be socialised towards the realities of professional engineering communities. However, managing disagreements efficiently is complex, as students must finely balance their needs to pursue educational responsibilities (e.g. challenging and proposing alternative theories) *alongside* the interpersonal norms of the institutional environment (i.e. without damaging their position as a fellow 'team-player') [9]. If we consider extract 1,

we gain insight into the standard – and considerably longwinded – flow of disagreements throughout the student-led PBL meetings:

Extract 1. "IT says redo the calculations"

- 1 John: the problem is the lack of pump calculations (.) we don't know
2 which calculations to use-we don't know what's
3 a:ctually happening
4 Eva: unless [the-yea:h
5 Conor: [YEAH
6 Eva: are we going off of this ((points at worksheet)) or are we
7 updating what's already filled in?
8 John: no: we don't update ((points at Luke)) [right? are we?
9 Eva: [okay sorry
10 John: because it says sum up the equations of the calculations
11 for the data sheet which is THIS ((points at worksheet))
12 Eva: okay so we don't-we just have to look at they ones?
13 John: maybe-that's what (inaudible) (.)
14 Conor: IT says redo the calculations blah de blah de blah
15 John: maybe we only have to-
16 Conor: but then ((points at worksheet)) all I'm saying is it says-
17 I don't know if I: (.) if I've read it-differently but I got
18 the impression that these are like the correct answers-
19 Luke: sh-she: said that once we do the calculations they'll put them
20 up so I thought we were just doing the bottom sheet
21 Conor: should we read-I think it would probably be a good idea if like
22 one of us was to just read the whole thing so that we can-
23 Eva: okay ((begins to read PBL case instructions aloud))

In the opening lines, John first establishes the problem at hand (“lack of pump calculations”, 1), making an explicit display of the whole team’s shared uncertainty (“we don’t know”; “we don’t-we don’t know”, 1-2). In line 4, however, Eva begins to suggest the group may have more knowledge than John has proposed (“unless”), but in light of Conor’s loudened overlap which confirms John’s stance (“YEAH”, 5), she withholds her turn, formulating only a minimal agreement (“yea:h”). Instead, by invoking the PBL worksheet in her clarification-seeking proffers (“are we going off of this”, 6), Eva raises the possibility that the group may pinpoint valuable information through this reputable shared object; a strategy for reclaiming conversational footing [10]. Here, Eva caters to the social demands of the educational environment, rather than being the first – and only – member to disagree with the certainty of John’s claims.

In line 8, John's responding turn ("no:") is accompanied by a pointing gesture towards group member Luke, coupled with two further hearer-specific appeals as means of strengthening his position ("right? are we?"). Whilst he receives no uptake from Luke, it is intriguing that Eva makes an immediate backdown ("okay sorry", 9), as though she is cautious of being perceived as too probing of John's stance, or perhaps orienting to the dangers of challenging such a dominant group member. Following Eva's apology, John works to justify his rationale in more depth ("because it says", 10), and as Eva did in line 6, makes direct reference to the tutor-provided PBL worksheet (11) to bolster his claims. Conor's interjection in line 14 follows a similar pattern ("IT says redo"). In this way, whilst they have not yet reached alignment in their thinking, they still function as a collective team, as opposed to engaging in more explicit confrontations regarding the group agenda.

Whilst the group members have been diplomatic with one another throughout, their continual preference for hedging around conflicting viewpoints has resulted not only in significantly lengthy discourse (e.g. recurrent overlaps and interjections) but has also undermined the development of a solid plan of action in carrying out the PBL case; a frequently arising issue throughout the corpus. Line 19, therefore, marks a pivotal point in their interactions. By invoking the tutor ("sh-she: said that"), Luke's utterances are particularly powerful, as it is difficult to overrule institutional authority, which demands that they should be "doing the bottom sheet" (20). Luke calls upon an expert knowledge source, and consequently, the group compromise on jointly revisiting the PBL worksheet instructions ("read the whole thing so that we can", 22). Throughout our examination of the data, students' reference to institutional power acted as a common interactional strategy for diffusing group disagreements. This is *not* to say that an immediate agreement was reached, but it allowed students to move on from dwelling on task setup for too long (a significant risk in student-led PBL), and to get back on-track with their educational business.

As we visit the second PBL group under exploration, the students are in the later phases of the semester and have experienced group member Callum's negative behaviours towards their teamwork for several weeks now. The main complaints made against Callum are his continual lack of contribution to the PBL cases, as well as his inability to engage in regular contact with his team members via the online discussion forum. During this time, the group have not directly approached the problem with Callum, opting instead for 'gossip talk' in his absence, coupled with – unsuccessful – face-to-face prompts to encourage his participation. In this current extract, however, the group dynamics appear to be considerably more strained than in previous meetings. These tensions seem to arise as a result of Callum's own discussions of what constitutes unfair group behaviours when referring to his work with another group in the laboratory class:

Extract 2. “They’re just being really difficult”

- 1 Callum: they're just being difficult ... they WANT to meet literally
2 every second day and they're just being really difficult (.)
3 this week they should be fine though-it's just the tray dryer
4 one we did
5 Craig: ↑AW tray dryer's (solid)-what do you love about it? the
6 results are like ridiculous
7 Callum: =no they're not (.)
8 Craig: what ↑tray ↑dryer?
9 Callum: ↑what? tray dryer's great-tray dryer's the best experiment
10 going (.)
11 Craig: NO: we're DEFINITELY doing different experiments-the results
12 took me ages
13 Callum: YEA:H YEA:H it's not that difficult though
14 Craig: WELL YEA:H but it TAKES you like: [four hours
15 Callum: [just pull up Excel
16 Craig: AW I'VE DONE ↑THATf
17 Callum: AW really?
18 Craig: want to see my Excel sheet? it's MASSIVEf
19 ((Annie raises her hand to Callum))
20 Annie: what would you (even) do with it?
21 Molly: I'm a good chemistry girlf (.) I don't know this

If we look at Callum's opening utterances, we see how he positions the expectancies of his lab group (within another degree module) as being overly demanding ("being difficult"; "meet literally every second day"; "just being really difficult", 1-2). This was a commonly employed strategy throughout the data corpus, where negative evaluations of out-group members were displayed as means of fostering in-group cohesion. In making this assessment, Callum also references an experiment previously undertaken by the current PBL group ("tray dryer", 3) in an attempt to secure their agreement ("we did", 4), as though his peers share insight into the simplicity of this task, and thus, they too *must* understand how unreasonable his lab group are being.

Instead of appeasing Callum's requests for alignment, Craig's responding turn (5) marks a clear point of disagreement (the loudened "↑AW" token, which is raised in pitch) where he challenges ("solid" is British slang for difficult) Callum's claim that the tray dryer experiment is an easy one ("should be fine", 3). In doing so, Craig indirectly raises the notion that the frequent meetings proposed by Callum's lab group are in fact reasonable, given the complexity of the experiment. These points of disagreement are recurrent throughout the ensuing lines (7-18), and in turn, Callum's misalignment with the group consensus becomes more apparent.

This extract is an intriguing portion of data, as typically, each of the studied groups worked consistently to maintain their sameness with one another as part of being a unified team (e.g. extract 1). However, in line 15, following Callum's continued proffers in support of his stance ("just pull up Excel"), Craig emphasises his own direct experiences of the experiment ("I'VE DONE ↑THAT£", 16) as an assurance that he will not be swayed by Callum's appeals. This establishes a competitive culture ("want to see my Excel sheet? "it's MASSIVE£", 18), and Annie's eventual involvement in the conversation adds power in numbers; jokingly raising her hand to Callum (19) as though he has been overpowered by Craig, and then questioning the relevance of the spreadsheet ("what would you (even) do with it?", 20).

In summary, if we reconsider the opening lines of the extract, we see how Callum's utterances prove to be dangerous conversational moves. By criticising his "difficult" lab group, Callum invokes the implicit social boundaries in place within the current team (i.e. he is no position to make such claims when he is already under scrutiny for similar offences here). That is, given his poor track record in committing to the duties of the PBL group during the course of the semester, Callum makes himself vulnerable to criticism amongst his peers. However, it is important to note that, despite their 'othering' of Callum through their institutional superiority, the group members opt for laughing voices in their resistance, where – like the diplomatic approach of extract 1 – they recognise the necessity of face politeness.

3 CONCLUSIONS

By examining the above extracts in detail, we hope to have shed light on the complexities of student group interactions, as well as the need for continued qualitative analyses in determining pedagogical best practice for engineering. Although the tutor figure was absent for the vast majority of the PBL sessions, each of the groups within the data corpus demonstrated considerable adaptability to the unfamiliarity of the floating facilitator PBL model, drawing upon a wide range of discursive strategies in doing so. The students co-constructed the norms of the PBL community, where they adhered to the notion of team solidarity, and the need for continued discursive

politeness; regardless of arising social difficulties or negative team members. This was achieved through reference to institutional power (e.g. invoking the tutor/PBL worksheets), displays of humour, and longwinded discourse as means of mitigating more serious conflicts [10]. In this way, knowledge disagreements (e.g. extract 1) and unsatisfactory levels of member participation (e.g. extract 2) were addressed by the groups, but in such a way that they remained neutral in matters so that they could continue in their educational business.

Given the emphasis on teamwork within the engineering discipline, this study provides students with the necessary platform to engage in the realities of professional team scenarios, and in moving towards being accountable for their learning. However, in terms of the university where the current project is based – as well as many other UK institutions – PBL tends to be implemented towards the end phases of the engineering degree, and as a result, this pedagogical transition can be difficult for students to adjust to. In light of this, the future aims of this study are to continue thorough analyses of these rich student interactions, where real-life data will then be used as authentic scenarios within PBL workshops in exemplifying what works – and what does not – in managing difficult group situations.

4 ACKNOWLEDGEMENTS

This project is funded by The Engineering and Physical Sciences Research Council Award (EPSRC Reference 1827113). The authors are extremely grateful to the student volunteers in making this work possible.

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Optimizing interfaces and inner faculty discussions: Toward a transparent design of engineering curricula

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Conference Key Areas: Curriculum Development, Sustainable Development Goals in Engineering Education, Educational and Organizational Development

Keywords: Modularisation, Transparency of Interfaces, Analysis of Module Interfaces

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INTRODUCTION

The modularisation of study programmes and the increase of potential contents of those leads to a growing number of selection choices and an increasing flexibility in the individual curriculum design. Furthermore, the Lisbon Recognition Convention eases the mobility of students during their studies. This allows the students to develop a more specific profile of competences. Therefore, an appropriate description of the learning outcomes of the individual modules and an increase in the transparency of the interfaces revealing the interconnection between the different modules is crucial for ensuring consistent personal curricula and the continuous acquisition of competencies.

Currently, learning outcomes are usually described in continuous texts using Bloom's taxonomy [1] or its revised version by Anderson and Krathwohl [2]. Although these taxonomies and the depicted way for describing learning outcomes is commonly accepted, there are problems regarding a clear description of the acquired competences in engineering sciences. Furthermore, the current approach impedes the evaluation of module interfaces in a database.

In order to overcome these issues, we developed a revised taxonomy and elaborated a strategy which introduces a tabular description of learning outcomes [3]. Moreover, we created a tool for the analysis of module interfaces, where module interfaces are gathered, visualised, and analysed in an interactive web-based content management system [4].

Chapter 1 summarizes theoretical considerations including the introduction of the revised taxonomy and an appropriate concept for describing learning outcomes. Furthermore, it presents a theoretical approach for the evaluation of module interfaces and explains the procedure for the detection of conflicts at module interfaces. Chapter 2 deals with the practical realization of an interactive web-based content management system for the analysis of module interfaces for an engineering study programme. It presents the user interfaces for students and teachers. Chapter 3 summarizes the resulting opportunities and chances and gives an outlook on further extensions. A final recap is given in Chapter 4.

1 THEORETICAL CONSIDERATIONS

This section introduces a revised taxonomy for engineering sciences as well as a new approach for the description of learning outcomes. It discusses how module interfaces can be evaluated, when learning outcomes are formulated by means of the suggested taxonomy.

1.1 Revised taxonomy for engineering sciences

Although the taxonomies of Bloom and Anderson and Krathwohl are commonly accepted, the order of the qualification levels and the coarseness of the classification lead to problems regarding a clear description of the acquired competences in engineering sciences. Thus, we extended Anderson's and Krathwohl's revision of Bloom's taxonomy for the explicit application to engineering studies [3].

We made use of the learning model of Hoffmann [5] as well as concepts of 4ING [6], the EQF [7], and the DQR [8]. Accordingly, we decided to express the level of qualification via a breakdown into quantified levels of **knowledge** (know what), **skills** (know how), and **competences** (know why). *Table 1* shows the resulting taxonomy.

Table 1: Revised taxonomy for engineering sciences

	0	1	2	3	4
Knowledge (Know what)	no memory	lookup-knowledge	learnt by heart	learnt and understood	analysis and evaluation
Skills (Know how)	no skills	passive scheme	active scheme	experienced processing	
Competences (Know why)	Level of compliance with the following wording: The students can put the respective topic comprising assigned knowledge and skills in a superordinate context. Combining different topics, they are available for discussions and can structure complex novel tasks using their stock of knowledge and skills, can identify contained gaps and plan their proceeding.				
	no compliance	low compliance	moderate compliance	high compliance	highest compliance

Corresponding to the definitions of 4ING, **knowledge** is “learnt, retrievable information on facts, the context, to which facts are associated, and the rules interrelating facts to contexts” [9]. **Skills** depicts “an ability that has been acquired by training, and that makes use of the implicit memory, to apply knowledge to standard situations, and to use know-how to complete standard tasks, and to solve standard problems” [9]. Finally, **competences** are “the proven ability to autonomously recognize interrelations between facts and the contexts to which they are linked, to apply this ability to systematically develop new methods, and, if indicated, to apply them to changed situations” [9].

1.2 New approach for describing learning outcomes

Besides the new taxonomy, we introduced a tabular description of learning outcomes replacing continuous texts. In order to set an appropriate level of aggregation, we formulate learning outcomes by rating module contents using the qualification levels provided by the new taxonomy.

Table 2: Exemplary classification of learning outcomes

Learning contents	Achieved learning outcomes		
	Knowledge	Skills	Competences
Equilibrium of forces	4	3	4
Multiaxial stress states	3	2	2

Table 2 exemplarily contains two learning outcomes, which are formulated using the presented approach. Apart from an appropriate and clear description of learning outcomes, which is suitable for engineering sciences, this approach enables the evaluation of module interfaces in a database.

1.3 Definition and analysis of module interfaces

Using the suggested concept, learning outcomes can be catalogued systematically. As a result, module interfaces can be defined and evaluated. Figure 1 depicts the structure of the interfaces of a certain module topic and the related learning outcome A. Besides an interface to one or more base topics and the related learning outcomes B, the module topic has interfaces to one or more subsequent topics and the related learning outcomes C.

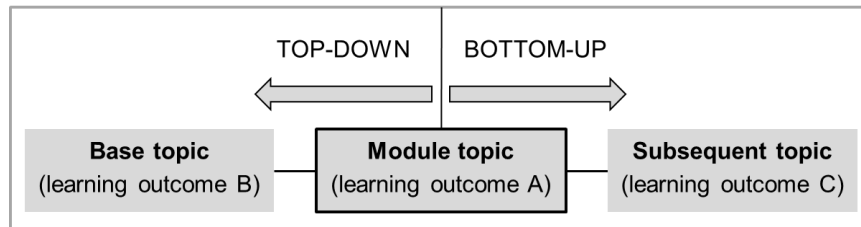


Fig. 1: Structure of a module interface

In order to generate interfaces between different module topics, it is necessary to define the required input and achieved output (learning outcome) related to each topic. As the description of learning outcomes represents the acquired output, teachers further need to define the required input of each module. Therefore, they need to check on which base topics they can build on and to define the required level of qualification in the selected base topics. Connections between module topics and subsequent topics are generated when module topics are defined as an input for the subsequent topics.

As a result, module interfaces can be evaluated and level conflicts can be detected. The evaluation can either take place Top-Down or Bottom-Up. Doing a Top-Down analysis of module interfaces, teachers examine, whether the chosen base topics deliver learning outcomes on the level required for their respective module topics. In a Bottom-Up analysis, however, they check, whether the achieved levels of qualification in their own module topic matches the level required for a subsequent topic. In order to detect time conflicts, teachers further need to define the sequence of the modules in the curriculum and the order of the different topics within a module.

2 PRACTICAL REALIZATION

This section describes the technical implementation of the web-based content management system developed for the analysis of module interfaces for an engineering study programmes. It shows the structure and content of the user interfaces for students and teachers.

2.1 Technical implementation

In order to display and evaluate module interfaces and consequently the structure of a study programme, an efficient technical implementation is required. As no satisfying solution was available, we developed a web-based content management system and have filled it with data from two bachelor programmes in engineering sciences. All

necessary information concerning module contents and interfaces is gathered in a MySQL-database. Metadata on courses, like contact information of teachers, can automatically be imported from the campus management system of the university. Using a PHP-based web-interface, teachers can manage their data and define interfaces efficiently. Furthermore, we designed a user interface for students which visualizes the interconnection between the different modules.

2.2 User interface for students

As schematically shown in *Table 3*, the student-interface gives information on the learning outcomes of the single modules and on the required input. Furthermore, modules which require the acquired learning outcomes as input are named.

Table 3: Extract from student-interface

Module: <i>Technical Mechanics I</i>														
Base topics		Module topics		Subsequent topics										
<i>Advanced Mathematics I</i> - Matrix calculus, determinants <table border="1"><tr><td>Knowledge</td><td>3</td></tr><tr><td>Skills</td><td>2</td></tr></table>		Knowledge	3	Skills	2	Equilibrium of forces <table border="1"><tr><td>Knowledge</td><td>4</td></tr><tr><td>Skills</td><td>3</td></tr><tr><td>Competences</td><td>4</td></tr></table>		Knowledge	4	Skills	3	Competences	4	<i>Hydromechanics</i> - Hydrostatics
Knowledge	3													
Skills	2													
Knowledge	4													
Skills	3													
Competences	4													
<i>Technical Mechanics I</i> - Forces and moments <table border="1"><tr><td>Knowledge</td><td>3</td></tr><tr><td>Skills</td><td>2</td></tr></table>		Knowledge	3	Skills	2	<i>Soil Mechanics and Foundation Engineering Basic Module</i> - Slope stability								
Knowledge	3													
Skills	2													
		<i>Technical Mechanics II</i> - Bending of beams - Shear stresses due to bending - Stability of elastic systems												

Table 3 visualises some interfaces of the module *Technical Mechanics I*, which is one of the principal core modules of Civil Engineering. Several consecutive modules rely on the related learning outcomes. One of the contained topics is *equilibrium of forces*; the related levels of qualification are listed. The two base topics are *matrix calculus, determinants* handled in the module *Advanced Mathematics I* and *forces and moments* dealt with in *Technical Mechanics I*. The required levels of qualification in the base topics, which are needed for *equilibrium of forces*, are named. The topic itself is related to a number of subsequent topics building on the archived learning outcomes, being for example the topic *Hydrostatics* handled in the module *Hydromechanics*.

2.3 User interface for teachers

Using the teacher interface, teachers can define the learning outcomes and required input of their modules and consequently generate interfaces between different modules. Furthermore, a tool for the evaluation of conflicts at module interfaces is available. This tool allows teachers to easily assess possible conflicts for their module topics. *Table 4* exemplarily shows conflicts related to the topic *multiaxial stress states*. Listing the acquired knowledge and skills of the base topic as well as the knowledge

and skills required by the subsequent topic, the tool provides both, a Top-Down analysis (first and second conflict) and Bottom-Up analysis (third conflict). Besides level conflicts, which are marked red, the tool can give indications on time conflicts, which are marked yellow.

Table 4: Extract from tool for the evaluation of conflicts at module interfaces

Base topic	Subsequent topic	Knowledge		Skills	
		taught	required	taught	required
Top-Down					
Equilibrium of forces (Technical Mechanics I)	Multiaxial stress states	4	3	3	3
Vector calculus and analytic geometry (Advanced Mathematics I)	Multiaxial stress states	4	3	3	1
Bottom -Up					
Multiaxial stress states	Procedure elastic-elastic (Metal Structures Basic Module)	3	3	2	3

3 BENEFITS AND FUTURE EXTENSIONS

Based on the findings depicted above, various benefits and chances arise, which are summarized in this section. Furthermore, an outlook on possible extensions is given.

3.1 Benefits of the revised taxonomy

The revised taxonomy in conjunction with a tabular representation facilitates the process for the description of learning outcomes. Compared to the current approach, qualification levels no longer have to be translated into appropriate verbal formulations and the level of aggregation of learning outcomes matches the one of the module contents. As the proposed taxonomy holds a finer scaling, the assignment of qualification levels is facilitated.

Besides enabling the evaluation of module interfaces, the proposed concept for describing learning outcomes facilitates important processes like competence oriented examination and the recognition of credits. Adapting questions to the aspired qualification level is facilitated when using the new approach for the description of learning outcomes. Having drafted an exam task, it is easy to check, whether the levels of knowledge, skills, and competences required for solving the problem match the aspired levels. Additionally, the new approach simplifies the recognition of credits, which becomes more important due to the increasing mobility of students. The comparison of the learning outcomes of different modules is facilitated when learning outcomes are described in tabular form, since this kind of description is more explicit and usually uses a lower level of aggregation. A prerequisite for a fair proceeding is, more than ever, a conscientious, realistic assignment of levels of qualification.

3.2 Benefits due to the tool for the evaluation

Having detailed information about the module interfaces and consequently the required input and acquired output of the single modules, students are supported in their individual curriculum design. Consistent personal curricula and a continuous acquisition of competences are ensured. Furthermore, information about module interfaces motivates students to practice for modules without obvious practical relevance when knowing in which modules the acquired competences are required.

Besides the benefits for students, the evaluation of module interfaces holds also opportunities for teachers. As the tool enables the detection of conflicts between learning outcomes of different modules, it enhances inner faculty discussions concerning the curriculum design. Based on the information provided by the tool, teachers can improve the adjustment of the single modules by adapting their content, the order of the topics as well as the sequence of the modules in the curriculum.

3.3 Outlook

The developed tool for the evaluation of module interfaces has even further potential. For example, a feature which automatically suggests appropriate modules to the students could be added based on personal user accounts containing the profile of competences which the students aspire to. Another possible extension is a feature for a further simplification of competence oriented examination. Based on the levels of knowledge, skills, and competences assigned to a module topic, the feature could propose suitable examination formats. In order to ensure the reliability of the gathered learning outcomes, a feedback loop based on a self-assessment of the students could be added. Thereby it could be checked, whether the learning outcomes estimated by the teachers match the qualification levels achieved by the students.

4 SUMMARY

The modularisation of study programmes, the increasing flexibility in the individual curriculum design, and the growing mobility leads to the requirement of an appropriate description of learning outcomes and an increasing transparency in the curriculum. In order to meet these needs, we introduced a revised taxonomy allowing for a tabular and precise representation of learning outcomes. Based on the taxonomy, this paper presents a tool for the evaluation of module interfaces. The web-based system provides a unique transparency of study programmes to students and teachers. Thus it enhances inner faculty discussions concerning curriculum design and supports students in achieving the individually aspired profile of competences.

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Predicting first-year engineering student success: from traditional statistics to machine learning

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Keywords: student success, retention, machine learning, first-year experience

INTRODUCTION

First-year student success in Engineering Bachelor programs is well-studied. Both traditional statistical modelling and machine learning approaches have been used to study what makes students successful. While statistical modelling helps to obtain population-wide patterns, they often fail to create accurate predictions for individual students. Predictive machine learning algorithms can create accurate predictions but often fail to create interpretable insights. This paper compares a statistical modelling and machine learning approach for predicting first-year student success. The case

study focuses on first-year Bachelor of Engineering Science students from KU Leuven between 2015-2017 and relates first-semester academic achievement to prior education, learning and study strategies, effort level, and preference for time pressure.

1 GENERAL

First-year student success and retention in STEM and Engineering bachelor programs are well-studied. The relation between prior academic achievement, learning and study skills and strategies, self-efficacy, self-regulatory skills but also gender and socio-economic factors have been the subject of many studies. Against the background of the increasing need for skilled scientists and engineers, the heterogeneous inflow of incoming students in science and engineering programmes is particularly challenging in universities with an open-admission system. These universities are therefore looking for predictors of first-year student success that might be used in advising on the one hand, and remediation on the other hand. While population-wide conclusions provide insight in the factors that are key, predicting individual student success allows to take the next step to advising individual incoming students.

The present study first applies statistical modelling to obtain population-wide insights on what is expected from the students to perform well in the first semester of their first year of an open-admission university KU Leuven in Belgium. Good performance in the first semester reflects a smooth transition to higher education and acts as an early indicator for completing the study program. Secondly, the predictive validity of the obtained statistical models was assessed. Finally, a dedicated machine learning approach was used for prediction. Such algorithms can fit complex non-linear relations between the independent variables (here: prior academic achievement and learning skills) and the dependent variable (first-year student success). They often result in high predictive performance but challenge the interpretability of the predictions: i.e. it is not easy to see which independent variables are mainly contributing to the predicted class. Getting interpretable insights from the prediction is however key for both individual predictions and population-wide analyses. Firstly, when the predictions are used for academic advising, one should understand the factors that cause a particular prediction: e.g. what causes this particular student to be at risk? Secondly, the machine learning approaches might discover non-linear relationships at the population level that were hard to hypothesize, but that should be interpretable in order to be usable. Different methodologies are available to create local interpretable approximations of the complex non-linear models.

This paper focuses on three research questions: RQ1: Do statistical modelling (multiple linear & logistic regression) and boosted trees identify the same factors for first-year engineering student success?; RQ2: Can boosted trees more accurately predict first-year student success than logistic regression? RQ3: Can Local Interpretable Model-agnostic Explanations (LIME) [1] generate interpretable insights in the factors important for predicting first-year student success?

The paper of Pinxten et al. [2] is key prior work as it used statistical modelling, and multiple linear regression in particular, to investigate the relation between first-year student success in the same study program as targeted in this paper and using a similar dataset. Specifically, the influence of secondary school math level, math and science secondary school GPA, diagnostic test score, study strategies, and advice of the secondary school teacher board was researched. While this paper focuses on a

similar problem and dataset, it focuses on predicting rather than explaining first-year student success. We refer to this paper for an elaborate literature survey on the factors that are important for first-year STEM student success.

Like the study of Ackerman et al. [3], [2] used explanatory statistical modelling, including linear and logistic regression, to study the factors that impact STEM retention and academic success. Another recent study on predicting academic success in Belgium used linear and logistic regression but as [3], they erroneously infer predictive power from explanatory power of their variables and use an in-sample accuracy to assess the predictive validity rather than a test set or cross-validation. While no doubt is raised on the theoretical validity of the studies discussed above, only their statistical objectives are criticised, so as not to come at incorrect scientific and practical conclusions.

Lin et al. [4] compared four different predictive models, namely, artificial neural network (ANN), logistic regression, discriminant analysis, and structural equation in predicting student retention using cognitive and non-cognitive data, where ANN was found to outperform other models. While the authors correctly evaluated the predictive performance on a test set, they concluded their research by suggesting the following: “The model results can also be used to provide faculty and advisors with informed course selection advice to first-year engineering students”, without however handling the interpretability of their models. The studies [5] & [6] (linear regression) and [7] (ensemble methods) soundly assess their models’ predictive power in predicting student success and retention while also addressing the interpretability issues.

2 MATERIALS AND METHODS

2.1 Available data

Data was collected of first-year Bachelor of Engineering Science students of KU Leuven in two academic years: 2015-2016 and 2016-2017 (N=811). The independent variables (IV) were collected using a paper-and-pencil questionnaire administered in the first week of the academic year. Two sets of IV operationalize “prior academic experience”: (1) *math, phy, chem*: math, physics, and chemistry grades obtained in the last year of secondary education self-reported using the following categories: 60%, 60-70%, 70-80%, 80-90%, and above 90%. (2) *hrs*: numbers of hours of mathematics per week in the curriculum of the last year of secondary education self-reported using the following categories: low (<6 hours), (6 or 7 hours), and high (8 hours). Regarding soft-skills the following data was collected: (1) *eff*: The effort level in secondary education is self-reported using the question “How frequently did you study to obtain your math and science results in the final year of secondary education?” using five categories (very low, low, average, high, and very high); (2) *mot, time, conc, anx, and test*: Five scales (motivation (*mot*), time management (*time*), concentration (*conc*), performance anxiety (*anx*), and the use of test strategies (*test*)), were used from the Learning and Study Strategies Inventory (LASSI) to assess the students’ learning skills (resulting in 30 questions). The internal consistency coefficients (Cronbach’s alpha) were: *mot* 0.77, *time* 0.76, *conc* 0.84, *anxi* 0.84, and *test* 0.71. These values are in accordance with both the standards provided in the user’s manual and with general standards [8]; (3) *press*: The preference for time scale of Choi and Moran [9] was used. *Press* was standardised and discretized into a 4-category ordinal variable with categories “Low”, “Low_medium”, “High_medium”, and “High”.

The dependent variable (DV) *GPA* operationalizing first-semester academic achievement (AA) was collected from the universities data warehouse. The GPA, between 0 and 20, is the weighted average of the grades on the first semester courses obtained before the resit, weighted with the ECTS credits of each course.

2.2 Methodology

The goal of **explanatory modelling** is to discover patterns IVs (student characteristics) and the DV (AA). Based on literature, three hypotheses were formulated: 1) “Prior academic experience positively affect AA.”, 2) “Affective and goal strategies positively affect AA.”; and 3) “Preference for time pressure does not affect AA.” Multiple linear regression was used to investigate these hypotheses.

Table 1 provides an overview of the explanatory models built. A sequential (or hierarchical) multiple regression (model 3) was built to test whether the variables *aff*, *goal*, *press*, and *eff* have a significant incremental explanatory power in explaining AA. To assess the **predictive validity** of the explanatory model for predicting AA, ordinal logistic regression was used to classify students in three groups at-risk ($GPA \leq 8.5$), middle group, and no-risk ($GPA > 11.5$). For logistic regression a cumulative odds model with proportional odds property was used.

Table 1: Explanatory models

model	regression type
1 $wavg \sim math + phy + chem + hrs$	standard
2 $wavg \sim aff + goal + press$	standard
3 $wavg \sim math + phy + chem + hrs + aff + goal + press + eff$	sequential

Gradient boosting was used for **predictive modelling**. It is an ensemble technique where new decision trees are sequentially added to compensate the errors made by the already existing trees, using gradient descent. The final prediction score is the sum of the prediction scores of each individual tree. XGBoost, which is based on the gradient boosting, incorporates various additional improvements to avoid overfitting, to handle sparsity pattern in data, and parallelization [10]. Instead of learning a multi-class classifier, two independent classifiers were used, as multiple binary classifiers are often easy to train and optimize than a single multinomial classifier. The first classifier, XGBoost_1, was used to distinguish students of class “ ≤ 8.5 ” (“at-risk”) from students of class “ > 8.5 ” (“moderate-risk” or “no-risk”) while the second classifier, XGBoost_2, was used to distinguish students “ > 11.5 ” (“no-risk”) from students of class “ ≤ 11.5 ” (“at-risk” or “moderate-risk”). The output of the two binary-classifiers model were combined into a multi-class classification (*Table 2*). In this paper XGBoost_1 and XGBoost_2 are optimized for high recall of ≤ 8.5 and ≤ 11.5 respectively (high identification rate of the “at risk”- students) and high precision of > 8.5 and > 11.5 respectively (few misclassification as “no-risk”). Once the two binary classifiers were learnt, LIME was used to construct interpretable approximations of the classifiers. LIME constructs “textual or visual artefacts that provide qualitative understanding” of the prediction. LIME, in short, approximates a complex classifier in the neighbourhood of an observation (for which prediction is required) with a simple interpretable model like linear regression.

All classifiers in this study are trained using a training set of 542 out of 720 subjects and evaluated using a test set of 178 out of 720 created using stratified sampling.

Table 2: Combining outcome of two binary classifiers into multi-class classification.
(other combinations, which rarely occur, are classified as moderate at-risk)

XGBoost_1 outcome	XGBoost_2 outcome	interpretation
≤8.5	≤11.5	at-risk
>8.5	<11.5	moderate at-risk
>8.5	>11.5	no-risk

3 RESULTS

3.1 Data preparation

As the five measured learning and studying skills are correlated, PCA was performed (after checking for the assumptions of linearity and removing outliers) to reduce the dimensionality of the data. PCA with oblique (oblimin with $\delta=0$) rotation yielded a two component solution accounting for 75% of the variance. Since the resulting association between the measured variables and the components (*Table 3*) is similar to that obtained by Cano [8], the same naming convention is used: “Affective Strategies” (*affe*) “Goal Strategies”(*goal*). The variables *affe* and *goal* are discretized into a 4-category ordinal variable and the categories are named as “Low”, “Low_medium”, “High_medium”, and “High”.

Table 3: PCA component loadings. Proportion variance explained by TC1 is 0.44 and by TC2 is 0.32. Pearson correlation: 0.17. RMS of residuals was 0.1.

	TC1	TC2	h ²	
mot	0.88	-0.15	0.75	affe
time	0.87	-0.04	0.75	
conc	0.73	0.36	0.74	
anxi	-0.17	0.92	0.83	goal
test	0.31	0.76	0.75	

3.2 Explanatory modelling

For **model 1** a significant regression equation was found ($F(11,708) = 37.97$ at $p < 2.2e^{-16}$), with an R^2 of 0.37. (adjusted multiple R^2 value 0.36). All included independent variables were significant contributors ($p < 0.05$). The unique contribution of math, phy, chem and hrs is computed as 6.6%, 2.3%, 4.5%, and 3.0% respectively. The remaining 20.8% variance is contributed by two or more input variables. These results confirm that prior academic experience, operationalized as math and science grades, and math level, positively affect the first-semester academic achievement.

For **model 2** a significant regression equation was found ($F(9,710) = 4.644$ at $p < 5.4e^{-16}$), with an R^2 of 0.06. The adjusted multiple R^2 value of 0.04 shows that soft skills are only a weak predictor of AA. Most variance explained by model 2 is contributed by *affe*, while *goal* and *press* together contribute less than 1%. Similarly, only the coefficients of *affe* are significant. These results show that students’ affective strategies influence AA, while goal strategies don’t.

The results of the sequential model (**model 3**) show that after accounting for differences in students’ effort level, the goal related strategies (but not affective strategies or pressure preference) become important in explaining AA.

3.3 Explanatory modelling with predictive validity

Logistic regression according to **model 1** showed that prior academic achievement is a strong predictor of AA (Nagelkerke $R^2=0.28$). Preference for time pressure and affective and goal strategies on the contrary are only weak predictors (**model 2**,

Nagelkerke $R^2=0.05$), they are however of added predictive value on top of prior academic achievement (**model 3**, Nagelkerke $R^2=0.33$). *Table 4* presents the detailed prediction outcome of model 3. This model, involving all IV, has a recall of 60% for the class " ≤ 8.5 ", which implies a high risk of not identifying "at-risk" students. Similarly, the precision of 41% for the class " >11.5 " implies the high risk of misclassifying many students as "no-risk". The F1 score, which is an overall measure of the predictive performance, is only 62% for the "at-risk" class and 43% if the "no-risk" class.

Table 4: Prediction outcome of logistic regression with wavg ~math + phy + chem + hrs + eff + affe + goal + press (model 3)

	precision	recall	F1-score	support
≤ 8.5	0.63	0.60	0.62	60
8.5-11.5	0.63	0.59	0.61	54
>11.5	0.41	0.45	0.43	64

3.4 Predictive modelling with comprehensible approximations

Table 5 shows the predictive performance of both XGBoost_1 and XGBoost_2 using all IV. The high recall of XGBoost_1 ≤ 8.5 shows that most at-risk students are correctly identified. The overall F1-score of 71% for the "at-risk" group (XGBoost_1 ≤ 8.5) and 69% for the "no-risk" group (XGBoost_2) shows that the overall predictive performance is adequate.

Figure 1 shows an example of the LIME output. Firstly, the prediction probabilities are shown. Next, a bar chart shows the importance (or weights) of each of the IV in the prediction in descending order. The "weight" in the bar chart indicates that if an IV does not take the displayed value, then the probability of the displayed class to which the IV is contributing will be on average be reduced in value equal to the weight. As such, the LIME explanations allow to assess to which level a IV contributes to the predication made: e.g. what are the aspects that make the student at-risk. Population-wide patterns can be discovered by listing how often the IVs occur in the prediction of students belonging to the different classes. Similar to the explanatory modelling this shows that IVs math, phy, chem and eff contribute more to the predicted probabilities than IVs affe, goal, or press. Additionally, some patterns, previously not discovered in explanatory modelling, can be observed here. For instance (*Figure 2*), (1) while hrs contributes to distinguishing at-risk students (≤ 8.5) from the rest, it is not key in distinguishing "no-risk" (>11.5) students from the rest; and (2) affe considerably contributes to distinguishing "no-risk" students from the rest, while it does not significantly contribute to distinguishing "at-risk" students from the rest.

Table 5: Prediction outcome of predictive performance with boosted trees.

		precision	recall	F1-score	support
XGBoost_1	≤ 8.5	0.64	0.80	0.71	60
	> 8.5	0.88	0.77	0.82	118
XGBoost_2	≤ 11.5	0.87	0.85	0.86	124
	> 11.5	0.68	0.70	0.69	54

4 DISCUSSION & CONCLUSION

The discussion is organized around the three research questions.

Regarding RQ1, we found that the both statistical modelling (linear and logistic regression) and boosted trees create the same insights regarding factors important for first-year student success: prior academic achievement, affective strategies, and goal

strategies affect first-semester academic performance. This confirms the findings of [2], which showed that the students' motivation/persistence, concentration, and time management skills significantly influenced first-year student achievement although the incremental value over prior achievement was small.

The results confirm that students' preference for time pressure has no influence on their academic performance as suggested by Choi and Moran [9].

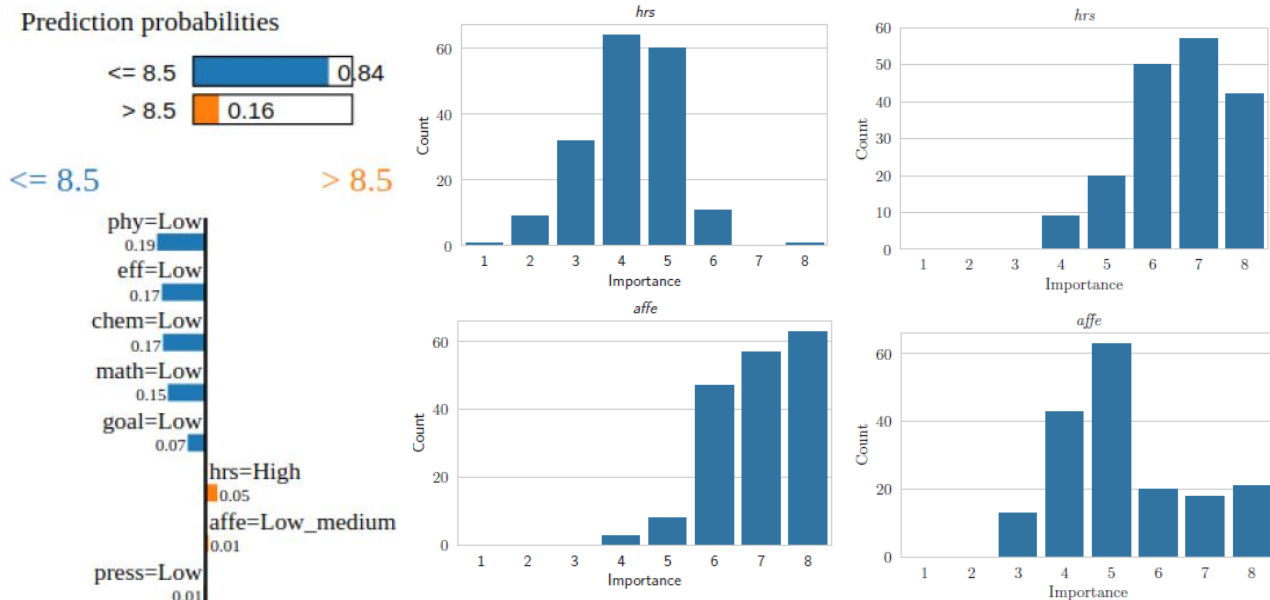


Figure 1: LIME output for at-risk student that was also predicted as at-risk.

Figure 2: Population-wide analysis of importance of IV hrs and aff for predicting at-risk students (left, XGBoost_1, ≤ 8.5) and no-risk students (right, XGBoost_2, > 11.5).

RQ2: Can boosted trees more accurately predict first-year student success than logistic regression?

The results show that boosted trees can more accurately predict AA, providing a positive answer to RQ2. Boosted trees outperform more-commonly used logistic regression, as both precision and recall increased by more than 20%. Additionally, we have shown that LIME can be used to get interpretable insights from the boosted trees model both for predicting individual student success as for studying population-wide patterns.

Future work should focus in including more IV such as recommendation by the secondary school teacher board [2], study effort [2], and positioning test score [11]. Furthermore, future work should not only focus on predicting first-year students success but also on long-term success, and explore different machine learning approaches to this end. The approach should be tested to engineering programs of other universities. Finally and most importantly, the usability of the interpretable models (LIME) for advising students should be assessed.

ACKNOWLEDGMENTS

This research is co-funded by the Erasmus+ program of the European Union (562167-EPP-1-2015-1-BE-EPPKA3-PI-FORWARD).

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ENGINEERING GRAPHICS CONCEPT INVENTORY (EGCI) CRITERION VALIDITY ANALYSIS

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Conference Key Areas: Curriculum Development; Engineering Skills; Innovative Teaching and Learning Methods

Keywords: Engineering; Education; Graphics; Assessment

INTRODUCTION

At the onset of a new course, students have prior knowledge on which they develop their understanding of a particular subject. Some of this knowledge is due to the interpretation of a collection of experiences and teachings that the students have amassed along their educational journey, some of which have been misunderstood. Such misconceptions can be a barrier for deeper understanding if not identified and addressed. There is a need for more accurate tools to better determine the misconceptions that exist in order to prevent

further perpetuation of those misconceptions in students. One instrument that can identify such issues is a concept inventory.

A concept inventory is a tool to aid in the identification of deep seated misconceptions held by students and to measure student learning. The antecedent Force Concept Inventory [1] has led to the development of a number of concept inventories, for example, in thermodynamics [2], heat transfer [3], statics [4] and now engineering graphics [5]. The use of concept inventories across different branches of engineering could prove to be useful in assessing effectiveness of instruction and providing insight on teaching methods that promote improved student understanding.

1. ENGINEERING GRAPHICS CONCEPT INVENTORY

1.1 Background

Engineering graphics is a branch of engineering which is common in a wide range of engineering curricula in the United States and was determined to be a suitable candidate for the development of a concept inventory. In 2013, a research team assembled to create an instrument that would serve as a nationally standardized means of assessing misconceptions in engineering graphics. The collaboration of faculty, staff and doctoral students at Embry-Riddle Aeronautical University (ERAU), Purdue University, Penn State Behrend, NC State University and The Ohio State University has led to the development of the Engineering Graphics Concept Inventory.

The development of the instrument began with the consultation of graphics experts who formed a Delphi panel. One-hundred-and-twenty unique engineering graphics topics were originally identified by the panel. These topics were later coalesced into 10 fundamental concepts and then further distilled into the five concepts that are currently identified and tested by the instrument [6]. A face validity study was conducted whereby the graphics experts reviewed the items in the instrument to verify that they were testing what they were designed to test. The experts confirmed that all items assessed the intended concepts, which suggests good face validity.

1.2 Item Selection

The current instrument is a 30-item multiple choice instrument that tests five engineering graphics concepts: sections, projection theory, mapping between 2D and 3D, planar geometry and dimensioning. The items were carefully selected through an iterative process to have a range of difficulty and be of sufficient discrimination (above 0.30). The distractors in each item were judiciously chosen to reflect a single misconception, such that they would be associated with a particular misunderstanding. The data used in this paper was taken from the fourth iteration – the “delta” version – and presently the instrument is undergoing its fifth iteration – the “epsilon” version. Figure 1 shows a sample item from the EGCI which tests the projection theory, specifically orthographic projection of inclined surfaces.

Select the set of views that show surface “A” correctly labeled in the top view and the right hand side view.

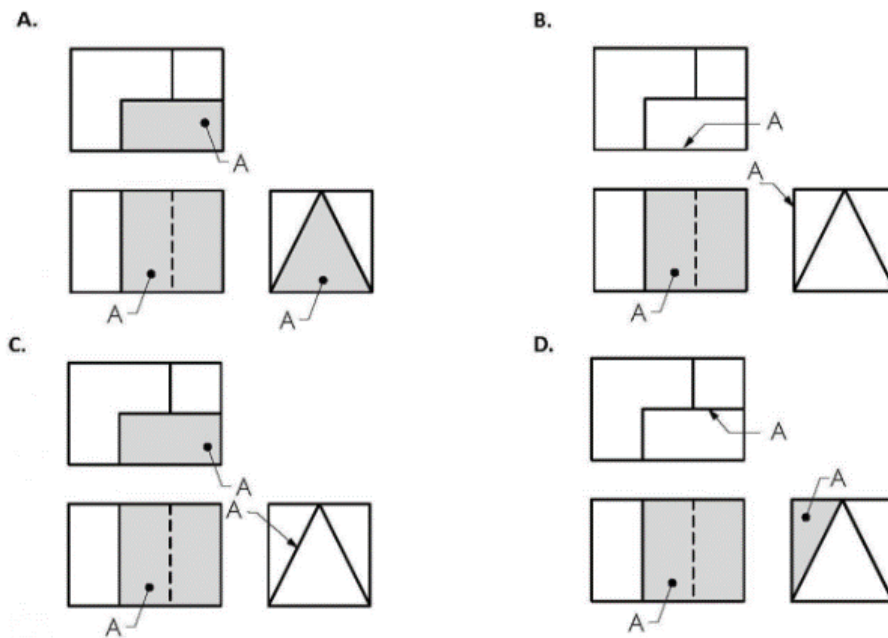


Figure 1: Sample Question from the EGCI on Projection Theory

Inclined surfaces appear as an angled edge in one orthographic view and as a surface in the other two orthographic views. From the right side view of every option it is seen that there are two angled lines which correspond to two inclined surfaces, both of which span the entire height of the object. Option C is the correct choice – surface A appears as a surface view in both the front view and the top view, and as an inclined edge in the right side view. Distractor A has surface A labeled as a surface three times, suggesting that A is an oblique surface, and not an inclined surface. Distractor B has surface A labelled as a surface only once, and as an edge twice, which is the behavior of a normal surface. However, when Surface A is projected onto the right side view it aligns with the inclined edge. Distractor D has surface A labelled as a surface twice and as an edge only once which is consistent with the behavior of inclined surfaces in orthographic views, however, the edge labeled in the top view is horizontal which would imply that surface A is a normal surface. The isometric view of the object, which is not included in the instrument, is shown in Figure 2 with surface A correctly labelled.

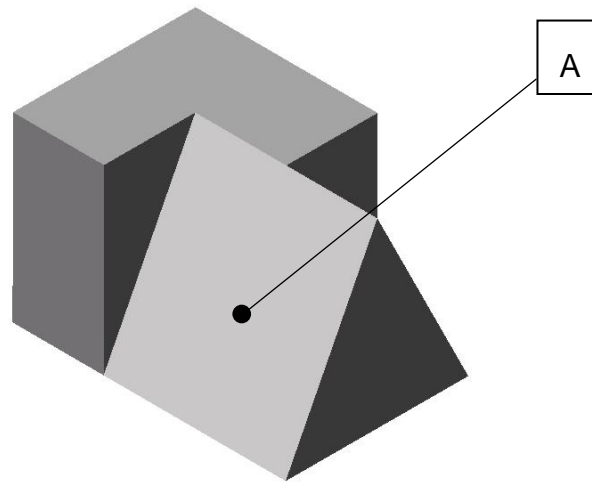


Fig. 2. Isometric View of the Object from the Sample Question on Projection Theory

1.3 Instrument Validity

Validity is the measure of the meaningfulness of a test. In order to determine whether the EGCI is indeed measuring what it is designed to measure the validity must be considered. Criterion validity is a measure of the relationship between two different sets of scores and is typically analyzed in terms of concurrent validity or predictive validity. Concurrent validation is the assessment of whether an instrument is able to distinguish between groups that in theory it should be able to differentiate between by comparing the scores to a known standard; predictive validation is the measure of the ability of an instrument to predict competence. For concurrent validation the EGCI scores were compared to the grade points of students who were enrolled in EGR 120 – a course in graphical communication. Predictive validation has not yet been measured and will require analysis of data collected over a longer period of time.

2. METHOD

2.1 EGCI Platform and Participants

The instrument was administered through the survey software Qualtrics to first-year engineering students at Embry-Riddle Aeronautical University, Penn State Behrend and Purdue. Two-hundred-and-twenty-nine ERAU students participated in the delta version of the instrument at the end of the Fall 2017 semester, 29 of which opted out of having their scores included in the analysis. Five different faculty members from the department of Engineering Fundamentals at ERAU, with a range of teaching experience from one year to 10 years, administered the instrument to students enrolled in their respective EGR 120 sections. ERAU was chosen for this analysis because of the ease of access to the relevant information while data from the other institutions was still being correlated.

The instrument gathered demographic data to record participant information. The participants then responded to the 30 multiple-choice items. The instrument required the participants to make a selection before moving on to the next item, which could be changed before final submission of the instrument. For data to be considered in the analysis, participants had to have responded to all of the items. While the overall scores attained by the students were further parsed into the performance for each concept, the particular responses to each item were not linked to the individuals.

2.2 Data Collected

The course grades for the EGR 120 students who participated in the EGCI were collected for the Fall 2017 semester. Grade points were assigned to correspond to letter grades. Table 1 shows the allocation of grade points per letter grade.

Table 1. Grade Points per Letter Grade

Letter Grade	Percentage (%)	Grade Points
A	90.00≥	4
B	80.00-89.99	3
C	70.00-79.99	2
D	60.00-69.99	1
F	<60.00	0

The participants were grouped based on their overall course grades and the mean EGCI scores for each group were calculated and analyzed. The null hypothesis states that there is no correlation between the performance in the EGCI and the overall course performance.

3. RESULTS

The overall scores of the students who participated in the EGCI are shown in Table 2 versus grade point. IBM SPSS was used to conduct the analysis of the results. The Pearson Correlation Coefficient was calculated for the individual EGCI scores earned and the course grade received. The coefficient was found to be 0.305 at a significance level of 0.01.

Table 2. EGCI Mean Scores per Grade Point

Grade Points	4	3	2	1	0
Number of Students	60	79	47	10	4
EGCI Mean Score	20.02	16.44	14.96	16.30	14.00
Standard Deviation	5.83	4.78	5.56	6.20	4.24
Standard Error	0.41	0.34	0.39	0.44	0.30

A total of 200 students' scores were considered in the analysis. The mean scores per grade point are shown graphically in Figure 3, along with the standard error per grade point. It is evident that there is a general trend for the EGCI mean score to increase with the grade point which suggests that the students who score better in the class generally perform better in the instrument. There is a discrete data point which does not follow the general trend for performance – students who earn 1 grade point, i.e. those who score a D in the course, have a higher mean score than students who earn 2 grade points, i.e. those who score a C in the course. The source of this outlier is believed to be due to a low n , as the sample size for students who score a D in the course is relatively small when compared those who score a C, and therefore a single student in this group who scores well has the ability to greatly impact the mean of the group as is seen in this case. Additionally, multiple choice assessments do not have the ability to determine when a student might have correctly guessed an answer and the performance of those who scored a D in the course could be attributed to guessing. Finally, there are only four students who earned an F in EGR 120, so even though the mean EGCI score for those students follows the trend, it is of negligible concern for this study.

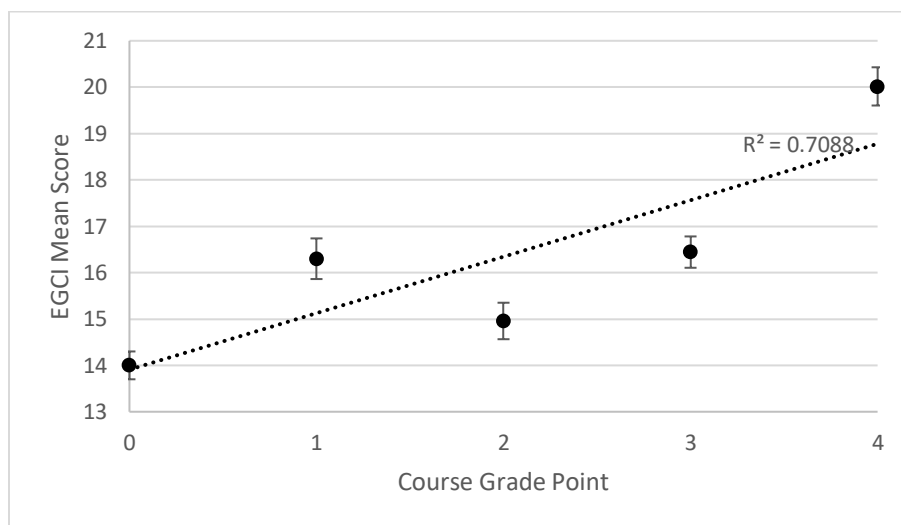


Fig. 3. EGCI Mean Score vs. Grade Point

The sample size for low performing students is low and the concurrent validity is not an adequate representation of the effectiveness of the instrument for the low performers. However, as data is collected for subsequent semesters it will be possible to predict a trend and further prove the criterion validity due to an increased sample size. This will form the basis of a predictive validity study.

Figure 4 shows the trend for students who pass the course with a C grade or better. The sample sizes are adequate to provide significance to the trend. The R^2 value provides an indication of how well the data conforms to the trend. The R^2 value for students who pass the course is 0.9463 compared to 0.7088 for the original pool of participants which implies that there is less scatter about the line of best fit.

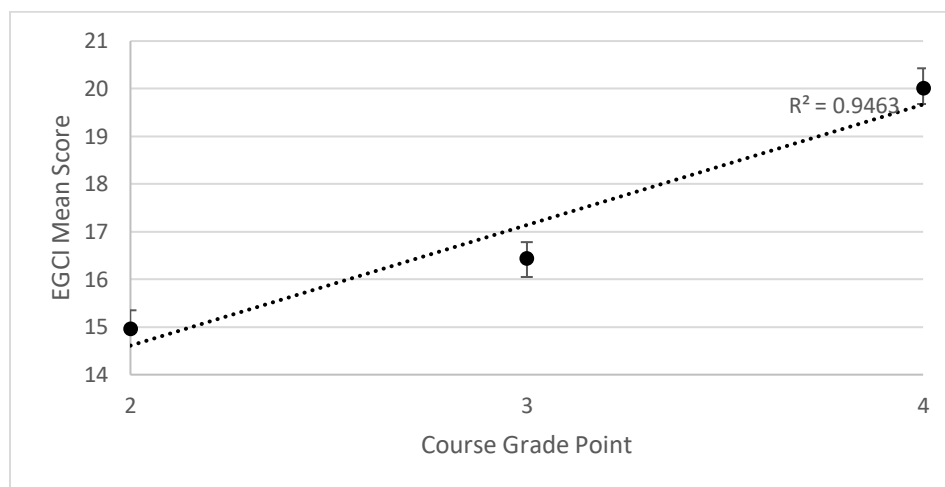


Fig. 4. EGCI Mean Score vs. Grade Point for Passing Students

4. CONCLUSION

To gain the most utility out of an instrument, it is critical to ensure that it is measuring what it is designed to measure. Validity considerations lend credibility to the assessment and prove its effectiveness. Studying the concurrent validity provides indication of criterion validity by comparing the results to a standard which is already recognized. An adequate sample size is necessary in order to obtain significant results. The data collected revealed a trend in performance and a positive correlation between the mean score in the EGCI and the number of grade points received for a course. Therefore, the null hypothesis is rejected – students who perform well in the EGCI generally perform well in the graphics course, which implies good criterion validity.

A study of predictive validation will likely further support the criterion validity of the instrument, and will allow the authors to further consider the performance of the lower scoring students given the larger sample size. However, at this stage of the study the low n of the lower scoring students make those scores fairly insignificant.

5. ACKNOWLEDGEMENTS

The research team would like acknowledge the support of NSF grants 1432280 and 1432288.

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Reaching out for girls

Raising interest and self-efficacy in engineering with ‘girls only’ workshops at a technical university

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Conference Key Areas: Gender and Diversity in EE, Recruitment and Retention,

Keywords: Outreach activity, Gender diversity, Interest in engineering, Self-efficacy in engineering

ABSTRACT

The paper presents an outreach activity targeted for elementary school girls to increase their interest and self-efficacy in technology and engineering. The activity consisted of visits to a technical university with two to four workshops on different

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science and engineering topics per visit. Five visits in total were organised for different girl groups during the year 2017 with 104 girls attending the activity.

The workshops were designed based on previous experiences and research findings about relevant topics and formats of activities. The workshops were made as interactive and practical as possible, and the topics and activities were connected with the girls' experience and spheres of life. The visits were offered exclusively for girls to prohibit the typical effect of boys on girls' behaviour in situations of this kind. Providing room for positive peer role models aimed at empowering girls by generating shared experiences among participants.

The participants were asked to rate their interest towards engineering/technology and their self-efficacy in engineering subjects before and after the visit. They could also make open comments about the workshops and the visit in general. The analysis revealed that the changes in both perceived interest and perceived self-efficacy were positive and statistically significant for the whole population and the smaller groups although there were differences between the groups both in the magnitude and significance of the change. Both quantitative and qualitative data seem to verify the original design principles and assumptions on what makes an outreach activity for girls interesting and efficient.

1 INTRODUCTION

The under-representation of women in technical studies and vocations is a well-known and cross-national phenomenon (see e.g. Joyce & Dzoga 2013, National Science Foundation 2018, Buccheri, Gürber & Brühwiler 2011). It has been found that even when females have the same competences in science as males, they avoid vocational choices such as being engineers or technicians (Buccheri et al. 2011). This has been explained for example with women's greater interest in people than things (Su & Rounds 2015), the mismatch between girls' self-image and the image they have of engineering-related subjects such as physics and mathematics (Taconis & Kessels 2009, Kessels 2015, Makarova & Herzog 2015), the influence of socializers, such as teachers, parents, or peers (Ikonen, Leinonen, Asikainen & Hirvonen 2017, Riegler-Crumb & Morton 2017), and the girls' fewer technology-related experiences in childhood and primary education (Niiranen 2016).

Along with the multitude of possible explanations for the gender disparity in engineering there is a wide selection of suggestions for ways of correcting the situation (Blickenstaff 2005). Henwood (1996) argues that many of the initiatives to get more women in engineering focus too narrowly on women's choices and attempt to solve the problem by changing women, i.e., giving them more information or trying to change their image of the field, and leaving the structures and culture of the field intact. Although it is undoubtedly true that changing only the communication resembles delivering 'fake news', which is more likely to make the situation worse than better, giving the girls better opportunities to experience and access the world of technology and engineering is at the heart of many outreach activities aiming to decrease the

gender disparity in the field. This should, however, not be seen as merely transmitting information – as at least the Finnish girls state that they are aware of the relevance of STEM subjects to their life (Microsoft 2017) – but more as a chance for girls to get personal experiences, and an opportunity to form an opinion based on themselves instead of hearsay or media images.

The outreach activities created to attract more girls in engineering come in different forms. They range from short workshops and day visits (e.g. Weston, Bonhivert, Elia, Hsu-Kim & Ybarra 2008, Molina-Gaudo, Baldassarri, Villarroja-Gaudo & Cerezo 2010) to longer projects (Ward, Lyden, Fitzallen & de la Barra 2015) to camps (Todeschini & Demetry 2017). They may be for girls only (Egbue, Long & Ng 2015, Weston et al. 2008) or also include boys (Jahan & DeJarnette 2014, Ward et al. 2015). Some aim at delivering specific contents to the participants, such as knowledge on electric vehicles (Egbue et al. 2015), whereas others focus on the engineering design process (Ward et al. 2016) or introduce engineering work and subdisciplines (Weston et al. 2008, Molina-Gaudo et al. 2010). Participants often come to campus, but sometimes the activities are brought to the participants for example with specifically equipped vehicles (Jahan & DeJarnette 2014).

Activities commonly show positive short-term impacts, but the research on the long-term impacts is unfortunately scarce. Todeschini and Demetry (2017) have conducted two longitudinal studies, which indicate that outreach activities may have a positive long-term effect on girls' intentions to study engineering, their perceptions of engineers, and sense of empowerment and self-confidence. The short-term effects are well in line with these. Molina-Gaudo et al. (2010) reported that a 'Girls' Day' improved slightly the motivation to pursue engineering careers and changed gender-biased views of the profession. Jahan and DeJarnette (2014) discovered that a mobile programme for enhancing engineering education increased participants' interest to become an engineer, and Egbue et al. (2015) concluded that after a workshop on electric vehicles the students had a clearer understanding of the engineering profession. Quite interestingly, using engineering activities to engage middle school students in physics and biology increased female students' interest in physical science but did not change male students' interests in biological science (Ward et al. 2015), and the hands-on type of activities increased girls' interest, knowledge and confidence in engineering notably more than in mathematics or science (Weston et al. 2008).

2 METHODS

The aim of the outreach activity was to increase girls' interest and self-efficacy in technology and engineering. The activities had to be designed in such a way that they could be used for groups of different sizes and participants of different ages, and conducted in slightly different time frames. The objective of the study was to discover the short-term impacts of the activity and thereby evaluate the effectiveness of the activity, but also understand what is essential in designing and executing outreach activities of this kind.

2.1 Design and execution of the activity

The first decision to be made was to target the outreach activity exclusively at females. Male peers with explicit gender/STEM stereotypes have been noted to significantly and negatively affect girls' intentions to pursue technical careers (Riegle-Crumb & Morton 2017). Girls also tend to get less time and attention compared with boys in a mixed STEM classroom with both genders taking this as a natural state of affairs and feeling unpleasant if the situation is changed (Paloheimo 2015). Thus, it was perceived that having no boys in the activity would enhance the girls' activeness and experience.

The original idea was to find groups that naturally consist only of girls, e.g. Girl Scouts, so that the whole group could be invited and nobody (i.e., the boys) would feel left behind. However, this proved to be challenging for many reasons, particularly timing (hobby groups could not easily book a school day for girls coming from many different schools, and the university laboratories were not available during weekends and holidays). In the end, there was only one Girl Scout group among the visitors. Fortunately, local schools were willing to collect girls only groups to come to the campus for a day.

In order to have the needed flexibility, it was decided to construct the activity to consist of a short introduction and a flexible number of different workshops. The workshops were designed based on earlier experiences of visiting child and adolescent groups and research findings, and suggestions found in the literature. A special effort was made to incorporate as many hands-on activities as possible, as they have proven to be effective (Weston et al. 2008) and longed for in the STEM teaching by Finnish girls (Microsoft 2017). Another focus was on connecting the activities with the girls' spheres of life. For example, Arduino programming was demonstrated with the use of sewable electronics, as Finnish girls are much more often familiar with textile than technical craft (Niiranen 2016), and the more traditional physics and electronics problems were connected with the fashionable escape room concept.

Each visitor group was given a short presentation about the university and careers in technology, and the group attended two to four of the following workshops:

Physics: In the physics laboratory, the girls were shown some phenomena e.g. in optics and magnetism, and they could test some of the phenomena themselves.

Arduino programming: Each girl practiced to connect a LED onto a circuit board and program it to blink at desired intervals. Some advanced to implement traffic lights with red, yellow, and green LEDs. The blink programme could also be tested with a LilyPad implementation (a badge with LED lights) to show how electronics and programming can be combined with handicraft. In the beginning of the workshop the girls were shown a brief video with different examples of LilyPad-use in everyday settings. This was hoped to stimulate the girls' thinking of possible personal use of the technology at hand.

Wind mill simulation: Girls built their own miniature wind mills, and then measured the amount of electricity produced by the mill attached to a miniature generator, using

a table fan for wind. The activity was organised as a competition, where teams with the highest production volume were given small prizes.

Chemistry: In the chemistry laboratory, the girls used indicators to identify different solutions. Further, balloons were filled by using the reaction of vinegar and baking soda.

Escape room in electrical engineering: The “pop up” escape room contained tasks related to electrical engineering, with solutions that gave codes for locks. In the locked bags or boxes, new tasks were discovered, until the students found a key to “escape”. The tasks contained mathematical calculations tailored for the level of the visitors, and the person responsible for the escape room gave hints when needed. The workshop was conducted by a female post-doctoral researcher in electrical engineering, who was also acting as a role model of a woman with a successful career in technology.

The workshops lasted 30–60 minutes depending on the topic and the size of the group.

2.2 Collection and analysis of data

The participants were asked to evaluate their perceived interest in engineering/technology (vertical axis) and their perceived self-efficacy in the subject area (horizontal axis) by marking an ‘x’ in the coordinate system at the beginning of the visit, and an ‘o’ at the end. The coordinate system is illustrated in *Fig 1*.

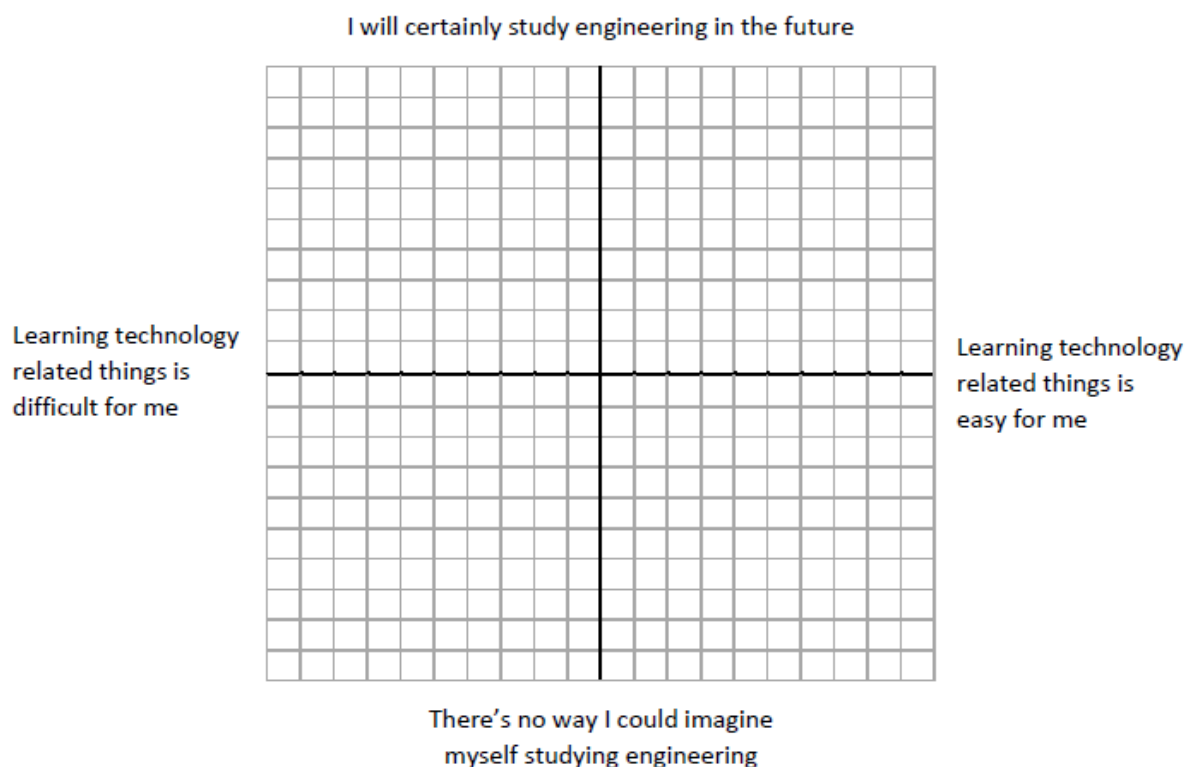


Fig 1. Coordinate system to evaluate one's interest and self-efficacy in engineering/technology

As the visits started and finished in the same room, the participants could leave their form on the table, and no names or other identification were needed. In addition to the

coordinate system, the questionnaire contained the following open questions, which were answered after the workshops:

- What did you find interesting/nice during the day?
- What did you find boring/unpleasant during the day?

The coordinate system was chosen in order to have the minimum number of questions and to direct the participants to think about their interest in relation to self-efficacy but also in relation to change in both aspects (did one change more than the other).

The filling of the form was instructed and illustrated with examples both at the beginning and at the end of the visit. Despite this, some answers could not be interpreted or considered reliable and were thus omitted from the analysis. After the visit, the forms were collected and the values were entered in an Excel sheet. When all the visits were over, the data were transferred to the statistical software Stata for analysis.

In Stata, the means and standard deviations for the pre- and post-activity evaluations as well as for the change, interest and self-efficacy were calculated for the whole group and for the different visitor groups. The significance of the change was examined with the paired samples t-test, and the differences between the two variables were investigated with the mean comparison t-test for unequal variances. The answers to the two open questions were grouped and analysed qualitatively.

3 RESULTS

Between April and November 2017, a total of 104 girls visited the campus:

- April 28th 2017: 16 seventh graders (age 13) from local school A
- June 7th 2017: 14 girl scouts of different ages
- September 28th 2017: 43 ninth graders (age 15) from three different schools in the neighbouring town
- November 9th 2017: 15 fifth graders (age 11) from local school B
- November 30th 2017: 16 seventh graders (age 13) from local school A (new batch compared with the group that visited in the spring)

For each group, workshops suitable for the age of the students were prepared and organised with a schedule agreed upon with the teachers. The combination of workshops for each of the groups is given in *Table 1*.

Table 1. Combination of workshops for different visitor groups

Group	Workshops				
	Physics	Arduino programming	Wind mill simulation	Chemistry	Escape room
7th graders from school A I		x		x	
Girl scouts		x	x	x	
9th graders from town X	x	x		x	x
5th graders from school B		x	x	x	
7th graders from school A II	x	x	x		x

Interpretable and reliable answers to the questionnaire were received from 96 participants. In most of the groups there was one questionnaire left unfilled or filled insufficiently (e.g. the same markings for the beginning and the end, or too many markings), but in the girl scout groups all of the youngest respondents (N=5) were left out as it was unclear whether they fully understood what they were expected to do. The means of the pre- and post-activity evaluations for both variables and all groups are presented in Table 2 and illustrated in Fig 2.

Table 2. Participants' pre- and post-activity evaluations of their interest and self-efficacy in engineering/technology

Group	N	pre-activity evaluation		post-activity evaluation	
		future in eng (mean)	easiness of tech (mean)	future in eng (mean)	easiness of tech (mean)
7th graders from school A I	15	-0.1	1.0	4.3	2.3
Girl scouts	9	0	1.2	4.9	3.4
9th graders from town X	43	-0.3	-0.2	0.8	1.2
5th graders from school B	14	1.0	1.9	3.6	3.6
7th graders from school A II	15	-1.5	-0.7	1.5	1.8
All respondents	96	-0.2	0.4	2.3	2.0

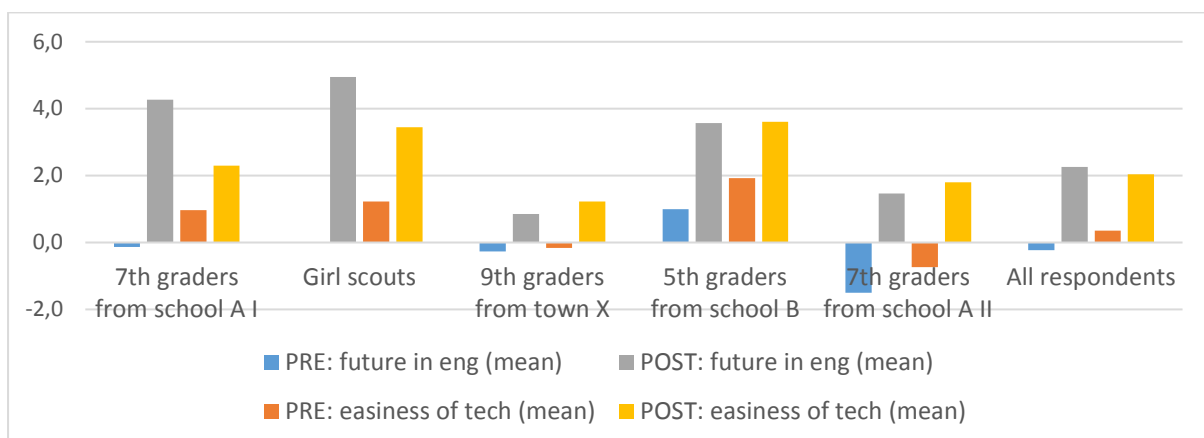


Fig 2. Participants' pre- and post-activity evaluations of their interest and self-efficacy in engineering/technology

The participants' pre-activity evaluation estimates for interest (future career prospects) and self-efficacy (perceived easiness) for the whole group were close to zero as can be expected with this kind of a measurement instrument (symmetric scale with zero in the middle) and the group of informants (rather large N and not expected to be biased in any direction). Although the mean of the pre-activity evaluation value for interest was slightly lower and the post-activity evaluation value slightly higher than for self-efficacy, the differences were not statistically significant ($p=0.3563$ for the pre-activity evaluation and $p=0.7118$ for the post-activity evaluation).

The change between the pre- and post-activity evaluation of both variables was, however, statistically significant for the respondents in total and for almost all of the groups separately. The means, standard deviations and the two-tailed p-values of the paired samples t-tests are collected in *Table 3*.

Table 3. Change in the participants' perceptions of the interest and self-efficacy in engineering/technology

	Change in future in engineering			Change in easiness of technology			Mean comp. t-test
Group	mean	stdev	p	Mean	stdev	p	p
7th graders from school A I	4.4	2.67	0.0000	1.3	2.13	0.0293	0.0018
Girl scouts	4.9	3.84	0.0048	2.2	3.07	0.0619	0.1175
9th graders from town X	1.1	3.65	0.0512	1.4	1.88	0.0000	0.6704
5th graders from school B	2.6	2.22	0.0008	1.7	2.81	0.0437	0.3599
7th graders from school A II	3.0	3.82	0.0095	2.5	4.43	0.0439	0.7764
All respondents	2.5	3.61	0.0000	1.7	2.68	0.0000	0.0785

For all respondents, the change in both perceived interest in engineering and perceived self-efficacy was statistically highly significant ($p<0.001$). With most of the visitor groups, the mean change in interest was larger than the mean change in self-efficacy, the ninth graders being the only exception. Yet, the only group where the difference between the magnitude of change is statistically significant was the first group of seventh graders (mean change in interest > mean change in self-efficacy, $p=0.0018$). The only changes with no statistical significance were in the girl scouts' perception of the easiness of technology ($p=0.0619 > 0.05$) and the ninth graders' interest in engineering ($p=0.0512 > 0.005$).

The open comments revealed that each of the workshops had their lovers and loathers. To the question regarding unpleasant things, some comments connected "just watching" or "just listening" with becoming bored. In general, the younger visitors seemed to like chemistry best and the older ones preferred programming or the escape room. Many respondents stated that everything was nice and nothing was boring.

4 CONCLUSIONS

The results support the findings from previous studies that these kinds of outreach activities have at least short-term positive effects on the girls' interest and self-efficacy in engineering/technology. It seems, however, that the interest is more easily triggered at the younger age, as suggested also by Molina-Gaudo et al. (2010).

Hands-on activities appear to be effective regardless of the topic and the age group. This poses a challenge for the design of the workshops as the challenge level of the activity needs to be adjustable. Too difficult tasks are unlikely to promote self-efficacy whereas too easy tasks are perceived boring and uninteresting. Even though female students wish for more practicality to the STEM teaching in general (Microsoft 2017), it can be considered especially important when introducing students to engineering, as the creative nature of engineering work often remains invisible to the adolescents (Capobianco et al. 2011).

Connecting the new experiences with girls' world spheres was done primarily through the Arduino programming and escape room workshops. In the former girls were helped to get ideas of possible personal use of employed technologies through a video of examples and a physical demonstration. The latter was designed in the format popular from the leisure activities and conducted by a potential role model. Both workshop were among the most liked ones among the older visitors.

Perhaps somewhat surprisingly, there were no comments in the questionnaires regarding the exclusion of boys from the activities. One piece of anecdotal evidence was received from the mother of one of the participants, who had asked her daughter about this and got the following answer: "It was good that they weren't there to mess things up." Although this is of course only a single comment, it would be worthwhile to look more closely at this issue for instance by observing the dynamics of the mixed visitor groups.

All in all, the outreach activity was a pleasant experience for both the participants and the organisers. As the gender disparity of engineering is a long-term and, to some extent, even stagnant problem, these kinds of activities will be necessary also in the future. More knowledge is still needed especially of the long-term effects of these activities, and this should be taken into account when designing and executing future outreach projects. One encouraging weak signal of the longer-term effects was received in April 2018, when two of the visitors presented a project in a local science festival and stated that they had received the spark and idea for their project from one of the visits described in this paper.

5 ACKNOWLEDGEMENTS

The authors wish to thank the Google Data Centers Grants Fund of Tides Foundation and the European Social Fund equality project NASEVA (S20777) for the resources of this project.

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Exploring Practices of Establishing and Maintaining Creative Learning Environments

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Conference Key Areas: Teaching creativity & innovation; Innovation as the context for EE; Fostering entrepreneurship

Keywords: creativity, inclusivity, innovation

INTRODUCTION

In the last decade and more there has been a call for teaching creativity and critical thinking. Yet, while instructors find it to be very important, they are unsure of how to incorporate creative learning in undergraduate STEM curriculum [1]. Conflicts gravitate around efforts to both 'teach' creativity and to *foster environments* where creativity will 'naturally' flourish. This struggle signifies the discrepancy between a top-down and bottom-up teaching approach. With top-down instructional methods it is difficult to engender a sense of creative thinking in students; however, the other end of the spectrum appears as directionless learning, which can be unnerving to both instructors who have never taught (or been taught) in this manner as well as students who are accustomed to well-structured classrooms [2].

1 BACKGROUND

The most prevalent model in engineering education is a traditional learning environment that employs lecture-based instruction driven by standardized content. Coupled with tests that assess content competency, these educational practices largely suppress opportunities for creative development [3]. Yet there are still opportunities to shift ownership of content and its application from instructor to student and to thus provide students with more opportunities for original thinking [4]. When students gain confidence

in their learning ability early, they are more apt to engage in adaptive lifelong learning. With reduced structure in classrooms, students become more active in their own learning, which also enhances their understanding of new concepts. Moreover, with a more relaxed classroom environment, it is possible for tangential and emergent concepts to be explored, which creates avenues for interdisciplinarity [4].

Undergraduate classes are largely bound by the discipline in which they are housed, which makes potential connections across them difficult to discern. The application across disciplinary content is an avenue of creativity cultivation that is lost when disciplines are taught in isolation. With the integration across domain knowledge, students and faculty are better prepared for making connections in seemingly unrelated fields [5]. Moreover, in learning environments that facilitate cross-disciplinary work, collaboration is inherently flexible in that students and faculty working across domain spaces must incorporate a level of risk-tolerance and exploration that is less prevalent in traditional learning environments [7]. The difficulty in implementing interdisciplinarity in institutions involves the traditional disciplinary structures of higher education, which inhibit interdisciplinarity for students and faculty. The lack of alignment in faculty pursuit of interdisciplinarity and institutional values surfaces in “departments, budgets, and promotion and tenure” for traditional disciplines [2, p.375]. When faculty face such obstacles, undergraduate students are left without opportunities in class environments to engage in interdisciplinary learning.

The relationships between faculty and students are key in establishing and maintaining creative learning environments. Without avenues for faculty to engage in flexible learning environments and collaborate in the development of less traditional courses, they may lack the experience to engage students in environments in that they are less familiar [5]. In such environments, there is a need to become comfortable with discomfort as faculty and ultimately as students. Conventions of disciplinary assessment largely prevent students from seeing discomfort as a learning experience and more as a barrier to achieving high grades [4, 5]. For flexible learning environments to be effective in cultivating creativity, assessment practices are used best as ongoing practices that focus on student development rather than on their deliverables [8]. Through this study we seek to answer the following research question: *What practices do students, instructors, and facilitators employ to establish and maintain creative environments?*

2 METHODS

We gathered qualitative data by interviewing past and present faculty who have been involved in designing and facilitating courses required in a new program that focuses on innovation. The classes cover critical inquiry, ideation, and market feasibility, with all three classes including content, instructors and students from across disciplines. This study was aimed at answering questions regarding creative learning environments from the perspective of faculty and students.

2.1 Data Collection

We interviewed faculty involved in founding and developing each of the three courses in the program. We interviewed a total of six instructors and eight students. Class observations were gathered from one semester of the class focused on market feasibility. IRB approval has been obtained for this study.

The setting for this study comprised three undergraduate courses each required for an interdisciplinary minor in innovation. The first course, *Innovation in Context*, has been developed for students to learn how to critically analyze innovation and its ideals. The second course in the innovation minor, *Create!*, focuses on ideation and design thinking, in which students work in teams to find, define, and solve real-world problems that require students to engage in perspectives from multiple disciplines. Lastly, *The Startup Class* provides students more opportunities to work in interdisciplinary teams in the context of a modern innovation environment. Students begin to determine the feasibility of commercializing inventive technologies by working with inventors, entrepreneurs, advisors and other collaborators to ultimately take their work outside of the classroom. Each of these courses has been designed and delivered by faculty from different disciplines and is open to students from different majors.

2.3 Data Analysis

Interviews were audio-recorded and transcribed by a professional service and analyzed in conjunction with the course using qualitative coding software NVivo12. We analyzed the transcriptions as we interviewed participants to allow for follow-up questions that could provide a more complex perspective of emerging themes, which follows the method to “cycle back and forth” between the data analysis and collection to reduce blind spots [6, p.70]. We employed an iterative inductive coding strategy to identify emerging themes (Table 1) compared across faculty and student interviews until theoretical saturation.

With regard to limitations of the study, there are several improvements to be made. For instance, although a range of faculty were interviewed, the interviewed students were only from *The Startup Class*, which was in session at the time of the study; future studies will include students from all three courses as well as past students who have taken more than one class, beginning with *Create!* in Fall 2018. Another limitation is that because the innovation minor is new, there are few students who have fulfilled the minor requirements, making it difficult to gather longitudinal insights from their interdisciplinary experiences.

Table 1. Overview of High and Low-Level Codes

	<i>High Level Themes</i>	
	Course Design	Course Implementation
<i>Low Level Themes</i>	Course design is iterative	Focus on process
	Faculty with cross disciplinary backgrounds	Discomfort
	Pragmatism associated with course design	Flexibility in teaching
	Institutional Barriers	Working across disciplines
	Getting students to select the course	Assessment

3 FINDINGS

From the data analysis, we noted several themes in the context of the classroom environment that we grouped into course design and course implementation. These high and low-level themes will be described in further detail in the section below.

3.1 Course Design

When speaking to faculty about their courses, all who were involved in the design of the course referred to it in great length. They highlighted the iterative nature of these courses, and how each iteration was refined based on the past experiences. One of instructors noted that “things take time to develop, and there’s a lot of trial and error and almost administrative things that come out that you don’t think of.” The details of the course began to surface as instructors gained more experience in facilitating a course with more flexibility. From the interviews, we gathered that the faculty see the course design as an ongoing process that they “refine a little bit each year, each semester,” by seeking out feedback from other instructors in the minor and their assessment of students.

In addition, some of the courses have been taught by multiple instructors from different disciplines, which inevitably changes the course’s “flavor.” Faculty who co-taught a course mentioned “a pretty steep learning curve” based on the differences in disciplinary education. This learning curve could be another reason for maintaining the flexible learning environment, in which faculty and students alike are learning how to navigate a space that integrates disciplines. When the faculty teaching teams were larger, a graduate student acted as the point person for logistics to “make sure that the instructors are in the room a half hour before class starts working through issues.” This role of “herding cats” proved instrumental in ensuring that the instructors were able to contribute to the course development while also maintaining their accountability in their other responsibilities as tenure-track faculty. With a logistics coordinator providing the spine of the course, these faculty “subject experts” were able to improve upon an existing plan rather than having to create it all from scratch.

For the faculty designing and implementing the courses, several factors helped shape the first iterations. For *The Startup Class*, there was a grant that initiated the course but once the grant ended, faculty from industrial design and business listed two courses at the same time in the same classroom to have a cross-disciplinary course that would fulfill their teaching requirements. Their literal cross-listing posed problems with “restrictions and constraints in governance and regulation,” which have been gradually overcome as institutional shifts accompany the creation of the minor as part of the university’s new general education initiative. The *Innovation in Context* course was initially adapted by a graduate student from a graduate level course for the undergraduate level. The *Create!* class initially started alongside the founding of an institute on campus, in which the course was “engaging in the essence of the original intention, which was to engage students in this broader process” in the same sense that the institute was trying with faculty. Yet, when *Create!* “connected with business and startup,” “it took a shift” and “ideation” became more prominent in the syllabus. The department the courses are listed in as well as how they are titled has largely been determined by pragmatic collaboration and these decisions have also been largely affected by institutional barriers.

Even in the midst of a university shift toward interdisciplinarity, cross-disciplinary faculty who have led these classes encounter disciplinary boundaries. For faculty, these courses have been difficult to commit to because “no one gets department credit... but everyone commits time and resources to it.” For these commitments to be sustainable, there needs to be a shift in the value the institution places on courses that lay at the intersection of disciplines. This shift would also inform how students come to value interdisciplinarity and better explain why they choose to enroll in these courses.

Within a university with a large engineering population, courses that speak to innovation and business become largely populated by engineering students. For *Create!*, which started out as an honors course and has since been listed as an engineering course, “60-70%” of the students are in engineering. *The Startup Class* is cross-listed in engineering, business, and industrial design, which largely determines the students who choose to enroll. These numbers can sway, however, based on how and where the course is advertised or if it will count for a major requirement. In such cases, students will take the course to fulfill their major requirements. These reasons become important in the implementation of the course; according to one instructor, the course “takes on the flavor of the students,” and thus understanding which students enroll and their reasons can shed light on the effectiveness of the learning environment.

3.2 Course Implementation

From the faculty perspective, students have trouble navigating what is expected of them in a course that has more open-ended deliverables. For many faculty, students come in with the mindset of “tell me what I have to do and I’ll do it,” which is difficult to overcome in a short span of 15 weeks. Many of the instructors noted that the students wrestle with figuring out what the instructor wants before realizing that they “don’t want a perfect solution – a clean product.” These realizations are “reflected in their final presentations” and even in “their conversations they have within their group and across groups.” Getting students to focus more on the process than the product in design is a prominent goal across all the interviewed instructors. Specifically, for *The Startup Class*, one instructor noted that getting to a product or service was “icing on the cake”; learning “how to actually go out and talk to customers...ask good questions...make good hypotheses, and analyze the data” to then “refine the process all over again” was more important than the “icing.”

Yet, getting students to value the learning experience and the process involved a level of discomfort for them and the faculty guiding them through it. For many of the students, the combination of working in different disciplinary spaces and lack of “concrete objectives” caused confusion and struggle. In the *Create!* class, one instructor spoke of a “kind of shock” that students undergo when exposed to disciplines far outside of their own, as an example, guest lectures by professional artists. This shock was something the instructor “didn’t have the knowledge to coach [students] through” and had to unpack with the students, in ways that were uncomfortable for both parties. But by encouraging such a foreign type of navigation in the class, this instructor and students “co-constructed” the discomfort and worked through it rather than compartmentalizing or ignoring it altogether.

When speaking of institutional barriers, faculty expressed the pragmatism they needed to overcome administrative and governance challenges. However, in the actual class, several instructors spoke of their “ownership to tweak” the class “here and there,” while still being “careful to maintain what was proposed and approved through the engineering college.” Once “you’re acting responsibly within those bounds” of governance, “professors come to realize that [they have] pretty good control about what [they] do in [their] own classroom.” This flexibility was seen in the form of guests from across disciplines coming into courses to mentor and coach students in their projects. These guests helped “students get out of their ‘I’m a mechanical engineer’ or ‘I’m a marketing major’” conceptions to “help them realize that this stuff doesn’t exist in a vacuum.” Real-world instances of interdisciplinarity were shown to students through these

guests, such that students could begin to effectively navigate across disciplinary spaces by seeing the value of interdisciplinarity and integrating domain knowledge over 'divide and conquer' approaches in multidisciplinary work.

In these learning environments, students wrestled with cross-disciplinary spaces and shifting thought processes only towards the end of the semester, so consequently instructors had to also focus on their roles as facilitators in effectively coaching students through the discomfort. This manner of "unscripted teaching" necessitated a certain level of risk, in which it was possible for student groups to "go off the rails and ...not do so well." Yet, as a common theme across the courses, "there's something that happens in those last two or three weeks" when instructors note the "pivot in their thinking...and they've caught on." One instructor describes it as when students have "let go of uncertainty... and understand that [their project] doesn't have to be perfect." Yet, waiting for this point each semester can be difficult for newer, inexperienced instructors.

This theme of embracing uncertainty was prevalent, especially in the context of assessment. Student expectations heavily influenced how they navigated through course concepts: some perceived value that did not extend beyond that of an elective that is "set outside" of their discipline. There was a need to break pre-existing, often discipline-specific molds of assessment with which students came into the course. Students from *The Startup Class* from more technical backgrounds (e.g., engineering) "wished to have a little more direction," whereas those from business expressed an appreciation of the freedom. One student maintained that he "thrived on ambiguity" and described how he was often at odds with his engineering teammate. For instructors, these differences can be difficult to work through, but each interviewee focused on assessment as a formative process. The feedback students were given was ongoing and intended to "meet students where they are" and how "they are changing" throughout the semester. Instructors knew each of their students well and could discern how each was changing across the course.

4 DISCUSSION

4.1 Course Design

For each of the courses there are overt and covert notions of design that run through the course's content as well as in the manner by which faculty develop and implement them. The iterations help instructors determine what works in the classroom and what students need more guidance working through. Often faculty must also focus on the experience of implementing these courses, which can be difficult to be satisfied with, especially when students evaluate them with notions of finality. Moreover, the unscripted nature of these courses makes it difficult for faculty to pass on the courses to incoming instructors. Their past teaching experiences govern a lot of what is developed for future iterations, so for newer faculty picking up where more experienced faculty have left off can be a challenge. From the findings, it is clear that the system for passing the courses from instructor to instructor requires intentional guidance for an effective transition to take effect.

From an institutional standpoint, situating the courses in multiple departments and pushing through governance was a challenge. Faculty listed the same course multiple times in different departments so as to attract students from different disciplines and have multiple instructors leading the course. This display of creative pragmatism was common in the set-up of the course and speaks to the adaptability of the faculty to existing governmental structures. This adaptability also served faculty well when confronted with

different student expectations of the course. Each time a course was advertised differently or fulfilled a major requirement, a different set of students enrolled, each with different expectations that changed the dynamic of the course. For faculty this open-ended aspect of the course was challenging, but also added to the verve of course in that faculty were experiencing similar aspects of design that they then tried to instill in the students.

The sustainability of such courses can be difficult to maintain when institutional barriers limit which faculty can take on a course design or instructor role. In courses without a graduate student “cat herder,” establishing a common language among faculty was a recurring challenge, which mirrored that of the cross-disciplinary students tasked with working together. In the courses that were co-taught, faculty experienced similar struggles as the students. This mirroring effect seemed to put faculty in the position of unpacking their own experiences, to then be able to turn the learning experiences into role-modeling and coaching opportunities for students experiencing similar issues. Moreover, there was a certain institutional value placed on the different disciplines when students from different disciplines had mentors from their discipline. In course offerings that involved faculty solely from engineering or business, there may have been a perceived difference in the value that students with majors outside of these could supply. Hints of this sentiment were conveyed by non-engineering students in *The Startup Class*, when they spoke of the heavy technical focus that seemed to drive the course.

The expectations that students bring into each course largely changes the flavor of each offering, and understanding them can be a learning curve in itself for less-experienced faculty. For students who take the class to fulfill a requirement or for students who come in with a startup idea that they plan to pursue post-graduation, there is a vast difference in what each will take out of it. Moreover, these differences can negatively affect how they engage with the material. For instance, the student trying to commercialize their idea comes in focused on the product they have envisioned, seeking to acquire a different set of skills than the student taking the class to fulfill a requirement. There is a clear need to begin the class with an exploration of who the students are such that instructors can adapt to the diversity of disciplines, values, and expectations.

4.2 Course Implementation

In the instruction and facilitation of the course, much of the struggle faculty had was getting students to focus on the process rather than finished products. Students coming out of the majority of K-12 systems as well many undergraduate courses learn the value of grades and deliverables. With these courses, faculty were challenged in dispelling notions that a perfect product would earn students the top results. However, for a 15-week semester class, these pre-existing notions of assessment were difficult to work through. Moreover, even when and if they were overcome, subsequent classes may still foreground the importance of grades through ironclad assessment rubrics.

As these three courses become more established in the institution and known to students in their relation to one another, the issue of time that all the faculty have pointed out might become less of a constraint. In the current model, where students do not pass through each of the courses, there is a notable transition period in which they have to overcome their expectations and begin to realize that “perfect solutions” are not the goal of the course. This shift to focus on the process takes time, but because it is an underlying theme across the courses, many of the current challenges may be mitigated when students take all three of the classes that comprise the minor. Still, conventions of design

focus on products and solutions. To get students to shift their focus to the process requires a certain level of discomfort and trust in their peers and their instructor to ultimately “let go of the uncertainty” as one professor described.

Discomfort plays a major role in cultivating creativity, for when faculty and students become comfortable navigating through discomfort, they learn to engage in processes that they may have shied away from in the past [5]. Contrary to the creative pragmatism employed by faculty in developing and situating their courses within the institution, the flexibility in the classroom has allowed for faculty to take ownership and control of their class environments. Yet, institutional barriers that must be overcome for interdisciplinary courses to supply credit to faculty instructors is a taxing experience and may inhibit the permanence of the minor’s mission. The misalignment between the institutional and course values acts as a recurring challenge that may ultimately tire faculty involved in the minor [2, p. 375]. Moreover, when interdisciplinarity is not overtly valued by the institution, undergraduate conceptions are handicapped at the start.

5 SUMMARY

The creativity of faculty in designing and implementing these courses is clear from how they have valued the process by refining and iterating the course. Stemming from flexibility and pragmatism, the traditional learning manner of instructor to student information transfer is transformed in these environments in which instructors and students learn from each other by maintaining a learning environment that values the process over the product. Future work will situate this study within current literature on creative engineering education pedagogies, with particular focus on project/problem-based learning, which foregrounds similar values.

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First year engineering students' use and orchestration of resources to develop *actual student learning paths*: the cases of Calculus and Linear Algebra

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Introduction

In most western (engineering) universities students now have access to a plethora of resources, both digital/online resources and 'traditional' curriculum resources, such as textbooks, readers, worksheets, provided by the university and by lecturers. In particular in large first year courses (e.g. CA), students are often expected to use and blend the available resources according to their individual needs, to support their learning. The rationale for our study is that, as students now have an ever-increasing range of materials and an ever-widening range of formats to draw on to support their studies, their effective management of these resources is crucial. Moreover, in order to be able to understand (and develop) 'blended' mathematics learning, one has to know, which resources are used by students (from the ones on offer), and how they use them for their learning of mathematics. This, in turn, can inform the designers and teachers/lecturers of blended mathematics courses in their efforts to enhance the courses.

Drawing on recent research in university mathematics education, in a recent review study Biza, Giraldo, Hochmuth, Khakbaz, and Rasmussen (2016) have described the opportunities afforded by introductory university mathematics **textbooks**, and the actual use made of these curriculum materials by students. Anastasakis, Robinson, and Lerman (2017) investigated the **different types of tools** ('external' (to the university) and internally provided resources) that a cohort of second year engineering undergraduates used. Their results showed that, although to some extent students used resources external to their

university, their practices were dominated by tools that their institution provided. The students in their sample chose certain tools mainly because these enabled them to pursue their examination-driven goals. The use of **visual resources** (e.g. online lectures) has been studied by Inglis, Palipana and Ward (2011). Using the Documentational Approach to Didactics Gueudet (2017) investigated mathematics teachers' interactions with resources at university, and Gueudet and Pepin (2018) explored how Brousseau's Didactic Contract can be interpreted, seen through the lens of (the use of) curriculum resources. In terms of LA, Grenier-Boley (2014) investigated LA tutorials: he noticed that the teacher's interventions and the student activity in class were linked to the kind of mathematical tasks chosen by the teacher from a list of exercises.

However, we note here that relatively little research is available on the broad range of resources available to first year university students to learn mathematics, and moreover how students actually orchestrate the resources in order to learn the mathematics. Typically, studies include the curriculum resources made available or recommended as part of mathematics courses, but there are also '**human resources**' (e.g. lecturers, tutors, peers) that students tap into, and **digital** and other resources mobilized by students themselves. In addition, we know little about the roles these various resources play in the intention of the lecturers (as compared to the students'). Inglis et al. (2011) suggest that students might need explicit guidance on how to combine the use of various resources into an effective learning strategy. Before this guidance can be given, or can be reified in a blended learning environment, more in-depth information on their actual use is needed. Hence, we ask the following **research questions**:

How do first year engineering students use and orchestrate the available resources for their learning of Calculus and Linear Algebra in their first year university, and which actual student learning paths can be identified?

Theoretical frames/literature review

The lens of "resources"

In this study we use the notion of "re-source/s" that students have access to and interact with in and for their learning. We assume that the ways university students learn mathematics is influenced/shaped by their use of the various resources at their disposal. By "use of resources" we denote, for example, which resources students choose (amongst the many on offer) and for what purpose (e.g. revision); the ways they align and orchestrate them (e.g. first lecture then checking the textbook); which ones seem central to achieve particular learning goals (e.g. for weekly course work, for examinations). However, we do not address the specific learning of CA and LA, that is how students interact with particular (e.g. cognitive) resources to learn particular topic areas in CA and/or in LA.

Gueudet and Pepin (2018) have defined student resources as anything likely to re-source ("to source again or differently") students' mathematical practice, leaning on Adler's (2000) definition of mathematics "re-sources" (in Adler's case used by teachers). In this study we distinguish between (1) material/traditional text/curriculum resource (including digital resources); and (2) human/social resources. As to (1) material/traditional

text/curriculum resources: a further distinction has been made between (a) curriculum resources (those resources proposed to students and aligned with the course curriculum), and general resources (which students might find/access randomly on the web). Curriculum resources are typically developed, proposed and used by teachers and students for the learning (and teaching) of the course mathematics, inside and outside the classroom (Pepin & Gueudet, 2014). They may include text resources, such as textbooks, readers, and websites and computer software, and, for example, feedback on oral/video-/computer-based work. General resources are the non-curricular material resources mobilized by students, such as general websites (e.g. Wikipedia, YouTube). (2) In terms of human resources we refer to formal or casual human interactions, such as conversations with friends, peers or tutors.

In terms of distinction between the concept of *curriculum resources*, and that of other resources, in an earlier definition Pepin and Gueudet (2014) referred to *mathematics curriculum resources* as “all the resources that are developed and used by teachers and pupils in their interaction with mathematics in/for teaching and learning, inside and outside the classroom.” Curriculum resources would thus include text resources (e.g. textbooks, teacher curricular guidelines, worksheets); other material resources, such as manipulatives and calculators; and web based/digital resources. For the term *blended learning* we adopt a pragmatic approach and define it as “using digital curriculum resources (Pepin, Choppin, Ruthven, & Sinclair 2017) in combination with other resources”, whether they are traditional curriculum resources (e.g. textbooks), or human resources.

Actual student learning paths

The research literature in mathematics and science education shows many different terms and concepts linking to student learning paths, often associated with instructional theory and curriculum design. The following have been used in mathematics and science education: Hypothetical Learning Trajectory (HLT, Simon 1995); Local Instruction Theories (Gravemeijer 2004); Learning Trajectories/ Progressions (Lobato & Walters 2017); Learning trajectories in mathematics education (Weber, Walkington, & Mc Galiard 2015). Whereas some of the approaches focus primarily on learners (see first three in Lobato & Walters (2017), Simon’s (1995) HLT approach includes instructional supports for learning and was originally conceived as part of a model of teachers’ decision making. Simon introduced the term HLT to capture the result of a process in which a teacher posits a conjecture regarding his/her students’ current understanding of a targeted concept (including potential challenges for them) and then develops learning activities that s/he thinks will support them in constructing more sophisticated ways of reasoning toward a particular learning goal. Simon and Tzur (2004) later highlighted the importance of and principles for selecting tasks that promote students’ development of more sophisticated mathematical concepts. Building on this work, Clements and Sarama (2004) define learning trajectories as descriptions of children’s thinking and learning in a specific mathematical domain and a related, conjectured route through a set of instructional tasks designed to

engender those mental processes or actions hypothesized to move children through a developmental progression of levels of thinking, created with the intent of supporting children's achievement of specific goals in that mathematical domain. (p. 83)

Whilst recognizing these important works, we regarded it necessary to coin a term that actually linked to our necessities: (1) when using the lens of resources to investigate students' learning paths, we looked at the alignment and orchestration of resources, not tasks or activities; (2) we investigated learning paths from the students' perspective, how they actually orchestrate² the resources for their own learning (and not how it was done by teachers/lecturers) and how they gave meaning to these self-created/orchestrated paths. We called these Actual Student Learning Paths.

The study

Using a case study approach, we explored two first year mathematics courses in a Dutch engineering university, CA and LA, as our cases. LA was taught to one group of approximately 130 students, mainly mathematics and physics students. CA was taught to approximately 2000 students (obligatory for all first-year students), in 6-7 groups of 300 students each (all types of engineering).

The CA course was organized with six hours of lectures and one hour of tutorials (in small groups of approximately eight students). It was also differentiated at three levels (A, B, and C), according to perceived level of difficulty and with varying level of emphasis on formal aspects of mathematics (e.g. proof). It appeared that the aims of the CA course were to provide students with a basic set of mathematical/computational tools they could subsequently use in their engineering studies and in their future work as engineers.

The LA course was organized with four hours of lecture per week, and three hours of tutorial (in groups of approximately 30 students). The LA learning aims were described as the acquisition of mathematical skills. Moreover, aims of the course were to help students develop the skills and realize the importance of correct mathematical communication, including writing formal proofs. Completing a mathematical writing assignment was part of the course requirements to reach this aim. It appeared that the purpose of LA was to prepare students for higher mathematics (used in the mathematics and physics courses).

In terms of participants: in total 24 students participated in the study: 18 CA students (involved in nine different engineering programs and all taking the B level CA course); 1 CA student who dropped out of university; 5 LA students (all studying for the 'applied mathematics' engineering course). In terms of background, of the interviewed CA students 15 came from secondary schools in the Netherlands, three came from other (international) educational systems.

For this paper we used data from the following data collection strategies for analysis:

- individual and focus group interviews with students (24): 19 CA (incl. 1 drop out) + 5 LA

- students' drawings (see example Figure 1): students were asked to draw Schematic Representation of Resource System (SRRS - see Pepin, Xu, Trouche, & Wang, 2017), and during the interviews students were asked to explain their resource use based on their SRRSs.
- analysis of documents/curriculum materials provided by the university for the students (e.g. examples of past examinations, syllabi, reader/s, textbook/s, video clips, videos of the lectures).

In terms of analysis, the interviews were transcribed and student interviews were analyzed with the help of the ATLAS-ti software. Interview quotations were coded with codes based on the themes from the literature with reference to the use of different resources, and to student approaches to learning mathematics, and then 'constantly compared' with those themes mentioned by students. In the next step student drawings of the *actual student learning paths* were compared with student explanations, what students said and how they explained their learning (and their resource systems), in order to identify patterns of those learning paths.

Results

Overall, students used different/additional resources in the two courses, and they used the available resources differently for LA than for CA: (1) Basically, all LA curriculum resources offered/provided were used, and students worked with them according to the lecturer's guidance. (2) The CA resources seemed to be a large bag of 'tools', a pile of 'bricks', that the students could pick from (according to their needs) and use for their learning. However, how to build an actual learning path for the learning of CA was not clear. These differences appeared to be related to (a) the size and student audience of the courses (130 students in LA; 2000 in CA), and this, in turn, was connected to different organizations of the courses (4 hours lecture and 3 hours tutorials in LA; 6 hours lecture and 1 hour of tutorial in CA); and (b) the organization and alignment of the resources with the assessment/tests. For example, there was a clear intended (by the lecturer) learning path in LA, with exercises aligned with the examinations. Students mentioned that if they worked according to/with the reader and did "all exercises in the reader" (plus of course the weekly assignments), they would pass the examination. In the CA course however, a large number of support tools were proposed (e.g. on the web, in print), with huge number of exercises, tasks, etc. that were not clearly aligned with the end examination. Students said that it was not possible to do all exercises, read all materials provided, and they often had difficulties choosing from the immensity of resources provided.

Using the lens of resources, more precisely we used students' drawings of their resource systems, to identify students' actual learning paths, that is which resources they used and how they orchestrated them for their learning. From these drawings and the accompanying interviews we could identify particular learning paths and different combinations of resource use. The learning path of the LA course appeared to be a traditional, which all students followed, where students could identify 'core resources' (e.g. the reader, past examinations, weekly tests), and where a particular 'blending of resources' was recommended. This would help students to understand the weekly coursework and to pass

the final examination. In addition, students had more help from the tutors and lecturer (which used to be their experience at secondary school).

In contrast, the students on the CA course outlined several learning paths, based on their individual experiences, and for each path different resources came into play/ were blended. For example, and in contrast to our survey results (where the lecture was “ticked” as one of the main resources; see Kock & Pepin, 2018), in their drawings and in the interviews only two students put the lecture as a center point for their learning. It appeared that the lecture was for information, what had to be learnt, rather than for the actual learning.

“If I hear them talk about it, it’s easier for me to revise/practice when I’ve already seen it, heard about it.” (see Joanna’s drawing/writing) below, Figure 1)

At the same time, either the lecture or lecture notes were mentioned by all students as a supporting resource for their learning of CA. Interestingly, a large number of students pointed to human resources, in particular their friends and peers, and the tutor, as main resources. As perhaps expected, books and tests/quizzes/exercises were mentioned as a huge help. Here the digital resources (e.g. You tube; Khan Academy) seemed to gain importance. Altogether, the CA learning paths showed a complex picture of students using a mixture and ever-increasing number of external resources (in particular human and digital nature). Due to a (re-) analysis of the SRRSs in relation to the interviews, we could identify a small number of ‘non-traditional’ but productive *actual student learning paths* that students seemed to develop for themselves, which we claim should be considered (by lecturers/course developers) when aiming to “blend” learning in a course such as the large CA course. (Examples and more explanations will be provided in the presentation at the conference.)

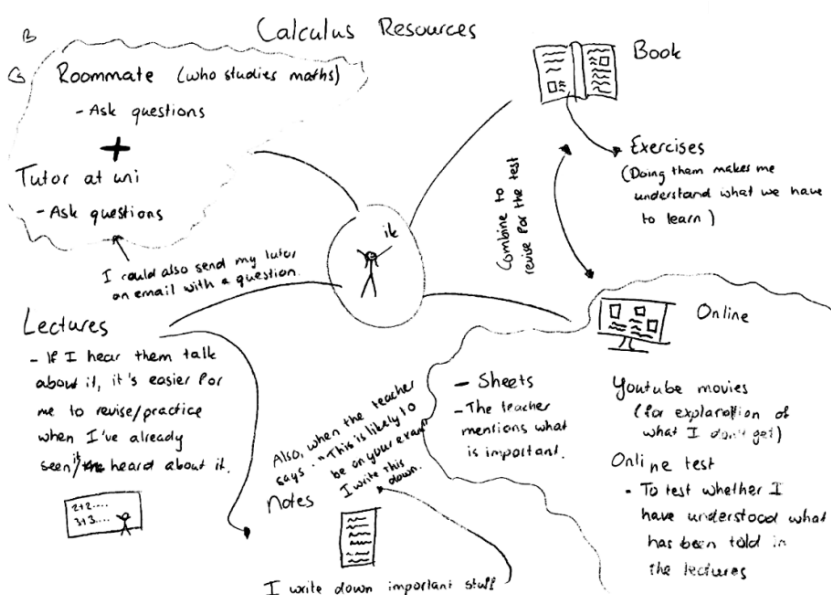


Figure 1 Joanna’s drawing of her resource system

Conclusions

Based on our results we claim that it is not sufficient to provide a plethora of curriculum resources, may they be digital, traditional text or human resources, but that serious consideration should be given to how students might combine these resources, orchestrate them into their preferred individual learning paths. In addition, it is advisable to help, perhaps even to train students how to develop such learning paths, and these might be different from one subject to another (even from one mathematics course to another), in order that students become more effective in their resource use.

This, we claim, is the responsibility of the lecturer/teacher/course designer. Such course development would involve purposeful design, including the development/envisioning of particular (intended) learning paths, possibly considering selected *actual student learning paths*, and the design of particular resources supporting such paths. Simply providing access to curriculum resources may not help students to 'blend their learning' and orchestrate the resources on offer, but may rather confuse and overwhelm them (due to the immensity of resources on offer), and drive them towards "learning for the test". As Anastasakis, Robinson, and Lerman (2017) claim, under such conditions "students use the most popular resources [and] they aim mostly for exam-related goals" and use "certain tools because these enable them to pursue their exam-driven goals" (p. 67).

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Comparison of 1st year student conceptions on their future roles as engineers between Belgium and The Netherlands

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Conference Key Areas: University-Business Cooperation, Engineering Skills, Curriculum Development

Keywords: Employability, Skills, Labour market entry, Professional Roles

INTRODUCTION

Triggering engineering students to reflect on their professional future is an important challenge for engineering institutions. Prior research showed that explicitly articulating student social identity and career goals has beneficial consequences for student learning [1], motivation [2,3] and retention [4].

Research by van den Bogaard [4] on first-year engineering students' study success showed that student who drop out during their first year have more trouble with the

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career perspectives of engineering than students who stay. Already from the start of their educational career, first-year students should therefore be stimulated to reflect on their identity within the engineering professional world. However, Karatas et al. [5] observed that first-year science and engineering students' beliefs about science and engineering are often flawed and unsophisticated. On the one hand, this is not completely surprising given that the engineering domain is very broad and there are endless career directions. On the other hand, to date, there is no overarching international validated framework to let engineering students reflect on their professional future.

Hofland and colleagues [6] have developed a first version of a professional roles framework for engineers based on the value disciplines of Treacy and Wiersema [7]. The study of De Norre and colleagues [8] describes some attempts to raise awareness for professional roles in the bachelor and master curriculum. Based on the results of these two papers, the central focus of the European PREFER project (Professional Roles and Employability of Future EngineerRs) was defined: the validation of a framework of professional roles for engineers and the implementation of dedicated skills education in engineering curricula to train students for this role [9]. The professional roles model is further optimized and validated based on mixed methods research at KU Leuven [10]. The study of the design and implementation of dedicated skills into the curriculum is performed at TU Delft [11]. And DIT, KU Leuven and BDO develop a test to measure the interests and the indications of the levels of mastery of the different professional skills [12].

The prime objective of the present study is to corroborate the research findings observed by De Norre and colleagues [8] and to compare the outcomes of two large representative samples of first-year students in leading engineering institutions in Belgium and The Netherlands. Additionally, we will evaluate the discriminatory power of some general learning outcomes to discriminate between the three professional roles identified by Hofland et al [6].

In this study we investigated which similarities and differences exist between the two populations on their view of their future, their preferred professional role and their preferences to work with people, objects and ideas. We also looked at which competences students feel they are already most developed at as well as the competences they feel they needed to develop most, in light of their preferred professional role.

1 PREFER FRAMEWORK

The development of an overarching framework to frame student perceptions regarding a complex engineering labour market is of paramount importance. Although conceptual frameworks often are a reduction of a complex reality, they offer very concrete opportunities to grasp particular aspects of this reality that goes beyond the engineering specialisation (e.g., electrical engineer, chemical engineer).

In strategic business management, Treacy and Wiersema [7] have put forward three different value disciplines: Operational Excellence, Product Leadership and Customer Intimacy. The main hypothesis of the authors is that companies who manage to focus their strategic vision on one of these value disciplines are more profitable than their competitors. The Treacy and Wiersema model proved to be a valuable framework to look at the variety of engineering functions. Hofland et al. [6] re-engineered the model and

tailored it to the engineering profession: Operational excellence (process optimization & increasing efficiency); Product Leadership (radical innovation & research and development); Customer Intimacy (tailored solutions for individual clients). Using an extensive industry questionnaire, the authors found that 91% of the respondents were able to recognize these different roles in their company.

2 PRESENT STUDY

2.1 Sample

An extensive paper-based questionnaire was administered among 197 first-year students at two campuses of the Faculty of Engineering Technology of KU Leuven, mid 2015 (response rate 41%) and 342 first-year students (response rate 83%) at the Faculty of Aerospace Engineering at TU Delft, mid 2017. The students at KU Leuven were in their 8th week of lectures and the students of TU Delft were in their 3rd week of lectures. All participating students were enrolled for the first time at university and generally did not have any industry experience (in both institutions, internships, company visits, etc. are incorporated in later stages of the engineering curriculum).

2.2 Measurement of professional roles

Using a questionnaire, we gauged students' perceptions of their professional future. Fictional job vacancies were used to measure first-year students preference for the three different professional roles. Each job vacancy consisted of a brief description of the job content and a profile sketch with required competences. For the *Operational Excellence* role, we opted for a team lead in production methods and industrialization (core tasks: analyse production process and implement optimization ideas). For the *Product Leadership* role, a stereotypical research and development vacancy was defined (core tasks: develop new concepts for industrial innovation & explore new market segments). Finally, the *Customer Intimacy* role was operationalised by a vacancy of a technical commercial representative (core tasks: tailored advice to new and existing clients & client portfolio). After choosing their top 3 job vacancies, students were asked to express their preference for working with ideas, objects, or people.

Regarding the required competences, we enquired whether they considered themselves as possessing the right competences for their most preferred job vacancy, based on their subjective perception. Additionally, the 11 official learning outcomes of the Faculty of Engineering Technology (KU Leuven) were presented to them together with a brief definition of each learning outcome (see appendix I). Students were then asked to indicate in which competence they considered themselves to be most, second most and third most competent as well as a top three of competences they felt they still needed to develop.

3 RESULTS

3.1 First-year students view of their professional future

From the answers on the students' view on their professional future (*Fig. 1*) we conclude that only a small proportion of the first-year students (i.e., 9% at KU Leuven and 12% at TU Delft), has a clear view of what they want to do with their engineering degree in the future. The large majority of the students indicate that they more or less know where to go and about 20-30% does not have a clue at all. A Mann-Whitney test was run to see

if the distributions are identical across both universities. Since $U = 27925.00$ and $p > 0.01$, there is no compelling evidence that they differ.

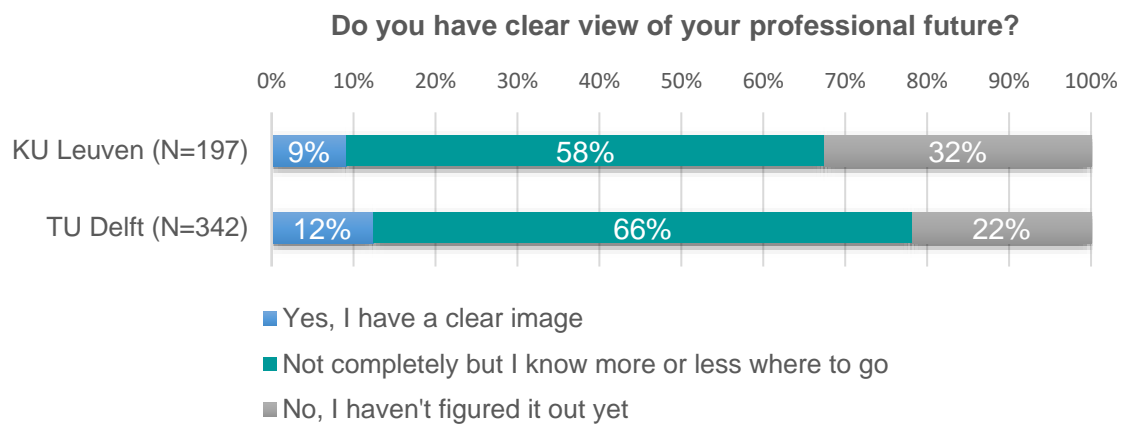


Fig. 1. First-year students' view of their professional future

These findings show that engineering institutions are in a unique position to assist students in shaping their professional future and that targeted interventions in the engineering curriculum (e.g., company visits, guest lectures) are needed.

3.2 Preferred professional role

In order to stimulate first-year students' reflection on this professional future, we offered three fictional job vacancies reflecting the three different professional roles and compared students' preferences (*Fig. 2*).

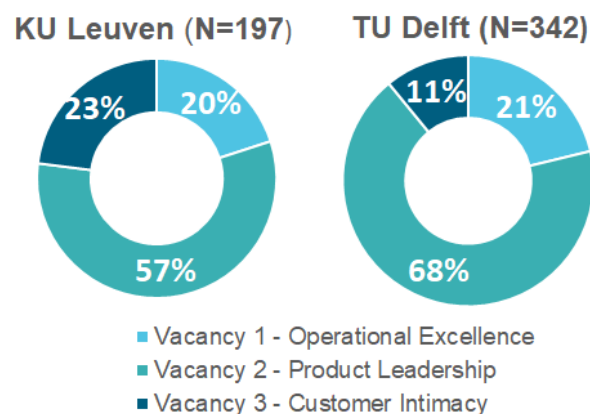


Fig. 2. First-year students' professional role preference at KU Leuven and TU Delft

A Chi-Square test of Homogeneity confirms that the frequency counts are distributed identically across the two populations ($\chi^2(2) = 16.955$, $p < 0.001$). In both engineering institutions, first-year students had a clear preference for the Product Leadership vacancy. This is in line with our expectations since the innovative conceptualisation aspect triggers a substantial proportion of engineering students. Especially at TU Delft,

the Customer Intimacy role (i.e., technical commercial representative) was the least preferred vacancy. In both universities, the Operational Excellence role appealed to one-fifth of the respondents. Altogether, these results indicate that already in an early stage of their educational career at university, students can be successfully triggered to reflect on their professional future. Interestingly, both at KU Leuven and TU Delft the majority of the students indicates there is no vacancy they would not apply for, 64% and 65% respectively. This finding shows that first-year engineering students are very open to their professional future. As a consequence, there are ample opportunities for engineering institutions to guide students towards the labour market entry.

3.3 Preference on working with ideas objects or people

Students with a preference for the customer intimacy role generally indicate that they prefer to work with people (*Table 1*). Both at KU Leuven and TU Delft, students who chose the Operational Excellence vacancy prefer to work with objects and people and to a lesser degree with ideas. For the Product Leadership role, our findings show mixed results. At TU Delft, 50% of these students prefer to work with ideas (and to a lesser extent with objects and people). At KU Leuven, however, this profile is rather flat with high preferences to work with ideas, objects, and people. Also, TU Delft students often only indicated 1 preference, whereas KU Leuven students often indicated multiple preferences.

Table 1. Preference to work with idea, objects or people per professional role

	KU Leuven (N=197)				TU Delft (N=342)		
	Ideas	Objects	People		Ideas	Objects	People
Operational excellence	31%	82%	56%		37%	43%	50%
Product Leadership	67%	72%	66%		50%	45%	29%
Customer Intimacy	35%	50%	92%		25%	14%	69%
General	52%	69%	71%		45%	41%	39%

Note: Students can indicate multiple preferences in working with ideas, objects and people, each counted as a choice. The percentage was then calculated over the number of respondents not the number of different answers.

Another Chi-square analysis was carried out to see if a significant relationship existed between the two groups of student's preferred roles and their preference to work with ideas, people or objects. Again, a highly significant relationship was found with $\chi^2(4) = 40.690$, $p < 0.001$.

3.4 Self-perceived mastery levels competences

When asked about their self-perceived mastery levels of the required competences of their most preferred vacancy, first-year students generally display high confidence levels. Especially at TU Delft, 48% of the respondents indicate that they already have the required competences (*Fig. 3*). Only a small proportion of students (2% and 13%) states that they do not yet possess the right skills.

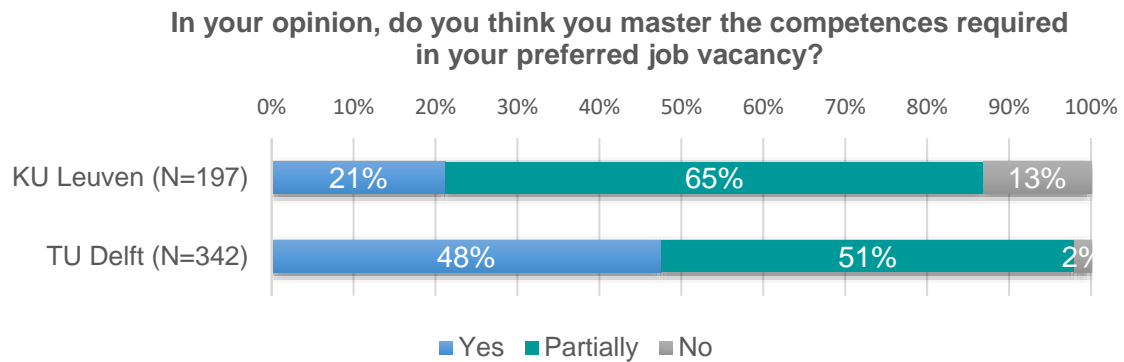


Fig. 3. Self-perceived mastery levels of listed competences

To see if these distributions were significantly different a Mann-Whitney test was carried out. This found that the two distributions differ significantly, $U = 21419$, $p < 0.01$, further research into the possible reasons for this is needed.

However, even per institution this remains an interesting find. If first-year students are already very confident in their own competences, they may perceive certain forms of learning as superfluous and therefore uninteresting, which may in turn have an effect on student motivation. It may therefore be good to have students experience whether or not they actually have mastered all the competencies they need for their preferred job vacancy. This will lead them to make better decisions about their educational choices.

3.5 Most competent and least competent competences

As stated above, each student was also requested to indicate the 3 competences they considered themselves to be most competent in, selected from a given list (appendix I). Based on a weighting scheme (1st Competence: 3 points; 2nd Competence: 2 points; 3rd Competence: 1 points), sum scores were calculated for each of the 11 competences. These sum scores were then ranked within the professional role student expressed their first preference for. The top 5 competences for each professional role are given in *Table 2*.

At KU Leuven, the listed competences for the Operational Excellence and Product Leadership roles were identical except for one competence: design competence (product leadership) and communication (operational excellence). Students with preferences in one of those two roles estimate their problem solving and team work at a very high level. Interestingly, students with a preference for the Customer Intimacy role considered themselves more communicative compared to their peers with a preference for the other two roles.

For TU Delft, we were unable to discriminate between the Operational Excellence and the Product Leadership role based on the listed competences. For these two roles, problem solving, team work, design, critical reflection and professionalism were observed as the most listed. Interestingly, the designing competence appeared higher in the list in the Product Leadership Role (like at KU Leuven), whereas team work was more pronounced in the Operational Excellence role. Students with a preference for the Customer Intimacy role considered themselves to be more competent in entrepreneurship and communication compared to the other two roles.

Table 2. Top five competences students felt they were most competent in grouped per preference for each professional role.

	Operational Excellence	Product Leadership	Customer Intimacy
KU Leuven (N=197)	1. Problem solving - 54	1. Problem solving - 113	1. Communication - 55
	2. Team work - 41	2. Team work - 111	2. Team work - 46
	3. Professionalism - 29	3. Designing - 89	3. Critical reflection - 45
	4. Critical Reflection - 27	4. Critical Reflection - 88	4. Professionalism - 26
	5. Communication - 21	5. Professionalism - 57	5. Ethical behaviour - 26
TU Delft (N=342)	1. Problem solving - 90	1. Problem solving - 298	1. Team work - 30
	2. Team work - 54	2. Design - 212	2. Problem solving - 29
	3. Design - 39	3. Teamwork - 125	3. Entrepreneurship - 27
	4. Critical Reflection - 38	4. Critical Reflection - 119	4. Communication - 24
	5. Professionalism - 36	5. Professionalism - 115	5. Critical reflection - 21

Note. Ranking of competences based on the sum scores for each competence (most competent 3; second most competent 2; third most competent 1).

The competences listed by both sample of first-year students show a high degree of consistency. The competences mentioned in the column of product leadership are identical. Interestingly, a number of competences were listed significantly less (e.g., application-oriented research, entrepreneurship, and information processing). Potentially, these competences are not well-known or are not addressed in secondary education.

Table 3. Top five competences students feel they still need to develop further grouped per preference for each professional role.

	Operational Excellence	Product Leadership	Customer Intimacy
KU Leuven (N=197)	1. Problem solving - 63	1. Problem solving - 134	1. Problem Solving - 68
	2. Designing - 49	2. Designing - 107	2. Designing - 50
	3. Communication - 30	3. Application Oriented Research - 87	3. Professionalism - 38
	4. Entrepreneurship - 26	4. Professionalism - 75	4. Application Oriented Research - 30
	5. Teamwork - 18	5. Entrepreneurship - 63	5. Entrepreneurship - 26
TU Delft (N=342)	1. Problem solving - 65	1. Problem solving - 202	1. Problem Solving - 38
	2. Communication - 47	2. Designing - 159	2. Designing - 37
	3. Entrepreneurship - 44	3. Teamwork - 155	3. Entrepreneurship - 30
	4. Critical Reflection - 42	4. Communication - 148	4. Communication - 16
	5. Professionalism - 41	5. Entrepreneurship - 136	5. Professionalism - 21

Note. Ranking of competences based on the sum scores for each competence (most competent 3; second most competent 2; third most competent 1).

Finally, students were asked to give a top 3 of competencies they feel they need to develop the most. Again, we calculated sum scores per preference and ranked them

within the professional role the student expressed their first preference for. The results can be found in *Table 3*.

Again, we see little real distinction between choices in every profile. Problem solving remains number 1 in all the lists. There is an apparent contradiction here, if we also take into account the outcomes reported in table 2. Students on the one hand feel most competent in problem solving but on the other hand also prioritize this competency when asked which competency they feel they need to develop further. This is also the case for at least two more competences in each role. This requires further investigation. On the other hand, we can see the desire by students to learn about entrepreneurship and application-oriented research. Although included in the KU Leuven curriculum, entrepreneurship is not mandatory included in the TU Delft curriculum. This may be something for TU Delft to consider given the outcomes. It is also worthwhile to mention that the competency the students least feel they need to develop further is ethical behaviour, which is in stark contrast with current universities', governments' and public opinion. Perhaps this is also indicative of their (in)ability to critically reflect as shown by their contradictory answers to the question whether they have mastered the competences required for their preferred future role.

If we assume that the competences students deem themselves good at, as well as those students feel they need developing, are predictive of the competences needed to carry out their professional role and given the high degree of consistency in the listed competencies, the general learning outcomes of the Faculty of Engineering Technology at KU Leuven do not appear to lend themselves to empirically discriminate between the three professional roles. This is especially true for the difference between the Operational Excellence and Product Leadership role. This finding suggests that more fine-tuning is required with more detailed behavioural indicators. Another possible explanation is that the three vacancies are not well described and do not distinguish enough between the three roles.

4 CONCLUSIONS AND RECOMMENDATIONS

In the present study we examined first-year students' perceptions of their professional future at two leading engineering institutions in European countries. Our findings (see Fig. 1) indicate that first-year students across both universities feel they do not have a clear view on their professional future. Since this lack is one of the contributing factors in student drop-out during the first year, we advise to increase the attention spent on the future disciplinary self during the first year at university.

Based on fictional job vacancies we let students reflect on different professional roles. We saw no differences between the two institutions. Product leadership seems to be the most attractive professional role. This can be explained since 'innovation' is a very popular term resulting in frequent use during classes.

The self-assessed level of preparedness for student's future roles is high, especially at TU Delft. This may lead to a dangerous form of students overestimating themselves and therefore denying themselves the acquisition of required competences. It may be worthwhile to have students reassess their actual competence level against a set standard so that they may verify their perception and adjust their learning strategies accordingly. This may be particularly true for their ethical behaviour skills as students overwhelmingly do not list them in their top three competences for development.

Students also indicate their need to develop their entrepreneurial competences as well as application-oriented research. Application-oriented research skills are part of both curricula; however, entrepreneurship is not mandatory at TU Delft. The outcomes of the survey may give reason to reconsider this.

Finally, the generally defined learning outcomes used in this research appear not to be sufficiently fine-tuned to empirically discriminate between the three different professional roles. More research is needed to identify the defining elements, skills, and competences of each professional role.

ACKNOWLEDGEMENTS

This work was supported by Erasmus+ programme of the European Union (grant agreement 575778-EPP-1-2016-1-BE-EPPKA2-KA) and is part of the PREFER project. The authors would like to thank their colleagues in the project as well as those colleagues who assisted with the rolling out of the questionnaire.

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APPENDIX I

	<i>Competence</i>	<i>Description</i>
1	Problem solving and analysis	Analytical thinking – A systematic approach for solving complex problems – Master complexity
2	Designing and developing	Plan and execute a creative design/development project
3	Application-oriented research	Formulate problem statement – plan a research project – selecting research methods
4	Ethical behaviour	Responsible behaviour for society and environment
5	Entrepreneurship	Taking initiative and have an eye for economical and organizational boundary conditions
6	To make operational	Executing basic, practical, discipline-specific acts and managing processes, systems and installations.
7	Information processing	Looking up, evaluating and processing scientific and technical information, and correctly referring to the information.
8	Communication	The correct usage of scientific and discipline-specific terminology and communicating in a second language that is relevant to the programme; Adequately documenting the results of one's own research, for both engineers and non-engineers.
9	Teamwork	Working as a team member in one or several roles and taking (shared) responsibility for establishing and achieving the team's goals.
10	Professionalism	working meticulously and demonstrating scientific and technical curiosity. Attention to planning and feasibility
11	Critical reflection	critically reflecting on one's own functioning and shortcomings independently; Dealing with contradictory sources critically and independently

A symbolic constructivist approach to exploring the philosophy and values of engineering

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Conference Key Areas: Philosophy & Purpose of Engineering Education, Continuing Engineering Education and Lifelong Learning,

Keywords: philosophy, symbolic constructivism, reflexive practice

INTRODUCTION

The global challenges of the future require engineers to be more reflexive and aware of the diverse cultural values, perspectives and philosophies that impact engineering practice and education. Yet, for the most part, engineering problem solving is embedded in Western philosophy, which has dominated the modern world. How can engineers become more conscious of the diverse worldviews, values, philosophies and dynamics that drive decision-making in world of ever-increasing complexity? This paper describes a methodology founded in a symbolic constructivist research approach which originated in psychologically oriented fields such as Jungian analytical psychology. The method allows for nonconscious material to be made evident and provides a way of expressing emotions and experiences that are often tacit and difficult to verbalise. As a case study to illustrate the method we present here part of our research where we invited engineering educators to co-construct a symbolic representation of three worldviews – Western, Engineering and Australian Indigenous – using wooden blocks and plastic figures. Collectively we explored the possible meanings of the symbols and metaphors created. We offer the methodology as a tool for opening discussions, for exploring intersubjectively-created understanding, and for undertaking research on the philosophy, values and worldviews that underpin engineering, be they those that currently dominate engineering education or those that are inadequately represented.

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1 BACKGROUND

This project continues our research into issues underpinning the low numbers of Indigenous engineers and engineering students in Australia. According to 2011 Census data, Indigenous people make up around 0.13% of university qualified engineers, compared to 3% of the overall population. A major outcome of the project was the development of a model for guiding the embedding of the perspectives of Aboriginal students and communities into engineering curricula [1]. The model comprises five sections – *Start with a new philosophy; Explore engineering from three perspectives; Consider and validate ‘an’ Aboriginal perspective; Engaging Aboriginal community; and Tailor the learning environment.*

Our research has indicated that a major challenge to embedding Aboriginal perspectives in the engineering curriculum lies in the first stage of the model – ‘Start with a new philosophy’ [2]. Further, while motivations and values indicate that there is significant support for embedding Aboriginal (and other) perspectives, there is a very small base of knowledge and experience of Aboriginal knowledges and worldviews and how they may change engineering itself [3].

The aim of the research presented in this paper was to expand one section of the model – *Explore engineering from three perspectives* (see Figure 1). In order to integrate the knowledge, philosophy and values of different worldviews into the engineering curriculum there is a need to know how engineering educators understand and differentiate between worldviews – and in this case the worldviews from a Western, an Engineering and an Indigenous perspective. But firstly, we need to ask “What is a worldview, and why is it important?”

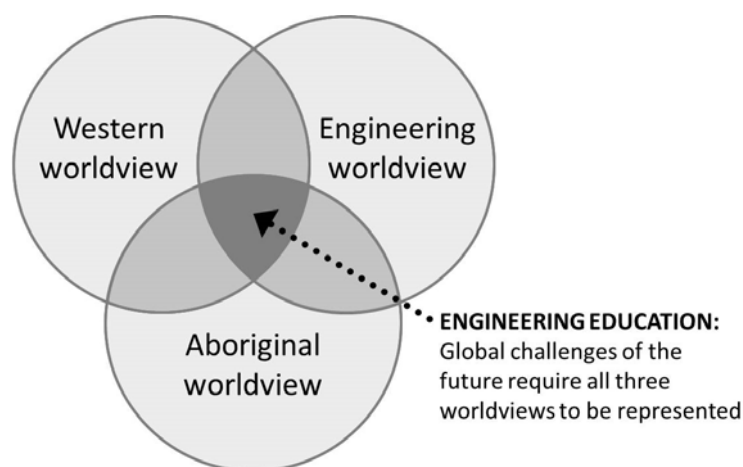


Figure 1. Bringing together three worldviews

1.1 What is a worldview?

The concept of worldviews has been described as the cognitive, perceptual and affective maps through which an individual interprets the world and interacts with it. These maps are developed throughout a person's lifetime through socialisation and social interaction. They are encompassing and pervasive in both adherence and influence. Yet they are usually taken for granted unconsciously and uncritically as the way things are. It also has been suggested that in any society there is a dominant worldview that is held by most members of that society [4].

James Sire, in his book *Naming the Elephant: Worldview as a Concept* [5, p. 16], highlights “two characteristics of any worldview: its understanding of prime reality and its pretheoretical (intuitive) character”. He expands on this (p, 141) to define a world view as “... a commitment, a fundamental orientation of the heart, that can be expressed as a story or a set of presuppositions (assumptions which may be true, partially true or entirely false) which we hold (consciously or subconsciously, consistently or inconsistently) about the basic constitutions of reality, and that provides the foundation on which we live and move and have our being”.

For sociologist Karl Mannheim, worldviews are virtually unconscious phenomena, which are taken for granted and are the prime movers in thought and action. More importantly he emphasis that, “as long as one does not call his own position into question but regards it as absolute, while interpreting his opponents’ ideas as a mere function of the social positions they occupy, the decisive step forward has not been taken” [6].

A worldview then involves the mind, and more importantly, the heart. But more fundamentally, the essence of a worldview involves first and foremost what lies deep in the inner recesses of the human self (unconscious). Therefore any research method used to explore worldviews needs to take into account the social and collective development of worldviews, provide a means for unconscious narratives to emerge and allow for reflexivity. With this in mind, symbolic constructivism was used as the research method of choice.

2 METHOD

2.1 Symbolic constructivism

Symbolic constructivism has its origins in the works of psychologist Carl Jung, who in 1912 wrote *The Psychology of the Unconscious*, where he distinguished between direct thinking, which leads to coherent logical patterns, and symbolic thinking, which is image-based and controlled by the unconscious [7]. Research over the years has shown that symbolic thought is both embodied and emotional [8-10].

Central to symbolic constructivism is the concept of symbol, which designates something that seemingly has determinable, sign-like form(s), meaning(s), and use(s) and that acts as a gateway to other understandings [11].

Symbolic constructivism is emerging as a qualitative research approach that uses an art-based portrayal (which can include drawings, photographs, sculpture, dramatisation) to elicit, explore, challenge, and shift existing sense-making frameworks. In the 1990s LEGO® developed a methodology called LEGO® Serious Play™ (LSP), where participants, primarily in a business context, use LEGO® bricks to build symbolic and metaphorical models and present them to other participants [12]. The method is strongly influenced by psychological theories of learning, and calls on ideas of play, constructionism, the Hand-Mind Connection, the use of metaphors and complex adaptive systems (emergence). More recently LSP has been adopted for use in a number of educational contexts [13].

2.2 Procedure

The participants for this study attended one of two workshops – “*Indigenous Engineering: Looking at Engineering from Different Perspectives, Practices and Principles*”, and “*Shifting Perspectives – Changing Direction: Integrating Aboriginal Engineering into Modern Engineering Curricula*”. Collectively the workshops brought together 32 engineering educators from a total of eleven universities around Australia and New Zealand who were interested in exploring how they might integrate

Indigenous perspectives into the engineering curriculum. All academic levels within Schools of Engineering were represented, from Associate Dean Teaching and Learning to tutor and included one administrative staff member and three people from outside the university sector. One person was Indigenous. There was a variety of previous experience with Aboriginal people or communities.

The goal of the workshops was for participants to explore their understanding of three worldviews (Western, Engineering and Indigenous) by constructing a symbolic 'landscape', and to reflect on how this might impact engineering education. There are three phases to the method.

Phase 1: Introduction

After a brief introduction to the goal of the workshop, the guidelines were explained:

- everybody takes part and contributes to building the symbolic landscape
- there is no ONE right answer
- there is no prescribed way of laying out the landscape
- play is an essential component [14]
- trust your hands and the process
- on completion, there will be a collective exploration of the symbols/metaphors
- finally we will reflect on implications for engineering education

Participants were then asked to choose a worldview they would like to explore and to group themselves accordingly.

Phase 2: Construction

Each group was given a large sheet of brown paper, a random collection of wooden blocks, Paymobil® plastic human figures, sticky notes and pens and invited to collectively create a symbolic representation of their chosen worldview. Construction began with a short period during which time participants 'played' with the blocks and figures while listening to each other's individual understanding of the chosen worldview. As this activity proceeded discussion became more focused, and participants in each group contributed to a shared construction.

Phase 3: Participatory meaning-making and reflection

When each group had completed their symbolic construction, we all gathered at each worldview landscape in turn. Each presenting group shared the meanings they assigned to the various constructions and object placements. Then the audience shared their reactions and responses, asked questions and explored further possible symbolic and metaphoric interpretations and understandings. By this process we were able to arrive at a collective understanding of the significance of each worldview landscape.

Occasionally, an individual commented about a construction they had placed in the landscape, saying "I have no idea what this might mean", or "I don't know why I put that there". This opened up the discussion to even further exploration with other participants offering possible perspectives. This can be a critical moment in the process and, indeed, a benefit of the method, since it allows an exploration of aspects that may not be fully conscious.

To add further depth and richness to the discussions each symbolic landscape was viewed as a 'rich picture' [15] and a Jungian picture interpretation framework [16] (see *Figure 2*) was used to support meaning-making of symbolic landscape.

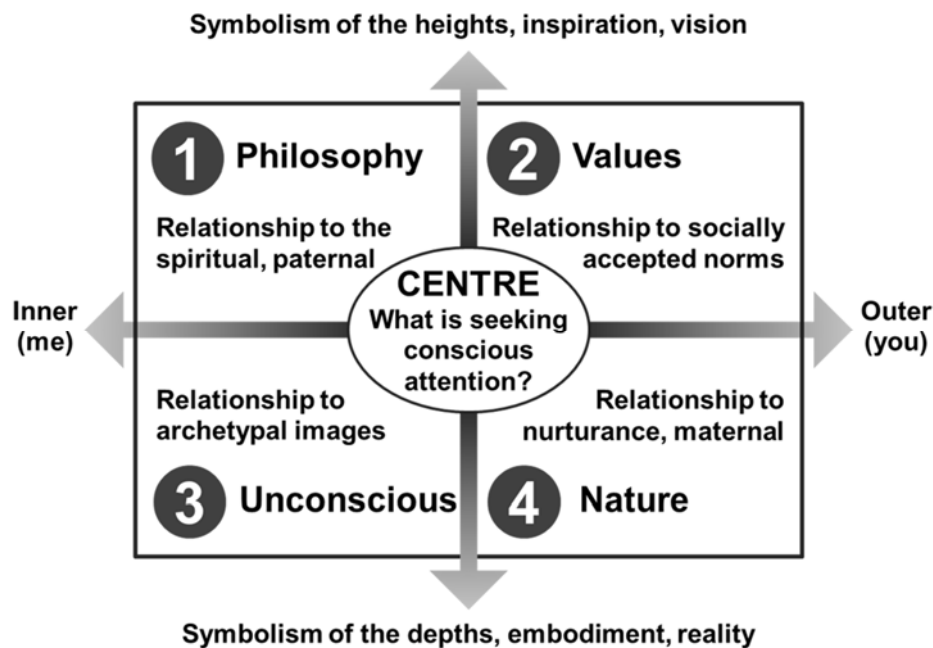


Figure 2. Jungian picture interpretation framework

3 RESULTS

Since the intention of this paper is to describe the symbolic constructivist methodology, only a limited analysis is presented here. A separate journal paper with a detailed analysis of the outcomes of the two workshops is in preparation.

3.1 Symbolic landscapes

Three of the symbolic landscapes constructed during one of the workshops are shown here (see Figures 3-5). Each landscape was photographed and annotations based on the final group discussions have been added to each worldview landscape to identify key individual features.

Western worldview

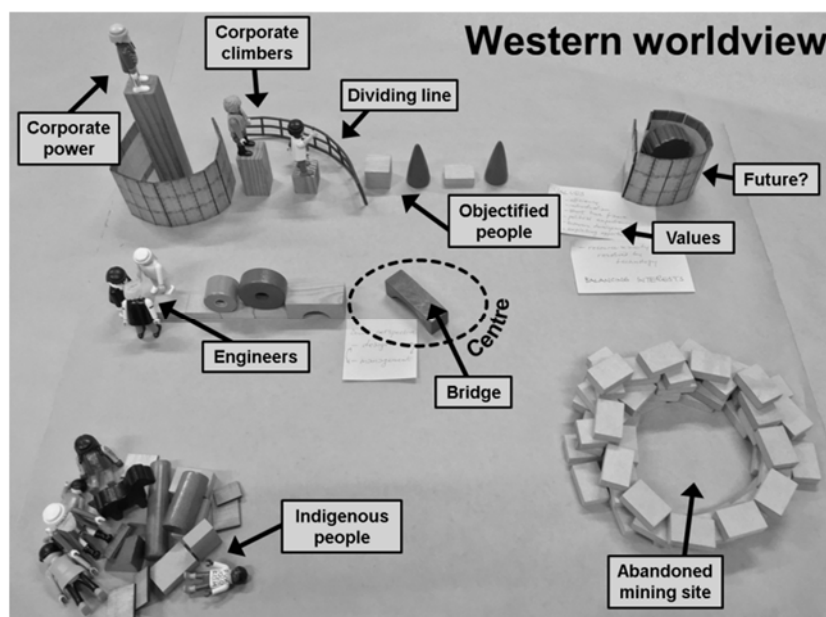


Figure 3. Symbolic construction of the Western worldview

Presentation of the Western worldview symbolic landscape (see *Figure 3*) began with the statement: “We have constructed all three worldviews”. The ensuing discussion explored how this might reflect an underlying philosophy that “we know everything!”, as further exemplified by the elaborate and considered construction in the ‘philosophy’ corner. This was in stark contrast to the placing of Indigenous people as an undifferentiated mass in the ‘unconscious corner’ of the landscape.

Some of the themes that emerged from the discussion are shown in *Table 1*.

Table 1. Themes emerging from exploration of the Western worldview.

Philosophy	Values
<ul style="list-style-type: none"> dominated by corporate power corporate climbing is important a dividing line between the ‘haves’ and the ‘have nots’ ‘ordinary’ people objectified with little time for relationship technical focus to problem solving 	<ul style="list-style-type: none"> efficiency individualism short time frame political expediency economic development exploring opportunity resource scarcity resolvable by technology
Unconscious	Nature
<ul style="list-style-type: none"> very little knowledge of Aboriginal people and Indigenous culture 	<ul style="list-style-type: none"> natural world is to be dominated and controlled, exploited without question little accountability for environmental impact
Centre – What is seeking conscious attention?	
<ul style="list-style-type: none"> How to bridge a corporate worldview with an Indigenous worldview? How to bridge a philosophy of materialism and corporate climbing with an accountability for environmental impact? 	

Engineering worldview

Construction of the engineering landscape (see *Figure 4*) began with participants competing to build the highest tower. A number of towers were built, toppled, and then rebuilt.

The church in the bottom right quadrant was the last construction added with the people included almost as an afterthought.



Figure 4. Symbolic construction of the engineering worldview

Some of the themes that emerged from the discussion are shown in *Table 2*.

Table 2. Themes emerging from exploration of the engineering worldview.

Philosophy	Values
<ul style="list-style-type: none"> empty, except for a scattering a wooden blocks towards the bottom of the quadrant Does engineering, as a very 'practical' discipline require a philosophy and values? Do the philosophies and values underpinning engineering need to made conscious and articulated? 	
Unconscious	Nature
<ul style="list-style-type: none"> because engineers are at the mercy of regulatory bodies and private ('pirate') developers: <ul style="list-style-type: none"> – there is a sense of meeting the minimum standard – creativity is constrained 	<ul style="list-style-type: none"> engineers construct buildings and infrastructure to support and 'nurture' society people added as an afterthought
Centre – What is seeking conscious attention?	
<ul style="list-style-type: none"> strength is important engineering can be visionary and inspirational engineers make sure that constructions are dependable 	

Indigenous worldview

It is important to note that the landscape symbolising the Indigenous worldview (see *Figure 5*) was constructed by non-Indigenous people and is therefore a Western perspective of an Indigenous worldview.

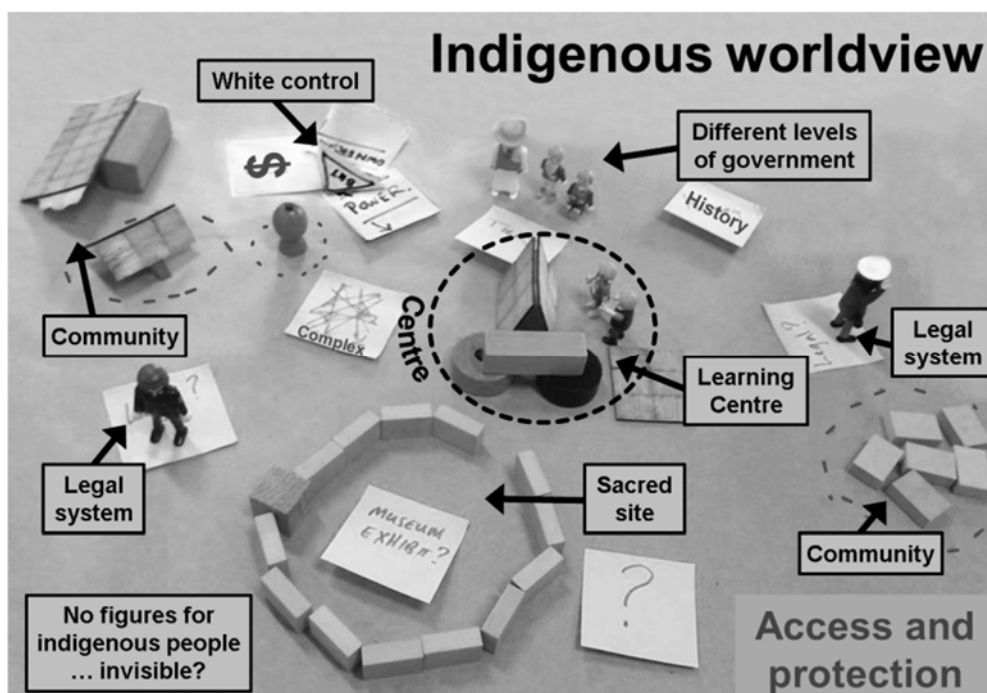


Figure 5. Symbolic construction of the Indigenous worldview

In contrast to the previous two landscapes, it was more difficult to explore the symbols of the Indigenous worldview landscape using the Jungian picture interpretation framework, which suggested that collectively our understanding of Aboriginal people and culture was difficult to frame. The participatory sense-making and reflexive discussion around this lands

cape opened up an exploration of some of the challenges of integrating a different worldview into the traditional engineering education framework.

The themes emerging from the discussions of this landscape are shown in Table 3, and are framed as questions engineering education may need to ask.

Table 3. Implications of some of the themes emerging from exploration of the Indigenous worldview.

General observations	
<ul style="list-style-type: none"> • absence of any Playmobil® figures to represent Aboriginal people – and the difficulty this implies in developing relationships with people who are invisible • the number of question marks in the landscape – suggesting the importance of acknowledging ignorance about Aboriginal culture • the repeated placement of figures symbolising legal systems – what is the legality of sharing Indigenous knowledge? 	
Philosophy	Values
<ul style="list-style-type: none"> • control by dominant culture – important to acknowledge equal sovereignty in relation to knowledge and worldview • community and focus on relationship – in contrast to focus on task 	<ul style="list-style-type: none"> • it is critical to acknowledge the history of Aboriginal people and the impact this has on engagement of Indigenous students in engineering • the value of Ancestral knowledge in current times
Unconscious	Nature
<ul style="list-style-type: none"> • circle – circular vs linear thinking • How might engineering education acknowledge the sacred? • There is a danger that Indigenous knowledge could become a 'museum exhibit' that is not seen as relevant or accessible to engineers 	<ul style="list-style-type: none"> • community provides nurturing and support • implications of collectivist compared with individualistic learning
Centre – What is seeking conscious attention?	
<ul style="list-style-type: none"> • Aboriginal culture and worldview has much to offer engineering education • How to integrate Aboriginal pedagogies in engineering education 	

4 Discussion and impact for engineering education

This paper presents a powerful methodology that can be applied to researching attitudes, beliefs, expectations, values and understanding (and much more) in contexts ranging from curriculum design to classroom pedagogy, problem solving and scenario evaluation. Its symbolic constructivist approach catalyses and facilitates sense-making and allows non-conscious material to be brought into the light and discussed, greatly expanding the depth of exploration and richness of insight around the subject being addressed.

The application of the methodology presented here has enabled a deeper exploration with participants of complex issues around underrepresentation in engineering. In this case, the exploration of Australian Aboriginal perspectives in relation to dominant Western worldviews and traditional engineering worldviews. Departure from the more common approach of sharing thoughts through text and verbalisation of ideas gives participants the opportunity to consider and question not just the views of others, but their own. It also provides the necessary stimulus for participants to express views and consider meanings that were previously difficult to put into words. In this instance, the method highlighted the inherent challenges in integration, or even respectful acknowledgement of worldviews that are not adequately represented in engineering education (in this case Aboriginal Australian). Although initiatives aimed at greater diversity and inclusion are increasingly common in engineering education and industry, deeper analysis of unconscious values and belief systems that have resulted in current underrepresentation of particular groups is critical.

The authors believe that this methodology could prove useful as an alternative method for workshopping a range of complex issues within engineering education where unconscious values and belief systems (also termed unconscious bias) can have such significant impact on enacting positive change.

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Using TRIZ for teaching innovation and creativity

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Conference Key Areas: Industry and engineering education, Education Concept
Specific for Engineering, Active Learning

Keywords: TRIZ, engineering education, creativity, curricula

INTRODUCTION

In the field of engineering education, great emphasis has been posed on developing innovative and appealing curriculum, with a major concern on innovation. Already in

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the 1990, the industry expressed concerns on how traditional engineering education can negatively impact on the creative potential of students and future engineers [1].

This because a lack of creativity represents a constrain in a rapidly changing technology world, while generating new ideas is essential for firms to survive and for social systems to evolve. Companies are increasing competing in no stable arenas and the commercial environment is suggesting that opportunities for innovative designs are accelerating [1]. For management engineering, challenges increase on how to innovate systematically without restricting creativity or overthinking customers' needs [2]. Often, this leads people to reduce the risk of failures by trying to find specific solutions to a problem and not considering the transfer between disciplines that could suggest more innovative solutions [3].

In the last years, creativity has been ranked by both industry and academia as a high desired "best practices" for new graduate engineers. Specifically, creative problem solving, innovation skills and the ability to save costs are recognised as important skills for engineering students. Furthermore, engineers must be able to balance trade offs. Innovative designs and solutions need to be built around conflicting performance parameters, where speed and reliability, quality and cost are acknowledged [1].

For the aforementioned reasons, difficulties in inserting the required skills in engineering studies are clear. Design and innovation processes are full of uncertainty and it is even more difficult to teach the required skills in engineering courses. The call to develop methods, models and theoretical discussions to spur creativity is open among scholars and practitioners. During the years, universities have responded to these calls by adding more design content and introducing more open-ended design problems into their engineering curricula [1].

However, students' curricula that aim to improve problem solving and innovation abilities are still a challenging task for professors when deciding the topics to be included in course programs. This also because cognitive processes such as divergent thinking, working memory, and relational reasoning required for creative problem solving are not well understood [4].

In this setting, the TRIZ methodology, a Russian acronym that stays for Theory of Inventive Problem Solving, represents a method for improving the originality and novelty of the designs generated by engineers and helps to work on the cognitive process afore mentioned [4]. It speeds up the innovation process, by generating an abstraction of systems and provides a systematic approach to analyse problems by using many tools such as the 40 inventive principles, the matrix of contradictions, the laws of technical system evolution and the substance-field analysis. It helps in identifying ways to transfer knowledge between different fields and guides the directions of innovations by establishing a system into which all known solutions can be placed, covering large proportions of physical, chemical and mathematical knowledge-base. This because knowledge is built at different levels of abstraction and it is independent from the specific application field. Moreover, due to its tension towards highly innovative solutions, TRIZ enable to reduce the content/use of Information, Time, Energy, Materials, Space (ITEMS) [5].

Different studies suggest how TRIZ helps to spur student creativity. Empirical studies emphasise the importance of involving engineering students in specialised courses on thinking and problem solving [6]. Moreover, it was found that while TRIZ tends to reduce the number of new ideas of design, they are significantly more innovative than other produced without a structured problem-solving approach [6].

Currently, TRIZ is adopted by universities and companies such as Samsung and Boeing. It has been integrated with other tools, as Function Decomposition Modelling (FDM) or other methods like Axiomatic Design (AD) despite of the different purposes. In addition, TRIZ alternatives arose during the years, as for example OTSM-TRIZ and TOP-TRIZ. Nevertheless, guidelines on how to teach TRIZ within engineering course have not been clearly defined [5].

On these grounds, to answer the research question “how TRIZ can be designed to spur engineering student creativity”, the current work proposes a picture of TRIZ, with a specific focus on education, and its potential exploitation for enriching engineering students’ curricula in innovation. From a review of the literature, we propose and test a framework for teaching TRIZ in engineering courses. Then, we try to verify if the framework follows the line of evolution of TRIZ literature, by adopting a Systematic Literature Network Analysis (SLNA) and a detailed analysis of the keywords. In conclusion, we point out directions of improvement for the proposed framework [7].

1 MATERIAL AND METHODS

In order to develop a framework for using TRIZ in teaching innovation, the methodology followed two main steps.

First, we reviewed the main articles related to TRIZ and TRIZ in education, with the aim to set up a “lean” framework for teaching TRIZ in engineering courses. Starting from the Altshuller’s proposition, we analysed the literature devoted to TRIZ education. We used the Scopus Database to extract all articles and conference papers mainly concerning practical applications of TRIZ in education. This allowed us to identify a framework for teaching TRIZ, that describes the main logical phases and the tools to be proposed. Then, we empirically tested the proposed framework in an international class of students enrolled in an industrial engineering degree, during Innovation Management and New Product Development course. This allowed us to check the feasibility of the proposed framework in a practical setting and detect possible weaknesses of it.

Second, we performed a part of the SLNA methodology, to verify whether the proposed framework is coherent with the evolutionary path of theory on TRIZ in education and to identify opportunities for further improvements. We applied a Systematic Literature Review (SLR) to select the most relevant papers on TRIZ and then we analysed them by means of bibliometric tools. After the definition of the scope of analysis, we located the study using as “keywords” TRIZ in abstract, title and keyword of Scopus database. Then, we analysed the abstract of all papers, cleaning from the ones that used TRIZ tool with a different meaning. Then, for the selected papers we identified the strong connected component and we applied bibliographic network tool called Louvain community. It permitted to define the communities where the topic of “education” is present. Then, for the selected communities we used some network visualisation tools for facilitating the investigation. For these communities, we extracted the keywords and their evolution over time and we compared the emerging trends against our proposed framework.

2 TRIZ THEORY AND A PROPOSED FRAMEWORK

Altshuller, the inventor of TRIZ, at the beginning of the XX century tried to structure the knowledge already available within the patents, by pointing out the patterns of technological evolution. Then, it made available this knowledge to all fields, that normally are highly specialized and focused on their own knowledge [8].

He set up a process to govern the creative development of new ideas. Thanks to the patent categorization, he discovered that often different industries, solve similar problems by applying the same principles, that could be reduced to a total of 40 fundamental inventive principles. In this setting, he realized that unsolved problems are matter of unresolved contradictions, in the sense that if the inventor tried to increase a parameter, it will impact negatively on others [8].

Then, Altshuller realized that the innovative solutions should not be found by trying to solve each single problem with a specific solution. The process needs a level of abstraction, where the aim is to identify categories of problems and then workout the “general solution” for each category. Following this reasoning, 4 main phases were suggested by Altshuller: starting with the “specific problem”, people should abstract to the “general problem” and then detail the “general solution”. Only then it is possible to detail the “specific problem” (see Fig. 1).

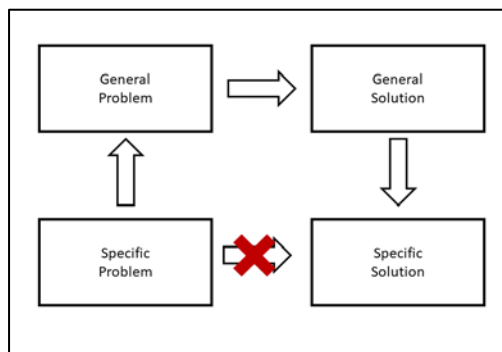


Fig. 1. Artshuller's TRIZ framework

Several tools have been adopted to teach TRIZ. For example, the contradiction matrix has been usually identified as a tool for generalising problems and the 40 inventive principles are usually associated with the identification of “general solutions”. But “lean” and standard guidelines on how to teach the whole TRIZ process have not been developed yet. Hereafter, in order to answer the research question: how TRIZ can be designed to spur engineering student creativity, we try to build such “lean” approach by a systematic re-

organisation of the main suggestions drawn from the literature and imprinting them on engineering students that own technical skills and analytical abilities.

Starting from the first phase of the TRIZ approach, to identify the “specific problem” of a technology, the literature suggests detailing the Situation Analysis (SA). It aims to question people about the problem perception. On this aspect, students are forced to think about the full system and describe the situation in which the object can be placed. It is a detailed description of the technology entire life, by considering real situations. According to the literature, two different ways can be adopted to describe the technology life, one more structured that accounts for the different functions of the technology [9] and one more qualitative that described the full life of the technology [6]. Moreover, still to detail the specific problem, authors suggest setting up the so-called Method of the Ideal Result (MIR). It is based on the TRIZ concept of the Ideal Ultimate Result (IUR) [10]. This helps in reducing common mistakes made by engineers. It aids users in identifying the available resources and reduce engineers’ tendency to introduce additional parts, or elements without having a clear picture of what resources are originally available and without accounting for the new costs that could arise. In this phase, the idea is to conjecture a solution that reduce the amount of information, time, energy, material and space (ITEMS) [6].

For the abstraction of the problem, in order to build up the phase of “problem generalisation”, a relevant and widely used tool is the Substance – Field (Su-Field) Analysis. It permits to translate the description of the SA in a structured abstraction, by translating a complex system to a simple and uniform structure. It is represented by a set of interacting elements. It provides a complete representation of substances and fields that composed or interact with the technology. Different arrows connect the substances and fields, representing the action that occurs between them. It helps in generating ideas and failure analysis [6]. Then, the other main suggested tool to be

used within this phase is the “contradiction matrix”. It lists the most probable design principles to solve a technical contradiction. Specifically, it reports on the rows the feature that needs to be improved and in the columns the feature that will be worsened. Each contradiction is represented by a square in which the principles that would help to identify the solution are listed [1].

Thus, for the identification of a “general solution”, the inventive principles must be adopted [1]. They are generally classified in technical and separation principles. They represent a sort of “recipe” that Altshuller discovered to have been successfully used in more than 20000 patents belonging to several fields of knowledge [6].

Once a general solution is identified, according to the inventive principles, students need to come down to the “specific solution”. According to literature, patents analysis represents the main tool and S-Curve appears to be one of the most adopted tools to have a benchmark with the state of art. It permits to identify the evolutionary status of the technology also in other fields and to understand the feasibility of the solution [9].

Moreover, by reviewing the literature, some authors identified the need to enhance the TRIZ process by recognising also other important phases, such as team building or motivation enhancement [11]. This because often TRIZ is a project-based activity carried out by groups of people, with different skills and backgrounds. To build a cohesively group, authors suggest starting with activities of team building, in order to find strengths and weaknesses of groups. In addition, to motivate students, authors propose to encourage people by means of competition activities [11].

Following these guidelines, a proposed framework for teaching TRIZ in engineering courses, with an active learning approach [12], is characterised by the following phases:

Table 1 Proposed Framework of the TRIZ experimental seminar

Mod.	Aim and Scope	Tool
1	Team building activity and warm up about the technology chosen for the study	Discussion of the chosen technology and Myers Briggs personality test
2	Definition of the “specific problem” by identifying the technology and its distance from the ideality	Situational Analysis, MIR and ITEMS
3	Definition of the “general problem” by mapping the technology functional relationships and its contradictions	Su-Field Analysis and Contradiction Matrix
4	Identification of the “general solution” by using the contradiction matrix, through the “solution triggers”	Inventive and Separation principles
5	Definition of the “specific solution” by studying the technological feasibility and technological benchmark with respect to “the state of art”	Patent analysis (suggest S-Curve Analysis)
6	Competition and commercialization of the technology to a panel of experts in order to evaluate the marketability	Poster and Pitch Presentation

To test the proposed framework, we set up the TRIZ experimental seminar. It was taught in an international class, within the course of Innovation Management and New Product Development. Students were divided into groups of maximum 4 people, for a total of 23 groups. Each group had to choose a product and re-design it by applying the TRIZ methodology. Each lesson lasted 4 hours, for a total of 12 hours, and it mixed theoretical lessons and practical activities. Even theoretical parts were supported by practical examples, to provide students guidelines about the process.

During the first lesson, we focused on the team building activity. Then, we carried out activities related to the definition of the “specific problem” and a first draw of the Su-Field Analysis. During the second lesson, we characterized the “general problem” and we start to implement the “general solution”. During the third lesson, we complete the TRIZ by detailing the “specific solution”.

The evaluation of the seminar was done with a mandatory project. We asked students to report their use of TRIZ to redesign the chosen technology. Moreover, a not mandatory final competition was proposed: students could handle also a pitch and a poster presentation of the improved technology. It would account for a maximum of three more points on the final project mark.

Positive feedback come from the students and university board. The university board decided to fund the project and establish a permanent TRIZ experimental seminar. Students ideated high innovative technological solutions. Nevertheless, often these solutions present a lack of real feasibility, despite of all of them correctly applied the TRIZ tool presented. All the students found difficult to identify the law of evolutions and to collocate the solution with a correct technology intelligence process. Moreover, while they were aware of strengths and weaknesses of the group, sometimes they ended up by splitting the initial group. The final competition to simulate the selling of the technology was enrolled only by 3 groups out of 23.

3 IMPROVEMENTS IN TEACHING TRIZ: SUGGESTIONS FROM A SLNA

Due to the success of the TRIZ experimental seminar and in order to identify avenues for further improvements, we decided to perform a SLNA. This methodology helped us to depict possible enrichment of our experimental seminar and align it with the most recent TRIZ trends. Thanks to the identification of the Louvanian community of the TRIZ citation network, we identified 2 clusters out of 7 concerning education and the engineering topics (see Appendix, Fig. 2). It is worth to notice that education related subjects, also within their specific communities, appear not well linked with the other TRIZ keywords and works.

The first cluster highlights the relation of TRIZ with the problem-solving concept and the technology design. Core concepts appear to be the function analysis of the technology and the use of the contradiction matrix. Suggestions for the improvement of the framework derived from the strong association of TRIZ with the technology life cycle, sustainability and cleaner production. Recent trends highlight the relation of TRIZ with open innovation and the use of computer aid innovation tools (see *Appendix, Fig. 3 and Fig. 4*).

In the second cluster, the TRIZ concept is strongly connected to inventive design, biometrics concepts and patent mining. Substance field appears as a core tool. Within this cluster, interesting suggestions emerge from the relation of TRIZ with notions such as commercialization and sales. Indeed, the customer value and sales related aspects seem to represent a concern of TRIZ. Moreover, TRIZ looks strongly related to topic such as intellectual property (IP), patent or lean. Furthermore, the presence of keywords as the Analytic Hierarchy Process (AHP) or the Quality

Function Deployment (QFD) suggest the integration of TRIZ with other tools. Learning platform environments emerge as a widely used support tool. The evolution of the keywords recommends the need of a case-based reasoning approach and the use of TRIZ for enriching curricula (see *Appendix, Fig. 5 and Fig. 6*).

4 CONCLUSIONS, LIMITATIONS AND FURTHER DEVELOPMENTS

The present work has proposed and tested a framework to teach TRIZ in engineering courses. Nowadays problem-solving capacity and creativity are fundamental skills for future engineering curricula. In this setting, TRIZ is a method to spur creativity and the proposed framework is a “lean” guidance on how this tool can be taught to engineering students.

The proposed framework strongly relies on a practical approach, where students have to use the presented tools to improve an existing technology. This choice is coherent with the evidence emerged from the keyword analyses, which bring into evidence that case-based reasoning is one of the best approach to teach TRIZ.

Looking at the empirical test and considering also the paper keywords and their evolution along time, further directions appear relevant for teaching TRIZ and improve the suggested framework for future application in lab settings.

Firstly, TRIZ is highly fitting with other subjects related to engineering studies. TRIZ could be integrated for example with quality related subjects, by joining TRIZ with the QFD. Nevertheless, this integration requires different and complementary skills that must be acquired already within other courses of study. As matter of example, TRIZ should also rely on knowledge related to lean approaches, IT and optimization that could be important to design “stronger” TRIZ solutions. This confirms the relevance that TRIZ could have in a curriculum also because it offers possibilities to exploit and integrate different fields of engineering. An interfaculty seminar of different engineering fields would be an opportunity to improve TRIZ results, because of different skills and backgrounds to be exploited. Secondly, prerequisites and knowledge in terms of patents and IP come out as necessary to implement innovative and feasible technology solutions. This suggests reflecting on the importance of introducing IP related topics in engineering courses. Thirdly, a strong attention should be given to eco-innovation and sustainability uses of TRIZ. In this direction, teachers should encourage the study of technology regarding the development of eco-sustainable products. Fourthly, TRIZ is highly scalable with an open innovation (OI) approach. On these grounds, different phases of TRIZ could include the presence of experts, with different backgrounds. This would help student in analysing the feasibility of their technology. Students would have the opportunity to meet people from the working world, giving new perspectives to innovative didactic in terms of involvement of practical experiences and not only academic competences. Fifthly, TRIZ could be implemented with more engaging and dynamic learning environments. For example, it can be used within learning platforms. By using these tools, classes of different universities of the world could participate to the TRIZ project in order to provide more interesting solution. Moreover, also experts would be more easily engaged to participate to a TRIZ experimental seminar. Lastly, the TRIZ framework should be more linked with market aspects and a strong focus on the client. In our empirical test, only few students participated to the “market” competition, despite of the extra points. In a total OI approach, the possibility to talk with experts and the chance to receive feedback from a sample of possible clients already when applying the TRIZ process would help students in improving the launch into the market of the new designed technology.

The paper presents also some limitations. The proposed framework was tested only for one year and in a class of mainly industrial engineers. We aim to test the proposed framework the next years and to enlarge the sample to other engineering faculties or see how it could also be used in workplaces with entrepreneurial goals. In addition, the TRIZ experiment was not been compared with other works on idea generation and concept definition that not adopt the TRIZ methodology. We aim to compare the results with our previous project that not adopt TRIZ and report statistics for example on the degree of inventiveness and on the final mark of the project. Lastly, the keyword analysis provides a real broad overview of the main and most recent concepts concerning TRIZ. Nevertheless, an in deep analysis of each paper would allow to have a more punctual understanding of the topic and its evolution.

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APPENDIX

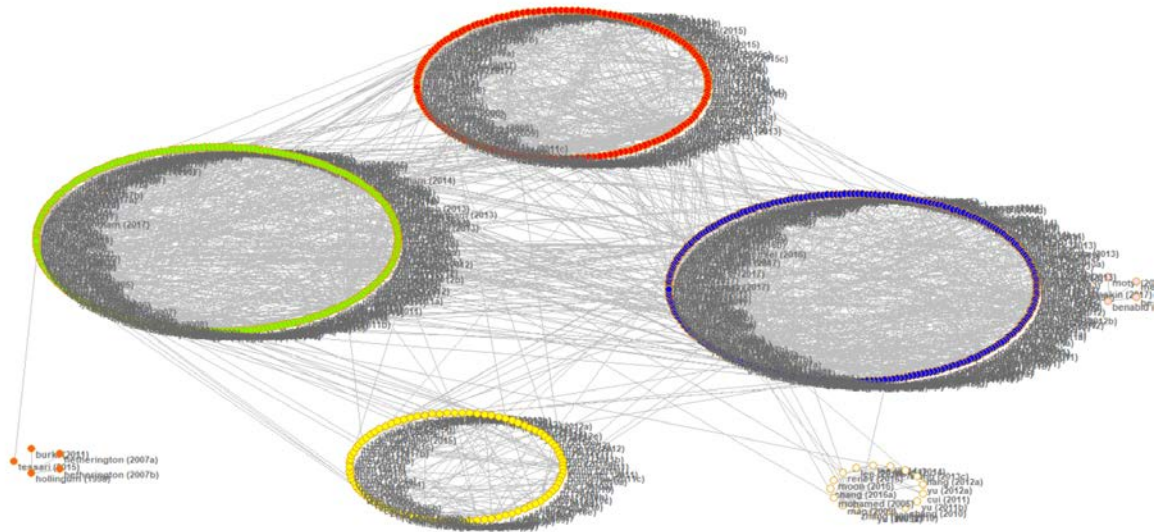


Fig. 2. Louvain Communities

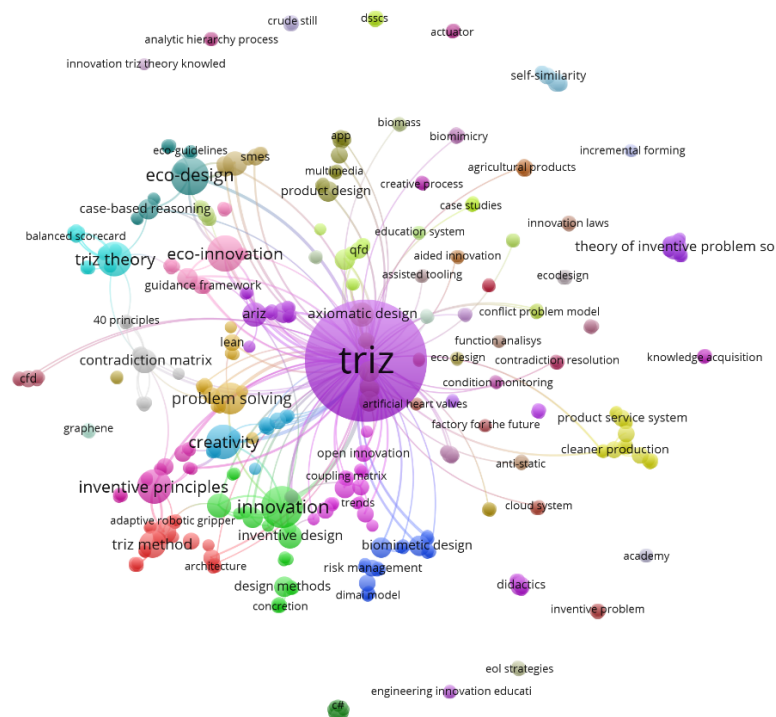


Fig. 3. VoSViewer Keyword depiction of the first community

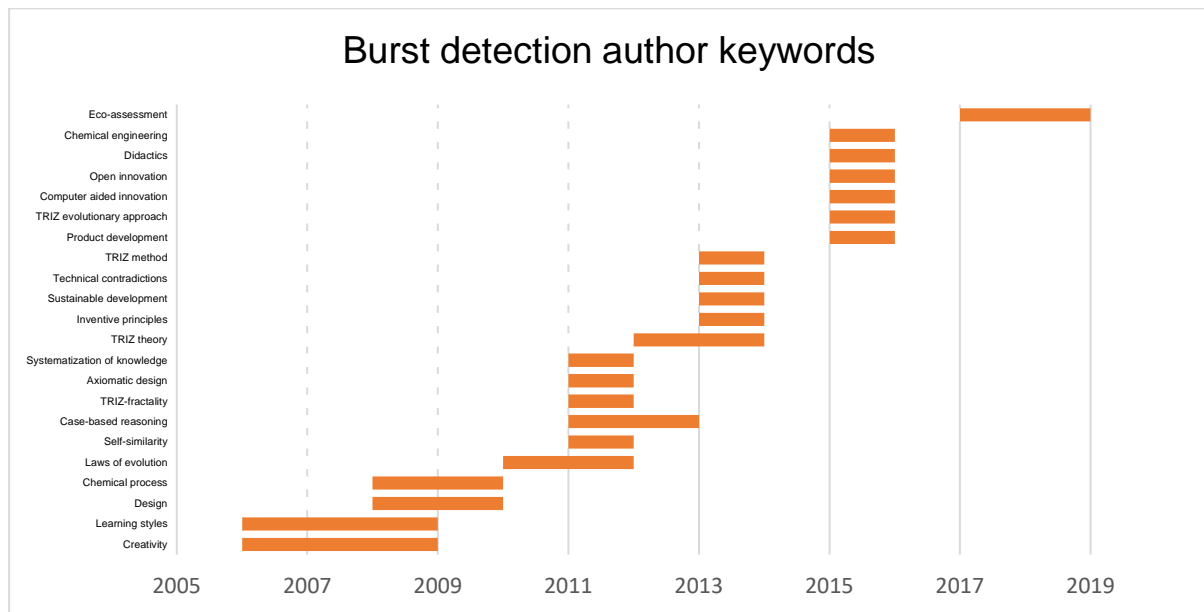


Fig. 4. Burst detection of the author keywords of the first community

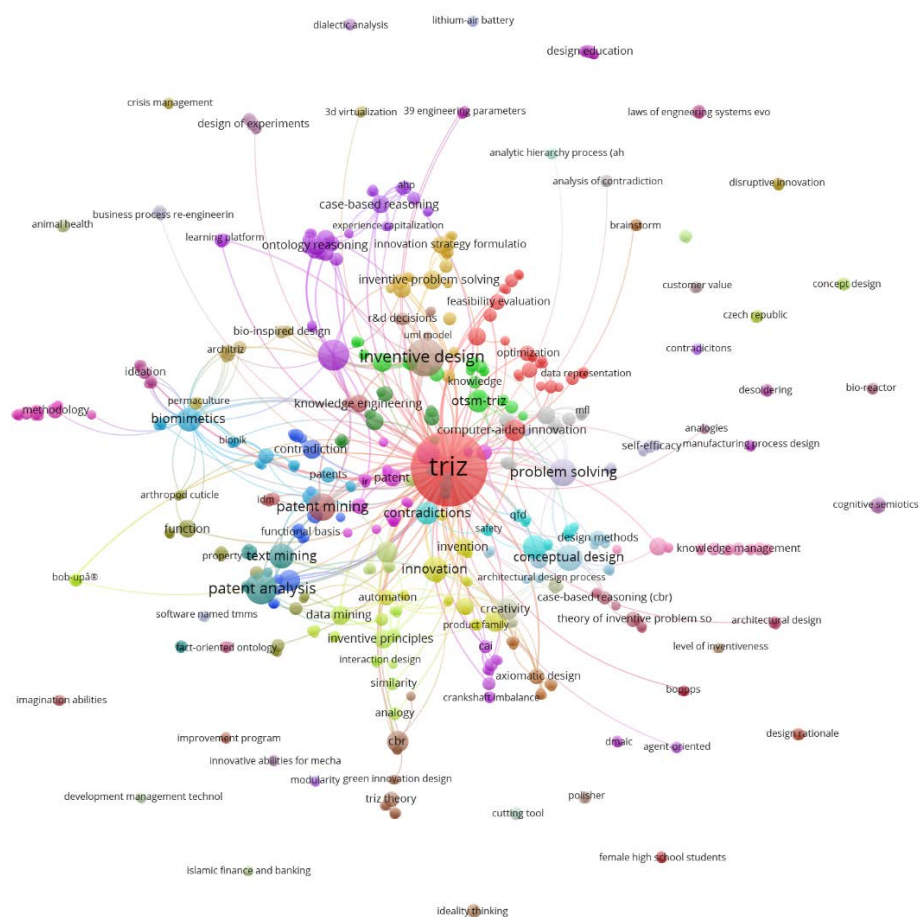


Fig. 5. Burst detection of the author keywords of the first community

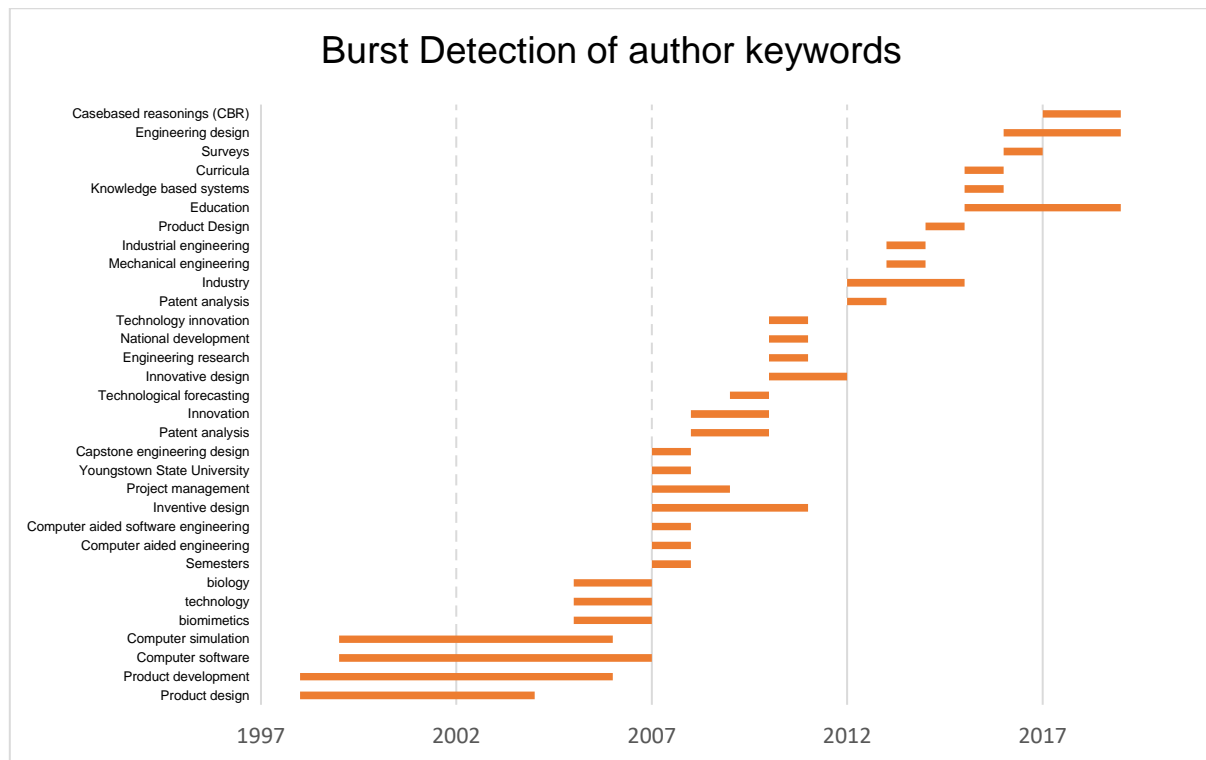


Fig. 6. VoSViewer Keyword depiction of the second community

How different are engineering design projects?

An analysis of middle school lessons and units

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Conference Key Areas: Curriculum Development, Engineering Skills, Innovative Teaching and Learning Methods

Keywords: design, K-12 education

ABSTRACT

Engineering education has gained momentum in K-12 education in recent years. However, available curricula and teaching materials take a variety of approaches, guided by limited research identifying or comparing these approaches. Using content analysis, I analysed, classroom-tested and published engineering lessons used in middle school grades (ages 13-15). The evaluation resulted in five types of implementation: design-build-test projects, experimentation tasks that highlight engineering science principles, contextualised problem solving through integrated STEM units, innovation projects where students identify a need and pursue their own projects, and optimization tasks with a focus on improving a suboptimal system. These implementation methods differ based on their goals, what part of the design process they engage, and the activities they emphasize. The variations in teaching models suggest differences need to be well-understood by educators and curriculum designers. Future research is necessary examining differences in student learning outcomes associated with the differences in the implementation models.

1 INTRODUCTION

1.1 The need for the study

In recent years there has been an increased interest in teaching engineering design in K-12 school as part of the STEM education movement that is gaining momentum globally. It is important that the university professors in engineering programs are aware of these developments, as these changes in K-12 education are likely create changes at the university level including who decides to pursue engineering and how those who pursue engineering perceive engineering.

In Europe, STEM education projects are promoted through programs such as ERASMUS+ and SCIENTIX. In the United States, the Next Generation Science Standards, further urges for the integration of science and engineering while promoting three dimensional learning that emphasize disciplinary core ideas, science and engineering practices, and cross-cutting concepts [1]. In alignment with these developments that emphasize the importance of teaching engineering in K-12 education, the National Assessment of Education progress (NAEP) in the US added technology and engineering literacy to its suite of assessments in 2014. Similarly, in 2015, PISA added a new test on collaborative problem solving to the group of its tests in reading, science, and mathematics literacy.

As these efforts evolve, it is important that K-12 educators have a framework for designing curriculum in alignment with the nature of engineering, and that teachers have the tools to be able to judge quality depending on the learning objectives they want to cover in their lessons.

1.2 Review of the literature

Teaching engineering in the K-12 classrooms is a fairly new practice. Although there is interest and necessity to teach engineering, teachers, curriculum developers, and even teacher educators are often not familiar with the discipline of engineering and the pedagogical methods associated with teaching engineering design. As a result there are a variety of ways engineering is taught in schools. However, there is little research comparing differences in these approaches (e.g., [2,3]). Svihla and colleagues compared kit-based projects and re-design projects, though their study was at the college level. Goldstein and colleagues compared a small-scale design project with a large-scale interdisciplinary project. They found that student learning in engineering science concepts were higher in the large-scale project while students who worked on the small-scale project developed a more robust understanding of trade-off decisions in design.

1.3 Purpose

While more studies on the status, role, and impact of engineering education in elementary and secondary school are necessary, as a first step we need to identify variations in implementation methods. Initially the analysis started with the goal of evaluating lesson plans for authenticity and to what extent they reflect epistemic

practices in engineering. However, the variations observed did not allow the use as scoring protocol that can be applied to evaluate each variation. Hence, the approach was revised to describe variation. To address the need to identify variation, this study involved the analysis of classroom-tested, peer-reviewed and published descriptions of units and curricula with a focus on engineering. The content of these articles is reviewed to identify variations in teaching engineering in K-12 education.

2 RESEARCH METHODS

2.1 Sample

The detailed descriptions of all lesson plans and units published in the decade (between 2007 and 2018) in the Science Scope magazine of the National Association for Science Teaching made up the data pool. The articles published in the Science Scope are peer-reviewed and have previously been used in the classroom (see <http://www.nsta.org/middleschool>). They are also authored by classroom teachers, university faculty, or both. A total of 71 articles mentioned engineering in the text. These articles are then reviewed carefully to identify those that describe a lesson or a unit with a focus on engineering. The resulting data set included 39, which were used for in-depth analysis.

2.2 Data Analysis

A thematic analysis method [4] is used to identify themes explaining types of lesson. First the researcher read all 39 articles in full. This process was accompanied with an open coding process. Multiple interactions of coding and re-reading led to the development of themes.

3 RESULTS

3.1 Themes

The analysis resulted in five different ways engineering is represented in middle school classes. These themes are determined based on their focus on specific components of the design process and include:

1. *Design-build-test* projects
2. *Experimentation* tasks that highlight engineering science principles
3. *Conceptualized problem solving* through integrated STEM units
4. *Innovation* projects where students identify a need and pursue own projects
5. *Optimization* tasks with a focus on improving a suboptimal system

The majority of the articles described lessons that used a design-build-test approach followed by eleven articles that had a focus on experimentation and engineering sciences (see Figure 1). In the **design-build-test** approach the students had some flexibility in determining their design solutions within the constraints of the materials that were provided. There was much variation in the authorship of these articles. Some were written by school teachers while others were authored by teachers and STEM

education faculty. In the **experimentation** category, students followed a fairly scripted procedure to build a testable prototype and were more engaged in testing the prototype in a controlled setting. These were typically authored by engineering faculty and graduate students.

The third category was **contextualized problem solving**. These included real projects that are implemented with an interdisciplinary team of teachers as well as simulated projects with a fictional client. In either case, however, students spent a considerable amount of time understanding the problems and the context before generating solutions.

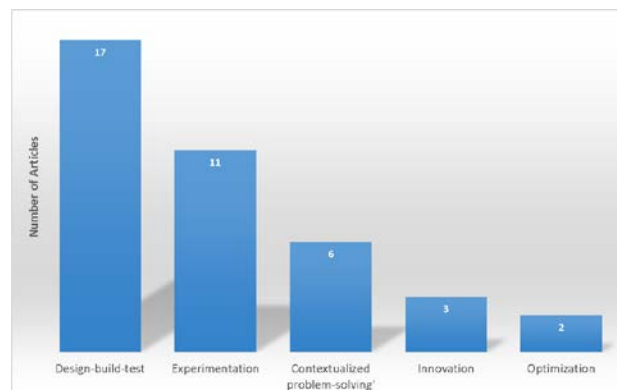


Fig. 2. The frequency of each type of engineering project or task

The fourth category was **innovation**. In these projects, students identified a need and determined their own projects to pursue within a broad topic are such as biomedical engineering. Teachers guided multiple variations of problems that the students pursued. In addition, experts (university professors) visited classrooms and presented their research and engaged students in small tasks associated with the topic. Hence, collaboration between the school and the university was vital.

The final category included **optimization** with a focus on re-design, rather than a new design. Students started with an existing solution that was suboptimal. They observed its problems and identified solutions to optimize its performance.

An example for each category is presented in Table 1.

3.2 Themes and the Stages of the Design process

Further analysis revealed that the five themes identified were also associated with specific stages of the design process (see Figure 2). For example, optimization tasks involved students in testing and re-design cycles as students started with a suboptimal solution. On the other hand, innovation category required students to define a need and engage a full design-process cycle.

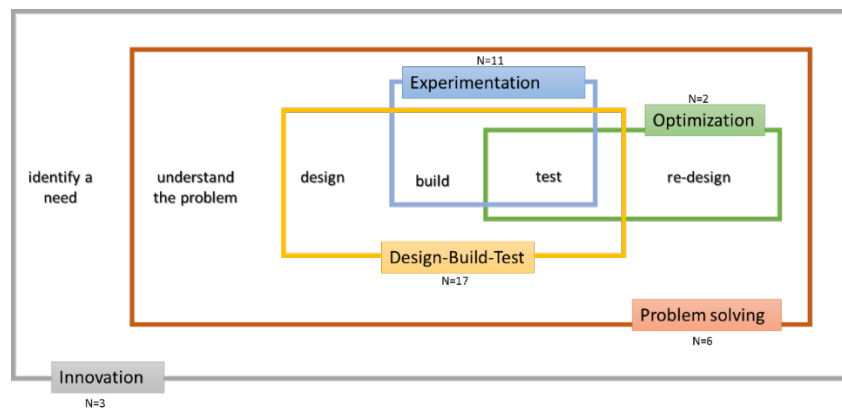


Fig. 2. Types of engineering projects and tasks represented in lessons

Table 1. Engineering task examples

Type	Articles in the category	Example Task
Design-build-test	Bartus, 2017; Berge, 2014; Crismond, 2013; Feille, 2017; German, 2017; Goldberg, 2013; Kennedy, 2014; Kern, 2015; Loterero-Perdue, 2013; Love, 2015; Meyer, 2014; Miranda, 2013; Moore, 2014; Thiam, 2017; Williamgham, 2016	Students are introduced to oceanography and tasked to design a self-sustaining ocean platform that can withstand the movement of water and sediments and with minimal impact on the ocean life [5].
Experimentation (build + test)	Turgeon, 2014; Vassilier, 2013; Ballyns, 2011; Chen, 2014; Garafolo, 2017; Hoffmann, 2013; Ing, 2013; Khaldi, 2016; King, 2014; Nguyen, 2014; Sandone, 2017*	In a lesson on tissue engineering, students followed a protocol to build columns made from alginate. They tested their specimens using compression tests. Their goal was to produce the strongest material using alginate gel [6].
Contextualized problem-solving	Ewalt, 2015**; Goldstein, 2017**; Karahan, 2014; Wang, 2017; Abbott, 2016; Rupp, 2014;	In a STEM curriculum composed of six lessons, the students are first introduced to an issue published in a local newspaper, describing how a farmer accidentally destroyed a pelican colony. After estimating the number of nests in pelican colonies (math) and ecology concepts and food webs (science) students design pelican nests that can be safely moved while maintaining the temperature of the pelican eggs [7].

Innovation	Helfer, 2016; Nicholas, 2015; Zwart, 2013;	Students are asked to identify gaps in the existing technology in neuromuscular control and prosthetics. They developed prosthetic design solutions to meet a specific purpose such as drawing [8].
Optimization (test+ re-design)	Dasgupta, 2017; Lancaster, 2015	Students are provided with a plumbing system which is not optimally designed. Students test the system to evaluate its problem and re-design an optimize system [9].

4 SUMMARY AND ACKNOWLEDGMENTS

This study examined variations in how engineering is implemented in middle school classrooms. The analysis resulted in five categories, where each had a different type of emphasis on an aspect of engineering (e.g., engineering science vs engineering design). This study is a critical contribution to the body of literature as these categories can be used: 1) to guide the development of curricula associated with a given type of implementation, 2) support research comparing different approaches used to teaching engineering concepts and practices in K-12 education.

This work presented in this manuscript is based upon work supported by the National Science Foundation (Grant DUE #1348530: Large-Scale Research on Engineering Design Based on Big Learner Data Logged by a CAD Tool). Any opinions, findings, and conclusions or recommendations expressed in this paper, however, are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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Do middle school students consider ‘conducting tests’ to be important to engineering design?

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Conference Key Areas: Engineering Skills, sustainable development goals in engineering education, teaching creativity and innovation

Keywords: conducting tests, design, K-12

ABSTRACT

Testing and experimentation are vital parts of the innovation process and also a critical practice of engineers. In this study, we examine secondary school students' understanding of this critical practice. We focus our analysis on K-12 education, where teaching engineering practices and core ideas are gaining momentum as part of the STEM education movement. We collected data from 746 middle school students using the Conceptions of Design Test (CDT), eliciting student's views of importance of conducting tests in design. CDT asks students to select five design practices from a list 20 and asks students to explain why they believe the practices they have selected are critical to informed design. We performed McNemar tests to quantitatively analyze students' changing conceptions of design before and after completing a design project. We also used the thematic analysis approach to qualitatively analyze variations in students' perceptions of 'conducting tests.' We found that after a design activity, "conducting tests" became a statistically more important practice to students. Students' explanations reflected two types of conceptualization of conducting tests: diagnose-fix iterative cycle and transformative iterative cycle.

1 INTRODUCTION

In recent years, there have been many efforts by researchers and educators to integrate engineering design into K-12 education. As part of these efforts, students engage in engineering design while performing design practices such as problem scoping, sketching, conducting tests, and communicating. While there are studies on expert designer' and undergraduate students' understanding of these practices [1–4], very few studies have been conducted at the K-12 level [5–7].

Engineering in K-12 classrooms is often taught by science teachers, who are familiar with scientific inquiry but not as familiar with the design inquiry. Both engineering design and scientific inquiry involve common reasoning processes (e.g., reasoning from evidence), cognitive activities (e.g., asking questions, evaluating, and inquiry practices (e.g., conducting experiments, communicating) [8]. Yet, these processes, activities, and practices have different purposes reflecting the epistemological differences between the two disciplines. The scientist asks questions to understand natural phenomena often decontextualized to form generalizations while the engineer asks questions to understand the constraints of a problem that is highly contextualized [8,9].

In this study, we focus on "conducting tests and experiments", a practice important in both science and engineering. In addition, experimentation is also a vital practice in innovation, as many innovators experiment with ideas, test design performances, and compare alternatives before pursuing ideas further [10]. Hence, we investigated students' conceptualization and prioritization of conducting tests in design as we answer the following research questions:

1. Do students' *prioritization* of "conducting tests" as a design practice change after completing an engineering design project? and

2. How do students *conceptualize* “conducting tests”?

2 THEORETICAL FRAMEWORK

The practice of conducting tests and experiments is common to both science and engineering disciplines. Both disciplines carry out investigations to understand the causal relationships between variables [11–13]. In addition, the novice practitioners in both disciplines have challenges in experimentation and tend to engage in confounded experiments [11,14,15]. Kuhn et al. (2000) in their investigation present that 6th and 8th grade students find multivariable causality challenging as they changed multiple variables at once and attributed the outcomes to all variables. Similarly, Crismond and Adams (2012) in their *Informed Design Teaching and Learning Matrix* suggest that beginning designers usually run confounded tests by changing multiple variables at the same time.

Engineers and scientists conduct experiments for various reasons. (See Table 1). Engineers use testing to gather data to specify design criteria, determine the optimization level of the prototype, evaluate whether the prototype achieves all of the requirements [16,17]. The feedback and data obtained from design experimentations can also be used to troubleshoot and improve the design solution to best meet the design parameters [18] (Lewis, 2006; Moore et al., 2014; National Research Council, 2012). Carrying out investigation in science is done to test a hypothesis and understand how empirical data compare to hypothesized results [8,19–21].

Table 1. The uses of experiments in engineering design and scientific inquiry

Engineering design	Scientific inquiry	Commonalities
<ul style="list-style-type: none"> • Understand “why” “how” and “what” simultaneously • Contrasts “predictions and possible explanations (hypotheses) of prototype behavior” [11] • Observations and data collected are used to specify design criteria [17], to determine the optimization level of the prototype [16], and to identify solution strengths and weaknesses in order to re-design [22] 	<ul style="list-style-type: none"> • Understand “why” • Understand how empirical data compare to hypothesized results [8] • Observations and data collected are used to test existing theories and explanations or to develop new ones [17] 	<ul style="list-style-type: none"> • Understand causal relationships [11,12] • Beginners of both fields do confounded experiments [11,14]

Given K-12 teachers as well as students are more familiar with science as compared to engineering, it is important to study any variations in their understanding of conducting tests in design.

3 DESIGN & PROCEDURE

3.1 Participants and Study Context

This study took place in three middle schools (ages 12-14) (N=746). One 8th grade class in an urban setting allocated two weeks to design three unique solutions (N=64 students). Another school with three teachers in a suburban setting used the same design task and timeline, with 367 7th grade students. The third school with 315 7th grade students in a suburban setting participated in a design project with an authentic client led collaboratively by mathematics and science teachers and spent four weeks of design time with labs targeting specific science concepts outside of their time in Energy3D. The diversity in school demographics and approach to design allowed variations in student conceptions and generalizability of results to diverse school settings.

3.2 Design Challenge

Students at all three schools designed single family homes that consumed as little energy over the course of a year as possible while being cost effective, and also being attractive/comfortable. Students used Energy3D, a CAD design environment with cost and energy performance simulation capabilities (See Figure 1).

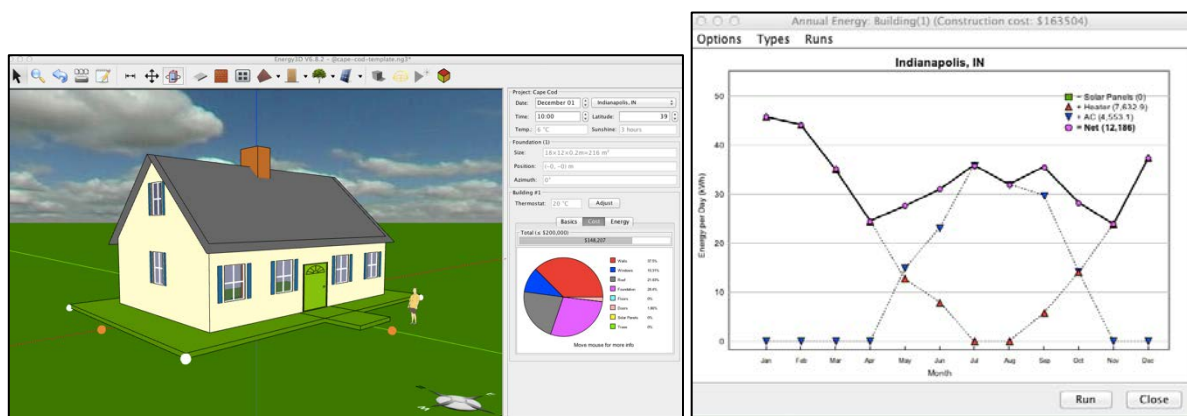


Fig. 1. Example student design & energy analysis in Energy3D
(<http://energy.concord.org/energy3d/>)

3.3 Data Collection with Conceptions of Design Test (CDT)

The Conceptions of Design Test (CDT) was used to collect data (See Figure 2). The CDT is adapted from an instrument designed by [3] to understand practicing designers' design language. Later revisions of the tool focused on college designers' conceptions of design [4,23,24]. The underlying conceptual framework of this instrument that serve as evidence of construct validity is that an important part of becoming a designer is learning the language of design.

CONCEPTIONS OF DESIGN TEST			Instructions
<ul style="list-style-type: none"> Analyzing data Balancing trade-offs (<i>considering strengths & weaknesses</i>) Brainstorming Building Communicating Conducting tests Evaluating 	<ul style="list-style-type: none"> Gathering information Generating alternatives Identifying constraints (<i>identifying limitations</i>) Iterating (<i>making updates</i>) Making decisions Modeling Planning 	<ul style="list-style-type: none"> Prototyping (<i>creating a test version</i>) Reflecting Setting goals Sketching (<i>using paper, computer, etc.</i>) Understanding the problem Using creativity 	<p>Selection: Which 5 would you consider MOST / LEAST important in terms of producing a high quality design?</p> <p>Open-ended response: For one of the MOST/LEAST important terms selected, please explain why</p>

Fig. 2. *Conceptions of Design Test*

4 DATA ANALYSIS

A multi method research approach [25] was used employing both quantitative and qualitative analysis of data collected with the Conception of Design Test (CDT).

4.1 Quantitative analysis

A McNemar's test, which is appropriate for paired dichotomous categorical data, was performed to determine whether students' tendency to prioritize "conducting test" as an important design practice has changed from pre- to post-administration [26].

4.2 Qualitative analysis

The second phase of the multi-method approach started by identifying the students who selected "conducting tests" as one of the five most important design practices and explained why this practice was important. Thirty-one students in pre-test and 52 students in post-test explained why conducting tests is important in design. We performed a thematic analysis [27] to systematically categorize students responses. In this systematic characterization, two researchers read the data and iteratively developed themes.

5 FINDINGS

5.1 Quantitative results

The McNemar test showed statistically significant differences. Significantly more students found "conducting tests" to be a most important design practice from pre- (29%) to post-test (36%) ($\chi^2 = 29.051$, $p = 0.003$). In addition, significantly fewer students considered it to be an unimportant design practice in the post-test (9%), compared to pre-test (16%) ($\chi^2 = .573$, $p = 0.000$). Moreover, students discussed "conducting tests" more frequently in the post-test, as the number of students discussing the term as important increased from 31 to 52 students.

5.2 Qualitative results

The thematic analysis provided insights into students' conceptualization of "conducting tests". The analysis resulted in six different conceptualizations of conducting tests,

grouped under two overarching themes (See Table 2). Diagnose-fix iterative cycle refers to micro-iterations often associated with design refinement and optimization. Transformative iterative cycle refers to macro-iterations where the iteration has more profound impact on the problem, process, or the solution.

Table 2. Variations in students' conceptualization of "conducting tests"

Theme	Purpose	Example of students responses
Diagnose-Fix Iterative Cycle	Test to determine whether the prototype is working as planned	<i>"I believe that Conducting Tests is the most important because you have to know if the product you are making works." [pre-test]</i>
	Test to find mistakes and flaws	<i>"One of the important design activities would be conducting tests. This step would help you determine a flaw in your design, and would give you ideas on how to fix it." [pre-test]</i>
	Test to find what works and what doesn't work	<i>"Conducting tests is important because it shows you what is good and what you need to work on. When you are conducting tests you can identify the problems. You can also see what you should keep and it gives you new information." [post-test]</i>
Transformative Iterative Cycle	Test to gather information on specific design criteria	<i>"Conducting tests are vital in this activity because the challenge is to find the most efficient home energy and price wise. Conducting tests gives the information needed to make improvements or fix constraints." [post-test]</i>
	Test to compare alternatives	<i>"I think Conducting tests is most important because, if you don't try different things, you won't be able to find the best of the options you have." [post-test]</i>
	Test to make strategic design decision	<i>"Conducting tests are important because they allow you to know what the best strategy is so that when you make a decision and begin to build you will not fail and have to tear down the building. Also, by doing this, you will have the most adequate and the best building because you have the ability of seeing all of the possible outcomes before." [pre-test]</i>

6 CONCLUSIONS & FUTURE RESEARCH

In the United States, the Next Generation Science Standards [28] and the broader STEM movement globally urge for the integration of engineering concepts and practices along with science practices in K-12 education. Yet, we need a better understanding of how students perceive these practices. This study suggests that after taking part in a design project, students recognized "conducting tests" as an important practice in design. Our analyses show variations in students' conceptualizations of design, recognizing its micro and macro iterations. In K-12 education, the emphasis is often put on micro iterations. It is important that curriculum and teaching practices also reinforce transformative iterations that are associated with strategic decision-making in design. While conducting tests is a practice very important to design, future research

is necessary examining both students' conceptions of this practice as well as their abilities to engage in systematic experimentation .

7 ACKNOWLEDGMENTS

We appreciate the contributions of Sharifah Omar to this study and are grateful for the students and their teachers who supported data collection efforts. This work presented in this manuscript is based upon work supported by the National Science Foundation (Grant DUE #1348530: Large-Scale Research on Engineering Design Based on Big Learner Data Logged by a CAD Tool). Any opinions, findings, and conclusions or recommendations expressed in this paper, however, are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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Motivational Orientations and Learning Strategies of Engineering Students using MSLQ

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Conference Key Areas: Continuing Engineering Education and Lifelong Learning, Engineering Skills

Keywords: Self-Regulation Skills, Learning Strategies, MSLQ, Self-Efficacy, Resource Management Strategies

INTRODUCTION

Determining university students' motivational orientations and their use of different learning strategies reveals important characteristics of their self-regulation skills and personal functioning. Psychologists and educational researchers have sought different ways to assess these characteristics e.g., by several questionnaires. One of the most well-known questionnaire is the MSLQ (Motivated Strategies for Learning Questionnaire) that has been developed by Pintrich et al. in 1991 [1]. In this study, goal orientations, control of learning beliefs, self-efficacy for learning performance, resource management strategies as well as cognitive and metacognitive strategies of 62 engineering students from TUT (Tampere University of Technology) have been assessed using an extract of 22 questions from the MSLQ plus five additional queries, which have been formed by the author.

The sample of 62 students consisted of 39 students from the Faculty of Computing and Electrical Engineering, 19 students from the Faculty of Engineering Sciences and 4 students from other faculties of TUT. Most participants were 3rd and 4th year engineering students, although a few 2nd year students participated as well. Data were collected at the beginning of the first lecture of the course *ASE-2411 Introduction to System Operation* in January 2018. The students were informed about the nature of

the self-report test and that the test would have no effect on their final mark. Students rated themselves anonymously using integers on a Likert scale between 1 (“not at all true of me”) and 5 (“very true of me”).

The rating distributions obtained indicate that the goal orientation of the students is mostly intrinsic than extrinsic. The students also have relatively strong control beliefs over their own learning. However, for some reasons, they have only moderate self-efficacy beliefs for learning performance. In addition, students’ use of resource management strategies like scheduling of own learning considerably varies between individuals. Relative large deviations were also observed within learning strategies scales. Nonetheless, the results from the questionnaire gives insight into students’ motivational orientations and their use of learning strategies, which help staff members to gain better understanding of different functioning of students attending to the class.

1 MOTIVATED STRATEGIES FOR LEARNING QUESTIONNAIRE

The MSLQ is divided into two sections; namely, to a motivation section and learning strategies section. The intention of the motivation section is to assess students’ goals and value beliefs, whereas the learning strategies section considers students’ use of different cognitive and metacognitive strategies as well as resource management skills. [1] In this study, a collection of factors was formed from both sections of the MSLQ to discover students’ motivational orientations, expectations for success, behaviour in different learning contexts, control of learning beliefs, and ability to regulate own cognitive activities. The factors in this study have been chosen on the basis of how well they have correlated with grades in previous research papers. The chosen factors and the corresponding components are described below.

1.1 Motivation section, its components and selected factors

The motivation section is divided into value, expectancy and affective components. The value component includes measures of intrinsic goal orientation, extrinsic goal orientation and task value. Goal orientation refers to students’ perception of the reasons why he/she is engaging in a learning task. If students have intrinsic goal orientation then they are likely to engage themselves in learning activities for reasons like curiosity, challenge and mastery, while extrinsically oriented students participate for reasons like rewards, grades, performance, evaluation by others and competition. Task value on the other hand refers to students’ evaluation of how interesting, important and useful tasks are for them. High task value should lead to more involvement in students’ learning, because it implies general interest, importance and utility towards learning activities.

The expectancy component consists of control of learning beliefs and self-efficacy for learning and performance. Control of learning beliefs is important, because it refers to students’ beliefs that positive outcomes are more dependent on their own efforts rather than external factors such as teachers. Students should study more strategically and effectively if they feel that they can control their academic performance. Hence, in a class where students display high values of control of learning beliefs, teaching and

learning relationship should be arranged to emphasize active student engagement and responsibility. Furthermore, control of learning beliefs interact with self-efficacy beliefs, which predicts well students' motivation and learning [2].

Self-efficacy for learning and performance assess two expectancy factors: expectancy for success and self-efficacy. Expectancy for success considers performance related things like good grades, whereas self-efficacy refers to student's self-appraisal of his/her ability to accomplish a task and his/her confidence in his/her own skills to perform a task. Self-efficacy for learning and performance has generally been found to correlate well with academic achievement [3; 4].

The affective component of MSLQ measures test anxiety, which has been found to have negative influence on expectancies and learning performance. Test anxiety has two components: a cognitive component, which refers to student's negative thoughts that distract performance during tests, and an emotionality component, which refers to physiological causes of anxiety. Practicing effective learning strategies reduces degree of anxiety, but students seldom use strategies despite of training [5].

The chosen factors from each component of the motivation section that are used in this study are listed below. The resulting mean μ and standard deviation s rounded to two significant digits have been placed in the parentheses at the end of each factor. Interested readers may examine each factor graphically using the following link: <https://padlet.com/pyrhonen/wcpwdta0n96p>

Component: **Value**

- Factor: **Intrinsic goal orientation**: "I prefer course material that arouses my curiosity, even if it is difficult to learn". ($\mu = 3.90$, $s = 0.82$)
- Factor: **Extrinsic goal orientation**: "Getting a good grade is the most satisfying thing for me". ($\mu = 2.90$, $s = 0.93$)
- Factor: **Task value**: "Understanding the subject matter of courses is very important to me". ($\mu = 4.00$, $s = 0.71$)

Component: **Expectancy**

- Factor: **Control of learning belief**: "If I study in appropriate ways, then I will be able to learn the material in this course". ($\mu = 4.20$, $s = 0.69$)
- Factor: **Self-efficacy for learning and performance**: "I believe I will receive an excellent grade in this class". ($\mu = 3.00$, $s = 0.80$)
- Factor: **Self-efficacy for learning and performance**: "I'm certain I can understand the most difficult material presented in this class". ($\mu = 2.80$, $s = 0.93$)
- Factor: **Self-efficacy for learning and performance**: "I'm confident I can understand the basic concepts taught in this course". ($\mu = 4.40$, $s = 0.66$)
- Factor: **Self-efficacy for learning and performance**: "I'm confident I can do an excellent job on the assignments and tests in this course". ($\mu = 3.10$, $s = 0.78$)
- Factor: **Self-efficacy for learning and performance**: "I expect to do well in this class". ($\mu = 3.50$, $s = 0.65$)

Component: **Affective**

- Factor: **Test anxiety**: “When I take a test, I think about how poorly I am doing compared with other students”. ($\mu = 1.80, s = 1.10$)
- Factor: **Test anxiety**: “I have an uneasy, upset feeling when I take an exam”. ($\mu = 2.10, s = 1.00$)
- Factor: **Test anxiety**: “When I take tests, I think of the consequences of failing”. ($\mu = 2.00, s = 1.10$)

1.2 Learning strategies section and selected factors

The learning strategies section is composed of cognitive and metacognitive strategies, and resource management strategies subsections. Cognitive and metacognitive strategies subsection measures student's use of basic rehearsal, elaboration and organization strategies, which help students to connect new information to prior knowledge. The subsection also measures student's use of metacognitive self-regulation activities, which are composed of three processes; namely, planning, monitoring and regulating.

Planning, such as goal setting and task analysis, assists in activating students to learn new material and to work with upcoming challenges. Monitoring activities like self-testing help students in understanding the material and connecting it with prior knowledge. Regulation refers to continuous adjustment of one's cognitive activities like changing one's way to study in the face of obstacles or other difficulties. Regulating activities improve learning performance by helping students to check and correct their behaviour when needed. Inability to regulate have been found to be a major inhibition to student's success in academic activities and life in general. [6–8]

The resource management subsection measures students' ability to manage time and study environments, which are now becoming more and more important because of digitalization. Time management include scheduling and planning one's time use efficiently, whereas study environment management refers to one's ability to organize a good place to study for oneself. The following factors from the learning strategies section has been used in this study.

Cognitive and metacognitive strategies: **Elaboration**

- “I try to relate ideas in this subject to those in other courses whenever possible”. ($\mu = 3.40, s = 1.10$)

Cognitive and metacognitive strategies: **Organization**

- “When I study for this course, I go through the readings and my class notes and try to find the most important ideas”. ($\mu = 3.30, s = 1.10$)

Cognitive and metacognitive strategies: **Metacognitive self-regulation**

- “During class time I often miss important points because I'm thinking of other things”. ($\mu = 3.00, s = 0.95$)

- “I often find that I have been reading for class but don’t know what it was all about”. ($\mu = 2.60, s = 0.75$)
- “I try to think through a topic and decide what I am supposed to learn from it rather than just reading it over when studying”. ($\mu = 3.00, s = 0.92$)

Resource management strategies: **Time and study environment**

- “I usually study in a place where I can concentrate on my course work”. ($\mu = 4.00, s = 0.93$)
- “I find it hard to stick to a study schedule”. ($\mu = 2.40, s = 1.00$)
- “I rarely find time to review my notes or readings before an exam”. ($\mu = 2.00, s = 1.00$)

Resource management strategies: **Effort regulation**

- “I work hard to do well even if I don’t like what we are doing”. ($\mu = 3.50, s = 0.95$)
- “When course work is difficult, I give up or only study the easy parts”. ($\mu = 2.10, s = 0.84$)

In addition to the above, the following supplementary items were added to the questionnaire by the author:

Supplementary items:

- “I schedule my studies”. ($\mu = 2.90, s = 1.10$)
- “I like to study on my own”. ($\mu = 3.50, s = 0.92$)
- “I like to study with my friends”. ($\mu = 3.10, s = 1.00$)
- “I set goals for my studies”. ($\mu = 3.50, s = 0.99$)
- “If I could decide, I would choose other means for course evaluation than final exams and midterms”. ($\mu = 3.10, s = 1.20$)

The above items attempt to determine student’s learning preferences in individual and peer contexts, intention for goal setting and scheduling, and preferences for alternative ways for course evaluation as opposed to traditional examination. Currently, universities and higher education institutes are moving towards competence-based curricula in which students are evaluated by much more versatile ways than before, and, as such, have likely affected to students’ needs and expectations. In addition, group working, collaborative problem solving, and other socially shared learning activities are fairly standard these days in higher education. Hence, it is justifiable to evaluate how students concern these factors in their own studies.

2 ANALYSIS OF SELECTED ANSWER DISTRIBUTIONS

In this section, the rating distributions of specifically chosen factors are briefly analysed. The analysed factors have been chosen either because the answer distributions represent prominent heterogeneity among individual students, or because the chosen factors are known to have relatively strong correlation e.g., with final grades.

Goal orientation and Task value: The goal orientation of the students seems to be much more intrinsic than extrinsic, which indicate that students pursue in academic activities for their own sake rather than attaining something from them. High values of intrinsic goal orientation are known to lead better results compared with extrinsically oriented motivation. Furthermore, students also display high task value, which indicate intrinsic interest towards learning activities. Usually, high intrinsic motivation leads to high task value.

Control of learning belief: Students seem to belief that their own efforts will lead to positive outcomes in contrast with external factors such as the teacher. This is a positive sign, because students feel that their own efforts to learn can make desired changes in their learning.

Self-efficacy for learning and performance: Students' expectancy for success is generally moderate, but high expectancy is obtained as regards to students' confidence in understanding the basic concepts taught in the class ($\mu = 4.40$, $s = 0.66$). Students' beliefs for receiving an excellent grade in this class is however significantly lower ($\mu = 3.00$, $s = 0.8$). Furthermore, students' expectancy for doing well in this class measures $\mu = 3.50$, $s = 0.65$. "Doing well" is a subjective matter and links to individual preferences and to perceptions on how "well" is interpreted among individual students. It should be noted that uncertainty in several different forms is involved within expectancy factors: A student may be uncertain regarding to his/her own abilities to accomplish a class based on his/her previous experiences and achievements. A class may have reputation of being difficult among the students, which may lower the degree of all expectancy factors. A student may not expect anything from the class, nor from himself/herself, which may result in more or less random answers or answers that lie in the middle of the scale.

Test anxiety: About 10% of students expressed that taking tests raises negative emotions that distract performance, and 15% spend time thinking about consequences of failing while they are taking tests. Such cognitive concern and preoccupation have been found to be one of the greatest sources of performance decrement. In this sense, 15% is relatively large percentage among 3rd and 4th year engineering students.

Elaboration and Organization: These factors from cognitive and metacognitive strategies subsection display large deviations, and hence, wide heterogeneity among students. It is unknown why such large deviation exists between students. However, it does indicate that some students use much stronger learning strategies, while others hardly use any strategies. Strong learning strategies are known to reduce e.g., test anxiety. Learning strategies also help students to store information in long-term memory and constructing connections between important information that has been learned, which, on the other hand, have positive influence e.g., on performance expectations. [1]

Metacognitive self-regulation: Students seem to be aware when they lose track during class time or during learning on their own. Surprisingly many do get lost during e.g., lectures, because they are thinking other things. Reasons that cause students to think something else during classes remain unknown in this study. Nonetheless, awareness of such events is not sufficient as regards to ability to regulate own cognition; rather, students should be capable of adjusting own activities based on their progress monitoring skills as well as on personal evaluations e.g., whether a chosen solution strategy has resulted in positive outcomes. Finally, planning activities like goal setting also indicate heterogeneity: almost 20% of students study with almost no intention on goal setting.

Time and study environment: Students rate themselves relatively skilled as regards to setting up a good place to study. Conversely, time management skills and ability to schedule own work show fairly large deviations. For example, the supplementary item: "I schedule my studies" show that almost 40% of students hardly schedule their studies at all!

Effort regulation: Effort regulation factors show that majority of students do not give up easily when they face difficulties or uninteresting tasks. Effort regulation is an important self-management skill in academic life, because it emphasizes commitment, and it produces completeness even if distractions occur.

Supplementary items: An interesting observation can be made from students' answers regarding to study preferences in individual and collaborative settings: students generally like to study both on their own and with their friends, but they clearly prefer more individual settings. However, most of the students do not have a clear opinion for either of the options, because most of the answers lie around the mean value of the distributions. There might be some level of uncertainty involved in these opinions owing to the previous experiences that students have gained e.g., in earlier courses. Finally, students' preferences for alternative ways for course evaluation as opposed to traditional exams are much dispersed: large portion of students seem to prefer exams while almost equal amount of students would choose other means of evaluation. One possibility to meet such needs is to offer different options for course evaluation for students to choose from.

3 COMMENTARY

Several important factors regarding to 3rd year engineering students' motivational orientations and learning strategies were rated in this study. However, the data obtained only indicate the state of the current situation. There are no data from the beginning of the studies, and hence, no information available on how these factors have been evolved during the previous study years. It is also impossible to predict changes of these factors that will occur in the future. Therefore, it would be reasonable to organize one or two longitudinal inquiries to find out how students' key regulatory skills and processes develop during university studies. In addition, different study paths with other courses may lead to diversified development of self-regulation skills.

Nonetheless, students in this study are generally intrinsically motivated, and they show high task value and strong control of learning beliefs. Unfortunately, expectancy for success and self-efficacy display somewhat low values. Furthermore, ratings for learning strategies factors and especially for self-regulation skills considerably varies between individual students. It certainly seems that students are willing to learn, but they may be unaware how they should learn, *as individuals*, and how to control their own learning processes and cognition. Many lack fundamental metacognitive skills such as planning, monitoring and regulation skills, which may degrade their academic performance, and hence, undermine their possibilities to develop essential life-long learning skills.

Furthermore, increasing uncertainty and rapidly changing world demand ability to tolerate changes and adaptive skills, which both require well-developed self-regulatory processes, volition and ability to control emotions. Hence, teachers may need to reconsider the design and organisation of their teaching and learning practices, if they attempt to foster the development of important self-regulated learning processes of students and prepare them for the upcoming challenges occurring in the future. An alternative possibility to improve these essential qualities of life could be mentoring. In TUT, a mentoring program has just begun, which is partly based on the MSLQ manual.

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Creativity, Conformity and Constraints

A Grounded Theory Study on Capstone Group Design Projects

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Conference Key Areas: Engineering Skills, Curriculum Development, Teaching Creativity & Innovation

Keywords: Project-Based Learning, Qualitative Research, Grounded Theory, Creativity

INTRODUCTION

Numerous definitions of creativity exist, however, Daly et al. have suggested that creativity is “a type of novel thinking, where people redefine problems, see gaps in knowledge, generate ideas, analyse ideas, and take reasonable risks in idea development” [1]. From this definition we can deduce that creativity skills are intertwined with one’s ability to solve problems. In undergraduate engineering courses, however, there exist a multitude of barriers for students

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to develop these creative skills for solving engineering problems. Learners tend to be viewed as passive receivers in traditional teaching methods. The shift to a student-centred paradigm, the learner now viewed as an active agent in his or her learning, has resulted in development of problem-centred pedagogies such as problem-based learning and Project-Based Learning (PBL). De Graff & Kolmos state that “Project work is problem-based by definition” [2], hence studies on PBL offer valuable insight into creative skill development.

As delivery of PBL varies substantially there exists a pressing need to conduct in-depth studies of deliveries to analyse the student experience. There are many publications that consider competencies and perceptions in the form of surveys and statistical researches. Outcomes of these studies suggest that creative “problem solving is the core of engineering practice” [3], however, these are still developed in the context of an academic setting. Paretti (2008) has suggested that there exists, in the student experience, a tangible dichotomy between the simulated workplace and the educational constraints of project work [4]. This idea is echoed by the Institute of Chemical Engineers (IChemE) who recognise that educators are working under academic constraints when delivering such projects [5].

1 PROJECT-BASED LEARNING

De Graff & Kolmos (2014) argue that new educational pedagogies, such as PBL, emerged from the change in nature of the relationship between the University and wider society towards one where the former holds responsibility for addressing the societal “need for engineers with relevant skills, and competencies” [6]. This conclusion carries substance with many accrediting bodies of engineering programmes introducing criteria that aim to meet the needs of industry.

According to Prince & Felder (2006), PBL can be formulated as “[beginning] with an assignment to carry out one or more tasks that lead to the production of a final product – a design, a model... The culmination of the project is normally a written and/or oral report summarizing the procedure used to produce the product and presenting the outcome” [7]. Thus, PBL exemplifies active learning in that it “involves students in doing things and thinking about the things they are doing” [8]. Often team-based, PBL presents an opportunity for students to develop other social skills for collaboration, such as communication and teamwork. PBL can be both formative, as a regular activity throughout a programme, or as a summative, capstone element that offers consolidates at the end of a programme.

1.1 Capstone Group Design Projects (CGDP)

Group Design Projects (GDPs) are characteristic to Chemical and Process Engineering (CPE) undergraduate programmes worldwide and are generally applicable to many engineering disciplines. GDPs are potential platforms to assist students’ development of professional identities as these can simulate the workplace. For CPE specifically, GDPs must take place as a capstone element of undergraduate degrees, as per the requirements set by accreditors, such as the IChemE. A Capstone GDP (CGDP) potentially offers one of the final interactions students have with education prior to employment. Unlike the limited timeframe involved in traditional lectures, tutorials or even problem-based learning, PBL typically lasts months.

2 CONTEXT FOR THE STUDY

This study examines CPE undergraduate cohorts at the University of Strathclyde. Originally founded in 1796, the University of Strathclyde (UoS) was established for the education of practical disciplines, hence the motto “the place of useful learning”. Engineering, a vocational

subject, has been at the heart of the university with just under six thousand students enrolled as of Autumn 2017. The first Chemical Engineering syllabus at UoS ran in 1870.

2.1 CGDP with Chemical and Process Engineering (CPE) at UoS

The CPE department has been an official part of the university since it gained its Royal Charter in 1964. CPE here has grown significantly over the last decade with an undergraduate intake that has increased significantly, more than doubling from 56 students in 2004 to 115 in 2015.

Characteristic to CGDP in the CPE department is the allocation of a small number of student groups (2-3) to an academic member of staff who acts as a supervisor and evaluates accordingly. Students and staff are provided with the same design brief which includes the problem statement to be addressed by all groups.

Table 1. CGDP delivery at the UoS CPE department and its supervision and assessment development over time

	2015		2016 & [2017]			2018	
Approach	2 concurrent projects		Single 3-phased project			Single 2-phased project	
Projects/Phases	Detailed design	Conceptual design	Feasibility /scoping (P1)	Detailed design (P2)	Economics /sustainability (P3)	Feasibility /scoping	Detailed Design & economics/sustainability
Duration in Weeks	12	12	4 [4]	4 [5]	3 [2]	4	7
Supervisors	7	9	6 [7]	10 [11]	6 [7]	18 (2 per group)	
Students	104		111 [112]			131	
No. of Groups + Size	18 (5-6)	18 (5-6)	16 (6-7)			19 (6-7)	
Assessment Type	Individual	Individual	Group	Individual	Group	Group + Individual	Individual (+ Group HAZOP)
Assessment (%)	66.7%	33.3%	26.7%	40%	33.3%	30%	70%
Assessable Outputs	Report	Report	Report & Oral Presentation	Report	Report	Report & Oral Presentation	Report

The CGDP has undergone significant changes in the recent past (see Table 1). For many years, the CGDP ran as two distinct projects undertaken simultaneously. From 2016 the CGDP was delivered as a single project with a phased approach. In 2016 and 2017, it consisted of three sequential stages focusing on Feasibility and Scoping (P1), Detailed Design (P2) and an economic and sustainability analysis (P3) respectively. P1 and P3 involved group assessment and were supervised by one staff member and the individually-assessed P2 was supervised by another. 2016 onwards, CGDP also differed to prior years, as each group were now given different locations and capacities in their problem statements.

In 2018, P2 and P3 were combined into a single phase thus the CGDP became two-phased. During this iteration of the CGDP, the supervision involved a pair of supervisors who saw the group through the project.

3 RESEARCH METHOD

3.1 Grounded Theory

Malmi et al. (2018), in their meta-analysis of research methods, suggest that the majority of Engineering Education (EE) research employs “data analysis methods [that] are simple descriptive statistics or simple/undocumented qualitative research methods”. The same authors “encourage authors to consider adopting more elaborate methods, both quantitative and qualitative” as a concluding recommendation. [9]

This research utilises a Grounded Theory (GT) research strategy, with the CGDP at the UoS’s CPE department as a primary case. GT offers a novel but rigorous approach with the principal function of developing an unbiased theory built upon empirical evidence. Further, as the CGDP was to undergo changes in delivery, a method that could account for variability was needed and GT not only allowed for variability to be introduced in the study but necessitated it for validity of the resulting analyses.

GT was developed by Glaser & Strauss (1967) from their work on terminally-ill patients [10]. The chief motivation of the authors was to address biases in traditional social research, emerging from researcher preconceptions and the ‘forcing of theory upon data’. Hence, traditional GT remains distinct as a formal research strategy as it rejects literature reviews as a pre-requisite to research. Instead, GT relocates the primacy of the literature review to the closing stages of research as the literature becomes another source of data for analysis.

GT employs varying methods to ensure the developed theory fits the data. The initial focus of the method is to remain open to the possibilities of the study in the substantive area, CGDPs in the case of this research, and thus explore variability. From the onset of data collection, analysis proceeds immediately in parallel. In this way, data collection informs analysis and vice-versa. As the developing theory becomes increasingly robust, theoretical sampling takes place, a technique by which gaps in the theory are addressed. Active pursuit of appropriate conditions and incidences that address evident gaps and even contradict the theory adds further robustness to validity.

3.2 Research Questions

The research questions underpinning this study were open, as the aim of the study was to determine what actually occurs during CGDPs and to explore the phenomena of CGDPs in an EE context. The research questions were formulated according to the principles of GT.

- What are the main concerns of students and staff participating in CGDPs?
- How do participants in CGDPs resolve and process these concerns?

3.3 Data Collection

Three iterations of CGDP (2016, 2017 and 2018) have been investigated within CPE at UoS. As per the GT dictum “all is data” [11], data collected for analysis varied in format. Project briefs (or problem statements) were collected as examples of guiding documentation provided to all students and staff. Written field notes and audio recordings of observations were made of weekly supervisory meetings: a total of 87 observations of 12 groups over two iterations (2016 and 2017) of the CGDP, were observed. The most theoretically-rich data collected were

audio recordings and subsequent transcripts of 27, semi-structured, in-depth interviews with both students (n=17) and staff (n=5). All transcripts were pseudo-anonymised to protect identities and here our analysis builds largely on the examination of interview transcripts from the 2017 CGDP participants.

3.4 Data Analysis

The presented discussion builds upon the process of incident-by-incident comparison as an analytical method for concept generation. Glaser & Holton (2004) suggest that the researcher begin analysis by asking questions to the data including “What is this data a study of?”, “What [conceptual] category does this incident indicate?”, “What is actually happening in the data?”, “What is the main concern being faced by the participants?” and “What accounts for the continual resolving of this concern?” [11]. As suggested by Charmaz, the initial data was analysed line-by-line and coded with gerunds (italicised in the analysis) to bring to light the social processes accounting for students’ behaviours [12]. By questioning the data in this manner and comparing incidents, higher level concepts are formed and then further developed from repeated comparison with incidents and the emerging concept.

4 DISCUSSION

Although a wealth of significant concepts emerged from the data, discussion focuses upon two concepts, *conforming* and *constraining*, that are particularly relevant to student creativity.

4.1 Conforming

The social process of *conforming with peers* (*conforming*) emerged from incident-by-incident analysis as significant to students’ experience of the CGDP, represented in Fig. 1.

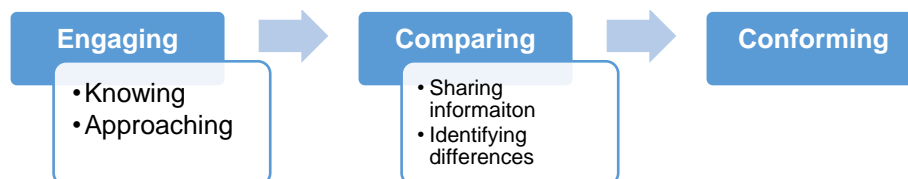


Fig. 1. *Conforming with peers* and its sub-processes

The significance of this phenomenon was deduced from a high frequency of reported incidents from student interviews, either in the first or second person. These were initially composed of fragmented codes which were then compared to form *conforming with peers* as a substantial category. Thereafter, questions addressing this process were introduced to subsequent interviews where *conforming* was absent otherwise, ultimately revealing conditions by which the social process comes about.

This process of *conforming* was a significant behaviour employed by students at the onset of the individual phase (P2) but was also reported during the group phases too (specifically, P1). The following discussion relates to individual phases (P2) unless specified otherwise. One of the conditions for the process of *conforming* to take place was students *engaging with similarly-tasked peers*. A pre-requisite to *engaging* was simply *knowing of similarly-tasked peers* without the need to have any significant prior acquaintance:

“...he got a Facebook message through from somebody who have not really spoken to at all, don’t really know any of their friends either... “All right, they’ve done this, I’ll try that.” – Cain Bruce (E1)

The above pseudo-anonymised extract suggests that prior interaction was not a necessary component in the decision about who to approach. Different media of *approaching* became

apparent too, ranging from students using online social media platforms to meeting informally with one another.

“Sometimes I’ll meet people who are from different groups who are doing something similar, we’ll have lunch and stuff together and talk about the ability to....” – Cain Bruce (E2)

Notably, there was a high frequency of self-reporting of the formalisation of such groups into autonomous learning groups (ALGs), contingent on task similarity. In many instances students reported these directly, as is the case for Natasha Douglas:

“... the individual phase, there was people doing similar things to you, so you’d work with them.” (E3)

The extract suggests that such behaviour was considered normative and the condition of similarity is what bound such groups together. Indeed, the same interview participant went on to retell her own account of leaving such a group upon losing the condition of similarity: *“So I was doing a different – they were all doing [equipment] in stage 1 and I was doing it in the second stage. So, I wasn’t dealing with the same thing as them.”* Other interviewees who did not join an ALG ascribed this to a lack of similarly tasked peers.

ALGs emerged as having properties distinct from original groups as these groups shared the same task, unlike original groups which involved differing sub-tasks. ALGs were self-selected and non-enforced, hence viewed favourably by students with students, such as Ellis Donaldson, describing these as *“...good, that was great”* (see also E5).

Engaging takes place for *comparing* to take place, the primary purpose of which is in *verifying one’s work*. *Comparing with similarly tasked peers* involves both *sharing of information* and *identifying differences*, both of which can be understood from the following extract.

“...he was like, “how did you manage to do that?” ... I just sent it to him and I was like “let me know if you notice anything that’s wrong with it.”... at least I’m getting something back” – Will Ross (E4)

Will Ross, a student who did not participate in an ALG, indicates how he was approached by a similarly tasked peer during P2. Multiple students experienced compulsions to share information upon requests from peers. In ALGs, sharing of information was expected of members and discussions would revolve around reaching collective agreement on design decisions:

“It was quite good working in this group because you’d come up with an idea and somebody would challenge it... I don’t really know if I did it completely by myself, how far I would have gotten... And then you’re completely wrong because nobody has really challenged you. – Natasha Douglas (E5)

Where ALGs promoted a form of instant-feedback and verification for students by the function described by this extract, those students who did not join an ALG faced the problematic situation of obtaining feedback by other means. Most individuals opted for re-establishing a connection with members of their originally assigned group.

Importantly, the feedback provided by supervisors was deemed inadequate as the supervisor was both guide and evaluator therefore some students suggested a fear of being evaluated negatively during these interactions by disclosing issues or raising questions:

“I just get quite stressed when I have to ask the supervisor a question. Because maybe this is something I should know – are they going to give me in to trouble.” – Natasha Douglas (E6)

After sharing information, a student comes to *identifying differences* where they are subject to a significant social pressure to account for these differences and must decide whether they will conform the standard of the collective.

"I think it's a sad situation where – within myself, when I'm thinking of making this design as original to myself as I can be – I feel like I'm putting myself at a disadvantage. When I feel like I want to design this entirely on my own, and come up with all my own, work it out on my own – do it all me – part of me is like "no one else is doing that and they are all going to do better than you because they're all going to have the same method." – Cain Bruce (E7)

Conformity is well-documented in the literature however, in organisational theory there exists the theory of "mimetic isomorphism" which can be viewed as a cautious strategy to ensure an organisation remains competitive by imitating competitors [13]. This process is reflected in the case of CGDPs, where conforming becomes a safer approach for students as there is the fear of challenging the position and views of the perceived collective. *E7* reveals the extent of the social force exerted on individuals seeking creative originality – they must not only embrace the dangers of distinction but deal with internal conflicts arising from comparisons with peers. Interestingly this phenomenon, with the same conditions, were observed in group phases too.

4.2 Constraining

Another concept emerging from student interviews that proved relevant to creativity centres on restrictions in the form of word and page limits, as mentioned by a staff member.

"possibly larger, give them more space to show off. And even more space to be creative, definitely – to come up with new ideas and appreciate that in the marking – the grading scheme." Courtney Murphy (E8)

While these limitations were introduced to simulate professional communication practice, and students understood the underlying logic, *constraining one's design* became a strategy to meet these limitations by *simplifying one's design*. Often this involved a loss of creative solutions and considerations as mentioned in *E8* and reflecting findings like that of Paretti [4].

5 IMPLICATIONS FOR PRACTICE

The formation of the aforementioned ALGs is of interest for educators in engineering as these were viewed favourably by interview participants, for their shared goal and social support. However, co-ordinators of CGDPs must be aware of student forming ALGs to ensure more accurate assessment measures for individual performance, such as a viva. Introducing greater variability in problem statements for groups will encourage fewer instances of conformity and thus encourage development of creative problem-solving skills but must be balanced with fair and objective assessment. The combined roles of supervisor and evaluator needs to be considered carefully as this potentially acts as a barrier to supervisor-student communication. Finally, communicating assignments must be designed by engineering educators to ensure appropriate encouragement of creative solutions.

6 FUTURE WORK

Staff experience, focusing on assessment and communication with students, will be explored with additional interviews and analysis. To obtain further understanding of CGDPs and student experience and behaviour, a UK-wide survey of CPE departments will be conducted to explore significant variables pertaining to the design of CGDP activities.

7 ACKNOWLEDGEMENTS

This work was supported by the Engineering and Physical Sciences Research Council under grant number EP/M508159/1.

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Describing ‘generic’ graduate engineer skills

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Conference Key Areas: Engineering Skills, Curriculum Development

Keywords: Skills, Generic, Solving real problems, Practice

INTRODUCTION

Being able to describe skills effectively is essential for teaching and enabling students to learn skills. A previous study [1], investigating the development of real industrial problem solving skills in a taught Masters course, found inadequate skill descriptions were a significant problem. On further investigation, it was determined that skills could only be described at a high level, unless the task and associated context was known. Such high-level descriptions e.g. project management, do not communicate the skills graduates need for work.

Describing tasks has been found to be an effective way of describing graduate work [2] and whilst this does not describe skills, by practising these tasks in relevant contexts, skills are developed. Task frameworks provide a way of organising and communicating tasks in a structured way and provide a holistic view of a particular type of work.

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A high-level task framework (see Fig.1) containing twelve process-stages and five 'generic' domains: **Manage the Client (MC)**, **Manage the Project (MP)**, **Manage Information (MI)**, **Work With Others (WWO)** and **Manage Self (MS)** was developed [3]. This was tested, along with individual process-stage tasks, in Short Industrial Placements (SIPs). These involve pairs of students spending two weeks, based at a company, to solve a real industrial problem.

The research question for this study was "What tasks contribute to the five 'generic' domains?" so that relevant, evidence-based frameworks similar to those for the process-stages could be developed.

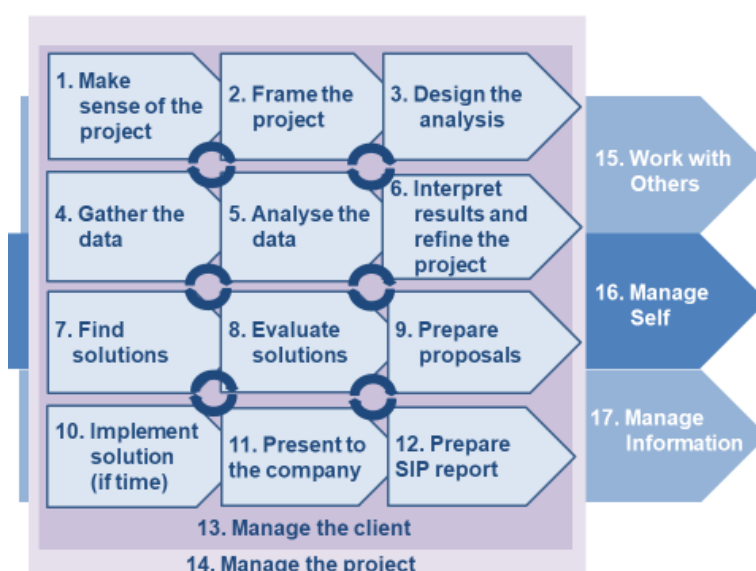


Fig 1. SIP Framework

This work is a summary of part of a PhD Thesis (to be published in September 2018).

1 PROBLEM DIAGNOSIS

The first step was to capture a description for each generic domain, and from multiple perspectives, so that any subsequent literature review could be sufficiently guided.

A student view of WWO, MS and MI was explored after they had completed four SIPs. 26 students recorded challenging tasks for each domain that generated three data sets of 45, 28 and 31 tasks respectively. An analysis of this data determined that; there was an extensive range of tasks per domain, each domain was different in nature, students experienced more challenges with WWO, tasks descriptions were at varying levels of detail and for WWO and MS, behaviours were a key feature. The student view was combined with that of course staff and course documentation to create the following high-level SIP specific descriptions.

Manage the Project (MP) Planning and executing the SIP in the two-week timeframe such that the required outputs were delivered on time and at a professional standard.

Manage the Client (MC) MC is a subset of MP, but highlighted separately to emphasise its critical nature due to the fixed, short duration of SIPs. The client was the SIP host company, typically with several key stakeholders e.g. problem owner, SIP supervisor, senior manager. MC involves determining who actually represents the voice of the client, getting access to required data, people and resources as early as possible, keeping the client informed of progress, validating assumptions and testing ideas regarding potential solutions.

Manage Information (MI) Managing a wide range of data and information where identifying data sources, dealing with incomplete and conflicting data are typical challenges. Some aspects e.g. gather and analyse data overlap with the process-stages, see Fig. 1.

Work with others (WWO) Building and maintaining a collaborative working relationship with their SIP partner and having an effective transactional working relationship with others. The most significant person is the allocated SIP partner. Others include their company supervisor, University tutor and other company personnel relevant to the problem.

Manage Self (MS) Acting in a professional manner – presenting themselves appropriately, being organised, on time, alert, focussed, open minded and engaged whilst demonstrating a ‘consultant’ rather than ‘student’ mentality. From the student perspective, this also covered physical health and mental well-being.

2 LITERATURE REVIEW

The descriptions above guided a search to identify academic and evidence-based practice literature that related to an early career work context or reflected ‘best practice’/‘standards’ adopted by professional bodies.

Before considering each domain, the Graduate Capability Framework (GCF) [2] was reviewed as it contributed significantly to thinking behind the SIP Framework [3], met the above criteria and included seven generic domains. The GCF was developed using a task work analysis approach describing the work to be done [4] so the name ‘Graduate Capability Framework’ is somewhat misleading implying that graduate capabilities are described.

An analysis of the GCF Generic Capabilities at the task level found: overlaps between domains e.g. communication was also a key aspect of both teamwork and project management, variable styles of task descriptions and, the inclusion of non-tasks e.g. works independently. A comparison with the SIP Framework (Fig. 1) found that only two of the GCF generic domains mapped directly onto a single SIP Generic Domain with the rest aligning with multiple domains.

This analysis suggested that categorising and describing tasks was difficult for generic domains. Three reasons are suggested, different interpretations of the domains caused by limited domain descriptions, overlapping domains, and describing tasks appeared more difficult in interpersonal and intrapersonal domains e.g. team-work and self-management.

A typical task description is an action verb followed by a direct object and sometimes followed by a qualifying statement that indicates how, when or why the task is done [4]. Tasks are also expected to have a clear beginning, middle and end and be directed towards a work goal. Whilst this is appropriate for discrete aspects of a job it could be problematic when looking at ongoing aspects of a job. The domains are now considered in turn.

MP - Project Management is a profession and a number of institutions maintain a best practice body of knowledge. The Project Management Body of Knowledge (PMBOK)[5], a global standard from the Project Management Institute, was selected as this best matched the single project SIP context and the literature search criteria. The PMBOK definition and scope aligned well with a SIP and its ten knowledge areas captured 47 processes, seen to be an equivalent of a task, provided a good basis for developing a SIP specific framework.

MC - Four PMBOK knowledge areas were found that covered the practice conception of MC.

MI - In the growing academic field of Personal Knowledge Management, thirteen different models were reviewed [6]. The one judged most relevant, was developed by academics who

conceptualised information skills as a set of problem solving skills that had both logical and practical components required for the “problem solving knowledge work of the twenty-first century” [7]. The framework comprised seven skills: retrieving, evaluating, organising, collaborating around, analysing, presenting and securing information.

WWO - A review of the professional expertise and interpersonal skills literature reinforced the importance of WWO but no rigorous, evidence based, frameworks were found at the right level of detail that provided a good match with the SIP description of WWO.

MS - The academic literature came from many fields including psychology and management. It was typically focussed on single rather than multiple aspects, and related to general work contexts rather than something as specific as a SIP. No suitable evidence-based framework was found that aligned with the MS description.

In summary, domain relevant frameworks were identified for MP, MC and MI but no literature was found that covered WWO and MS with a rigorous evidence base.

3 RESEARCH

To answer the research question “What tasks contribute to the five ‘generic’ domains?” two different strategies were adopted. For MP, MC and MI, a top-down approach of deriving a framework from theory and validating it empirically applying a variance research design. This approach had been effective when deriving the process-stages[3].

For WWO and MS, a bottom-up approach was selected to derive a framework from empirical data because no relevant, evidence-based frameworks were identified to provide a firm theoretical basis. A Grounded Theory, research methodology was selected where an abstract theory of processes, activities or events grounded in the views of the participants is derived [8, 9]. Many researchers use the first part of this methodology as a way to systematically analyse qualitative data [9] rather than go on to develop theory and such analysis would answer the research question and contribute to framework building.

3.1 MP, MC and MI

The frameworks identified required adapting for the SIP context. The PMBOK framework was designed for practising project managers and not novice students. The authors reviewed and adapted it identifying 7 knowledge areas and 33 tasks as an initial framework, of which 4 knowledge areas and 9 tasks were the MC subset. The authors were not in full agreement so all 47 tasks were to be tested with the students.

The MI framework was derived from an analysis of its skill descriptions [7] identifying 15 tasks. Overlaps were found with the process-stages particularly numbers 4, 5, 6 and 11 (See Fig.1). The authors agreed that the adapted framework appeared to be a good fit with a SIP and it highlighted important aspects previously uncaptured such as ‘secure information’.

In terms of research design, a three-stage approach was adopted:

Stage 1: test the frameworks to determine if they cover the range of tasks students do.

Stage 2: identify the specific SIP tasks that students undertake in each domain.

Stage 3: test the results with experienced tutors to provide an alternative perspective.

3.1.1 Testing – Stage 1

A variance research design [10] was selected to compare the adapted frameworks with the student view of what they did. During one Masters programme, data was collected after each

of the four SIPs for MI and after the last two SIPs for MP and MC. 304, 181 and 202 statements were collected respectively. The data was analysed for fit and the results, see Table 1, show a lower % fit for MC, caused by students describing behaviours rather than tasks. Once separated, the % match aligned around 90% giving confidence that the domains were interpreted fairly consistently. The three frameworks covered the range of tasks students do as all tasks could be allocated, but overlaps remained with the process-stages.

Table 1. % Fit of responses with domains

Generic Domains	% Fit	% Fit (No behaviour)
MC	77	91
MP	89	0
MI	91	0

3.1.2 Testing – Stage 2

The objective was to identify specific SIP tasks and this testing took place with the subsequent year group to Stage 1. A variance research design [10] was selected to compare the frameworks from Stage 1 to the student view of practice. MI was tested after SIP 1 and MP after SIP 2 and student participation rates were 80% and 66% respectively.

For MI, out of 153 student task descriptions, 13 or 8.5% were considered to be variances with the derived framework. A review by the authors, determined these were part of other domains/process-stages or at a more detailed within the MI framework. So the framework with 15 tasks was confirmed, see Table 2, with refinements noted to extend some task descriptions.

Table 2. MI Domain SIP Framework

MI Task clusters	MI Tasks
Retrieve information	Search for information, Gather information from different sources e.g. print, electronic, people
Evaluate information	Evaluate relevance, Determine quality and status of information, Deal with incomplete or inconsistent data
Organise information	Determine an appropriate way to organise information given the context Undertake regular and systematic organisation of information
Collaborate around information	Determine appropriate information/communications systems, Determine procedures for information exchange, retrieval and cataloguing
Analyse information	Determine an appropriate method and tool for data analysis e.g. excel Process the data, Analyse results to extract insights
Present information	Determine an appropriate format to communicate to the audience
Secure information	Protect information, Keep all sensitive data information confidential

For MP, 37 rather than the predicted 33 PMBOK tasks were done by students. On reviewing the variances, 4 tasks and the Quality Management task cluster was reinstated resulting in the framework in Table 3. The need to provide extended task descriptions was identified by both the authors and the students to increase confidence that that the tasks were being interpreted consistently.

The methods successfully identified variances between the frameworks and the student view of what they did but there is no guarantee that all potential variances were uncovered.

Table 3. MP Domain (*incorporating MC*) SIP Framework

MP Task Clusters	MP Tasks
Integration Management	Develop Project Charter, Develop Project Management Plan, Direct and Manage Project Work, Monitor and Control Project Work, Perform Integrated Change Control, Close Project
Scope Management	Plan Scope Management, Collect Requirements, Define Scope, Create Work Breakdown Structure (WBS), Validate Scope, Control Scope
Time Management	Plan Schedule Management, Define Activities, Sequence Activities, Estimate Activity Resources, Estimate Activity Durations, Develop Schedule, Control Schedule
Team Management	Assess Project Team Capability, Develop Project Team, Manage Project Team
Quality Management	Plan Quality Management, Perform Quality Assurance, Control Quality
Communications Management	Plan Communications Management, Manage Communications, Control Communications
Risk Management	Plan Risk Management, Identify Risks, Perform Qualitative Risk Analysis, Plan Risk Responses, Control Risks
Stakeholder Management	Identify Stakeholders, Plan Stakeholder Management, Manage Stakeholder Engagement, Control Stakeholder Engagement

3.1.3 Testing Stage 3

Both frameworks were tested on six established tutors using semi-structured interviews. There were only a limited number of tasks where tutors could provide an evidence-based view because they only observe, or are involved in, a minority. The MP framework was seen to need more adaptation to the SIP context but there was full agreement with the MI framework.

3.1.4 MP, MC and MI Conclusions

It was shown that: MC did fit fully within the MP framework, there are multiple overlaps between MI, MP and the process-stages which correlates with the findings from the development of the GCF [2] and, the MP and MI frameworks generated, whilst requiring some refinement, do represent the tasks that students do or should do in a SIP.

Reflecting on the SIP Framework (Fig. 1) the seventeen categories are not presented at a consistent level as the process-stages align better with a generic domain task cluster than a generic domain. This results in five high level domains: 'Do the project' comprising the 12 process-stages, 'Manage the Project' comprising MC and MP, plus WWO, MS and MI.

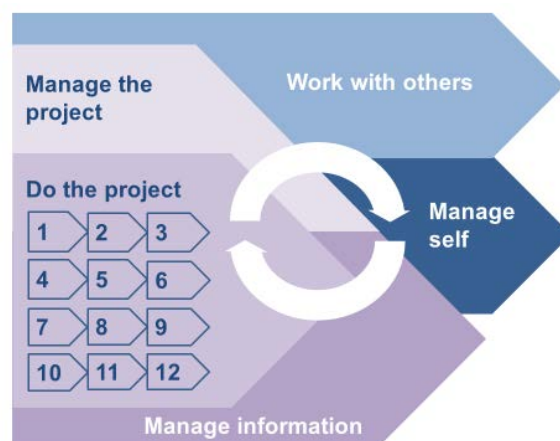


Fig. 2. SIP Framework – new representation

A new representation of the SIP Framework is in Fig. 2. The three purple domains are closely interlinked and are delivery-centric whilst the two blue coloured domains are people-centric and underpin delivery. The large circular arrow depicts the domain interconnectedness.

3.2 WWO and MS

A five-step research method was designed to collect and analyse data.

Step 1 – Collect three descriptions of important tasks from each student for four SIPs.

Step 2 – Analyse the data to test the fit with the domain descriptions in Section 1.

Step 3 – Develop a coding framework using grounded theory principles of letting the categories emerge from the data and applying constant comparison followed by peer review.

Step 4 – Code the data and test fit with the framework using an iterative process until each statement fitted within a single framework category.

Step 5 – Identify tasks by analysing action verbs associated with direct objects [4].

3.2.1 WWO

Step 1: 344 student task descriptions were captured.

Step 2: 37% of descriptions aligned with another domain or process-stage describing tasks that were 'done together' but were not about working with another person. 19% of descriptions referred to behaviours rather than tasks.

Step 3: After a number of iterations, including peer review, two distinct domains were identified as Communication and Partnership and multiple sub-categories emerged in each.

Step 4: Coding the data resulted in framework refinement and the WWO framework that emerged is below in Table 4. 16 behaviours were identified, where 'trust' was the most cited.

Step 5: Further data analysis enabled 81 different tasks to be identified.

Table 4. WWO Domain SIP Framework

Communication		Partnership	
Sub-category 1	Sub-category 2	Sub-category 1	Sub-category 2
Mechanism	communication plan	Way of working	pace
	meetings		approach / style
	interviews		review of partner's work
	format		pattern
	discussions		resolve disputes
	questions	Team	goals / objectives
Content	ideas		performance
	information		leadership
	issues / problems	Tasks	allocation / split
	opinions		capability requirements
	findings	Capabilities	strengths and weaknesses
	recommendations		skills
	expectations		confidence
	feedback	Relationship	empathy
Verbal	terms and phrases		understanding of partner
	structure / logic		agreed positions
	fluency		partnership attitude
Non-verbal	body language		

3.2.2 MS

Step 1: 311 student task descriptions were captured.

Step 2: Preliminary data analysis found strong alignment with the MS practice description but thinking tasks were missing. The only domain overlap was with WWO, accounting for 8% of responses, which was attributed mainly to the task context.

Step 3: After a number of iterations, five main categories emerged centred on health, thinking, self, 'being professional' and 'managing my work' with sub-categories at two levels. Following peer review a few minor revisions were made.

Step 4: Coding enabled some new sub-categories to emerge from the data and the final framework is shown in Table 5. There was a clear link between 'Managing my work' and the MP time management tasks. 19% of all MS task descriptions referred to behaviours. Sixteen behaviours were identified, with 'being focused' and 'open-minded' the most important.

Step 5: Further analysis of the data enabled 77 tasks to be identified.

Table 5. MS Domain SIP Framework

Sub-category 1	% split of total	Sub-category 2	
Health	12%	physical	Mental
Thinking	11%	objectivity	logic and structure
		decision making	Reflect
		creativity	
Self	23%	knowing me	being me
		learning about me	motivating me
		learning new things	managing my emotions
Being professional	7%	Etiquette / cultural norms	
Managing my work	47%	Goals/objectives	Organisation
		Plan/ schedule	Delivery (tasks)

3.2.3 WWO and MS Discussion and conclusions

The research question was answered from a student perspective since they do these tasks and some are not-observable by others e.g. thinking tasks. The task lists may be incomplete because only a limited number of tasks per student were asked for and the domains remain to be explored fully in literature.

37% of WWO responses, aligned with tasks that were 'done together' but belonged to another domain or process-stage because WWO tasks often happened in combination with others. The name WWO was insufficiently specific and a split into 'communication' and 'working in a partnership' should be better. The narrower definition of 'working in a partnership' at a host company explains the lack of fit with the literature reviewed which was predominantly employee focussed.

The analysis has identified task clusters for review in the literature to contribute to the ongoing development of both frameworks. The through-SIP nature of these domains was confirmed and behaviours were identified as an important component of a description.

4 OVERALL CONCLUSIONS

Describing 'generic' skills is more challenging than describing 'process-stage' skills. The work analysis concepts applied may be better suited to discrete process tasks than tasks repeated throughout a process, and behaviours are an additional component of describing people-centric tasks. The relative size of the people-centric domains was larger than previously reported [2]. This adds to the limited, but growing, evidence that engineering practice is an intellectually challenging socio-technical activity [11].

5 IMPACT AND IMPLICATIONS

Adequately describing the generic aspects of what Engineering graduates do in practice has the potential to significantly improve Engineering Education because it will enable these aspects to be communicated in ways that multiple stakeholders can understand and interpret consistently. As a result, there will be a better understanding of engineering practice, the most important people-centric skills can be identified and taught, and students will be better prepared for practice.

The SIP Frameworks developed would require some adjustments to apply to other real problem solving projects or placements used in HE as SIPs are not common. However, it is likely that only some of the domains would require adjustments and the main categories and the relationships between them would remain the same.

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Educating Engineers for Sustainability: understanding student differences

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Conference Key Areas: engineering education, education for sustainability, discipline-specific teaching and learning.

Keywords: Sustainability programmes, comparison of engineering programmes, student learning

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1 INTRODUCTION

Our society deals with many challenges such as food security, economic growth and social inclusion, which are amongst the biggest issues facing the world today (WEF, 2016). Sustainability issues like resource security and climate change also made it into the top 10 of the biggest global challenges (WEF, 2016). Universities play an important role in educating engineers that can deal with these challenges.

Society and companies require engineers with a wide range of knowledge and competences that allows them to meet labour expectations and to venture successfully into a rapidly changing world (Guerrero, Palma and La Rosa, 2014). The profile of a good engineer should be based on the ability and willingness for learning, a solid understanding of basic natural sciences and deep knowledge of any field of technology, in addition to general human values (Palma et al. 2011 in Guerrero, Palma and La Rosa, 2014: 833). Moreover, a good engineer has to be prepared for lifelong learning and must also possess good communication and teamwork skills. Technological competencies alone are not enough in the contemporary world (Maffioli and Augusti, 2003). The need to expand engineering competences is recognised by engineering academies (e.g. (National Academy of Engineering, 2004), and engineering accreditation boards of Engineering (e.g. ABET, 2014). Sustainability education has had a strong position in this call for a renewal of engineering competences. As stressed in one of the criteria in ABET (2014:3), engineers have to gain “*the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context*”. This challenge of sustainability raises a demand for a new range of qualifications and requirements for future engineers (Haase, 2014).

Engineering often deals with its responsibilities by defining three separate stages (society is responsible for the demand of technology, the engineers create it, and society is again responsible for its application) (Mulder, 2004). In the area of their expertise, engineers have been the ones who created solutions to the challenges of mankind and their judgement has been unchallenged (de Graaff and Ravesteijn, 2001). However, sustainable development is not solely a technological problem and there is a need for engineers to be able to communicate and collaborate with other experts as well as citizens involved (Mulder, 2004). In order to deal with sustainability issues, we need to educate a new kind of engineer who is “fully aware of what is going on in society and has the skills to deal with societal aspects of technologies” (de Graaff & Ravesteijn, 2001: 420).

Sustainability demands a specific kind of learning (Segalàs, Ferrer-Balas and Mulder, 2010) and in order for individuals to be in a position to engage with sustainability-related issues, a change of perspective in education is required (Rieckmann, 2012). This is the case for the way of educating students for sustainability, but this is also the case for the way the discourse of sustainability has been interpreted in higher education. One of the problems when teaching sustainability is the dominance of traditional single discipline based subjects with universities still primarily structured along disciplinary lines (Howlett, Ferreira and Blomfield, 2016). Embedding sustainability in the curriculum poses a new challenge to the academic system (Rieckmann, 2012). If we want to bring about a paradigm shift in higher education in order to deal with the sustainability challenge, we need to understand our students better and we need

to answer the question; to what extent are engineering students prepared to enter the profession?

In general, engineering education is responding to these challenges by establishing engineering programmes with focus on sustainability that rely on sustainability sciences as core content and other, more traditional engineering domains. In an employability perspective, there should be a strong link between engineers working with environmental management and corporate social responsibility and engineers working in other departments to innovative and produce sustainable products and services.

The question is if engineering students in sustainability programmes experience themselves prepared to their profession differently, compared to engineering students in non-sustainability programmes?

We will explore this by studying to what extent differences exists between engineering students in non-sustainability programmes and engineering students in sustainability programmes in terms of preparedness, when they start their study and when they finish. Preparedness is about how well-prepared students assess themselves to be for different engineering key competences. Based on the comparative study, we will discuss potentials for cross-programme activities, which could enhance students' learning of sustainability.

2 METHODS

In this article, we use data from the PROCEED (Program of Research on Opportunities and Challenges in Engineering Education in Denmark) and PROCEED-2-WORK studies. PROCEED included a survey on all Danish engineering students who enrolled in 2010 and was extended to follow the cohort until after their graduation with data collections in 2010, 2011, 2015 and 2016 in a longitudinal study. In this article, we seek to measure students' self-assessed preparedness, with specific focus on differences in preparedness between engineering students in sustainability programmes, and engineering students in non-sustainability programmes when they enter their study and finish their study. The purpose is to point out potentials for learning outcomes from these students working together, as significant different levels of preparedness can motivate peer-learning activities.

The framework for studying engineering skills and competences was adopted from the Academic Pathways Studies of People Learning Engineering Survey (APPLES) prepared by the Centre for the Advancement of Engineering Education, US (Atman *et al.*, 2010; ABET, 2011). According to Atman *et al.* (2010), these items have been developed from the ABET criterion 3 programme outcomes list (ABET, 2011) and the National Academy of Engineering report, "The Engineer of 2020" (National Academy of Engineering, 2004).

The population in PROCEED and PROCEED-2-WORK made up 4.339 students across eight educational institutions in Denmark. The response rate in 2010 was 46% and in 2015 30%. It should however be considered that the data set from 2015 suffers from a systematic underreporting of response rate since it has not been possible to extract the approximately 25% of students who dropped out of their chosen education since 2010 from the dataset.

In order to differentiate between general and sustainability programmes, we have taken point of departure in the description of the study programmes in the online guide of all educations in Denmark (<https://www.ug.dk/>). Study programmes that explicitly mention "sustainability" in their description as part of the core profile are categorised as being sustainability programmes.

All other programmes as non-sustainability programmes. This categorisation is used as the education guide is an element for students' choice of engineering education.

The respondents in the PROCEED project for this analysis is as follows, see table 1.

Table 1. Respondents in comparable programmes

Population	2010	2015
Engineering students in sustainability programmes	73	210
Engineering students in non-sustainability programmes	1609	1084
<i>Total</i>	1682	1294

We will present data from the surveys in 2010 and 2015. 2010 is the year in which students enrolled in the study programme as first years bachelor students. This year has been chosen as this particular survey gives a measurement of the first year students' preparedness and acts as a control for already existing differences in the subpopulations. In 2015 the students were about to finish their master's degree, which gives us the most accurate measurement of the effect of the particular education they have undergone. In 2015, two additional items were added, "*Environmental impact*" and "*Social responsibility*", these items are therefore reported for 2015 and not 2010. As shown in table 1, the number of students in sustainability programmes has increased from 73 in 2010 to 210 in 2015. This can be explained by the fact that from the cohort who enrolled in 2010 a large group of students have chosen a sustainability master programme, whereas their bachelor programme has not been characterised as a sustainability programme. In table 2 we present the proportion of the students in each subpopulation who answered that they were "very well prepared" to incorporate each of the items as well as the results from Pearsons Chi-square tests of significance.

3 Results

In the following, we present results on similarities and differences between engineering students in sustainability programmes and engineering students in non-sustainability programmes in order to point to learning potentials across programmes. During the presentation, we refer to the data presented in table 2 of how well-prepared students assess themselves to be for different engineering key competences in 2010 when entering the study, and in 2015 when they are about to graduate.

For the majority of the variables, there are no significant differences between students' perception of being very well prepared (see table 2). In 2010, this goes for:

1. Engineering analysis, data analysis, conducting experiments and the use of engineering tools, i.e. items concerning specific engineering knowledge
2. Design, teamwork, creativity, communication and life-long learning, i.e. items related to process competences
3. Professionalism, business knowledge, leadership and management skills, i.e. items considering business awareness

4. Awareness of the societal context, global context, ethics and contemporary issues, i.e. contextual knowledge

Table 2: Students self-reported levels of preparedness to incorporate a selection of items while practicing as an engineer. % Very well prepared for sustainability programs and non-sustainability programs (* $p < .1$, ** $p < .05$, *** $p < .01$) (2010 $N=1562$, 2015 $N=1145$).

Please rate how well prepared you are to incorporate each of the following items while practicing as an engineer		Test of significance 2010	Test of significance 2015	2010 - % Very well prepared		2015 - % Very well prepared	
				Non-sustainability	Sustainability	Non-sustainability	Sustainability
Engineering knowledge	Engineering analysis (theoretical understanding)			4.8%	1.5%	28.3%	27.4%
	Engineering tools (professional methods)			4.9%	2.9%	26.7%	25.1%
	Conducting experiments		*	6.5%	2.9%	21.6%	14.6%
	Data analysis			5.1%	2.9%	24.6%	26.4%
Process competences	Communication			9.7%	4.3%	16.5%	16.2%
	Creativity			15.0%	15.9%	20.4%	17.7%
	Life-long learning			12.0%	4.3%	20.2%	17.3%
	Design			6.6%	5.8%	14.6%	13.1%
	Teamwork			23.7%	20.3%	41.7%	47.5%
Business awareness	Management skills			5.9%	2.9%	11.4%	12.7%
	Business knowledge		**	8.2%	4.3%	12.9%	6.1%
	Leadership			8.8%	7.2%	7.4%	8.1%
	Professionalism			12.9%	10.1%	26.3%	21.2%
Contextual knowledge	Contemporary issues			4.6%	8.7%	7.5%	10.7%
	Ethics		*	8.5%	5.8%	12.9%	18.9%
	Global context			5.0%	5.8%	10.3%	14.3%
	Societal context			5.7%	7.2%	7.7%	11.8%
	Math	*	*	14.4%	5.8%	24.2%	16.2%
	Problem solving	**	*	15.5%	2.9%	44.9%	36.2%
	Science	*		8.2%	1.4%	23.2%	23.6%
	Environmental impact		***			12.9%	35.5%
	Social responsibility		*			13.1%	19.7%

In 2015, when students are about to graduate, the above picture from 2010 is rather stable, however significant differences have emerged as the sustainability students experience themselves more prepared in relation to ethics, environmental impact and social responsibility whereas the non-sustainability students experience themselves more prepared in relation to the conduct of experiments and business knowledge.

There are differences between engineering students in sustainability programmes and engineering students in non-sustainability programmes in regard to their own experience of preparedness to the future profession. The non-sustainability students experience themselves more prepared for a number of the engineering knowledge variables.

These differences occur for students within the two types of engineering programmes. This provides a solid platform for cross-program-collaboration – they are in popular terms “speaking the same language”. However, there are also some clear peer-learning potentials, as we will turn to below.

When asked about how well prepared they are to incorporate a number of items while practicing as an engineer, engineering students in sustainability programmes rate themselves significantly below engineering students in non-sustainability programmes on math and science as well as on problem-solving (see table 2). In 2015, there are still significant differences in terms of math and problem solving, but there are now also significant more students from non-sustainability programmes that assess themselves to be very well prepared to conduct experiments and incorporate business knowledge.

In another question from 2010 (see table 3), all engineering students in both sustainability programmes and non-sustainability programmes were asked to assess themselves on a number of competences in relation to their fellow students in engineering programmes. More engineering students in sustainability programmes consider themselves average or below average their fellow students considering self-confidence (social), math, science, leadership ability as well as their public speaking ability. The relatively low self-rating in terms of math and science supports the conclusion. But the significant differences in the other items also points to more general self-confidence issues.

Table 3: Students self-assessment relative to other students on selected items (only items with significant differences are presented)

	Average or below average	
	Non-sustainability programmes	Sustainability programmes
Self Confidence (social)	65,3%	86,0%
Leadership ability	63,8%	88,4%
Public speaking ability	67,3%	87,7%
Math ability	54,6%	69,9%
Science ability	51,3%	69,4%

4 Discussion and perspectives

In this paper, we show that there are differences of preparedness between engineering students in non-sustainability programmes and engineering students in sustainability programmes when they start their education and when they finish their studies under the assumption that significant different levels of preparedness can motivate peer-learning activities. The findings are based on a longitudinal empirical survey study carried out in 2010, 2011 and 2015. 4.339 engineering students from 104 different study programmes at eight Danish universities and Schools of Engineering have participated in this study.

These findings could point to learning potentials for students in sustainability programmes to work together with students from non-sustainability programmes by establishing activities across programmes. In cross-programme activities students from sustainability programmes could be important carriers in the paradigm shift to education for a sustainable development and at the same time gain from the self-confidence of students from other engineering programmes in relation to math and maybe also push sustainability science students towards a problem-solving mind-set. Sustainability problems are complex and call for analysis, but at the same time, sustainability scientist should not take a role of formulating problems for others to solve. In the same way, engineers in general have to understand sustainability problems in order to contribute with sustainable sound innovations.

The most obvious hypothesis when considering what sustainability students could teach other engineering students is of course related to what they have specifically been trained for: sustainability. However, as obvious as it might seem, there is a lack of research to reveal the actual potential for using students peer-learning across-programmes to enhance education for sustainability.

The difference in terms of social responsibility is, however, not as strong as expected. Note that as 19,7% of sustainability students rate themselves to be very well prepared in relation to social responsibility; this is also the case for 13,1% of the other students. At least for sustainability programmes it is rather surprising that only about 1 out of 5 consider themselves to be very well prepared in relation to one of the three pillars of sustainability. The same goes for ethics, where less than 20% of the students in both categories assess themselves to be very well prepared when entering the work place.

Furthermore, there are some points, which, based on the Danish context, could motivate reflection on the design of sustainability programmes. As this study shows that students from non-sustainability programmes assess themselves as more prepared to incorporate business knowledge; programme designers might ask themselves whether their sustainability programmes could be more integrated with business. Another question, based on this study could be, how the programme in fact is covering the social pillar of sustainability.

In the perspective of education change, we can point towards some potential for cross-programme activities taking place in study environments designed to foster inter-disciplinarily learning and collaboration, A problem-based learning environment, where students work in cross-programme project groups to deal with a sustainability problem that call for both disciplines is one way to go. No doubt, that the students can learn from each other across programmes – structures, however, have to be in place in order for the students to find each other and release this potential.

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Cheating and Student's Learning and Achievement Motivation

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Conference Key Areas: Ethics in EE, The teacher as a Supervisor, Quality Assurance

Keywords: cheating, academic integrity, learning motivation,

INTRODUCTION

Passing exams, writing essays and completing assignments in a way that conforms to the general expectations of academic integrity are at the heart of gaining a Bachelor's or Master's degree. An interested student seeking to learn and to achieve a high level of mastery is the faculty ideal, but what are the student's motives to learn and how do they cope with these requirements? Complaints continue to increase that students do not seek mastery but instead seek points or credit. Students don't ask the question: "What does that mean and how does it work?" They prefer to ask: "Do I have to learn this to pass the exam?"^[1] Two questions arise on the side of professors. The first is culturally pessimistic: "Which abilities and competencies has the new generation of graduates acquired when they leave the university to fulfil their future jobs? Furthermore, is it enough to know how to find the answer with google or is personal knowledge still necessary?" The second is more pragmatic: "How do we cope with those mere credit point collectors?" Or: "Do we have to disband the ideal of the motivated learner or is there a possibility to change teaching in a way that is catchy

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and enticing to the majority of students?” As Nicholls et al wrote in 1985 with regard to school children:^[2]

“Views about the purposes of education vary in the degree to which they represent school learning as an end in itself versus a means to an end.” (683)

When the grade is seen as an end, usually with the goal of getting a good job, mastery per se is not as valuable as credit points. Taking this into account, “cheating is a strategy that serves as a cognitive shortcut”.^[3, p. 2] Unfortunately, it is a promising strategy when detection rates are roughly one or two percent. Taking this further into account, we get to the somehow obvious conclusion: Student motivation and cheating behavior are closely connected. Therefore, we interviewed a sample of 683 students from various disciplines (engineering, social sciences and arts) to gain a deeper insight about the relation of the two.

1 STATE OF THE ART

1.1 The German discussion

Even though we complain in Germany about the fading image of the ideal student, the scientific community gives little attention to these questions from a research perspective. Especially the scientific literature in English shows a massive body of research addressing the topics of interest and motivation of student learners as well as aspects of academic integrity and the so-called cheating epidemic. Various texts have been cited several hundred times like those by Haines et al (1986)^[4], McCabe and various co-authors^[5] or one of the early contributions by Bowers^[6]. The German discussion of academic integrity differs significantly: A small number of papers has been published so far. Until today, cheating has mainly been an issue treated in the national newspapers' weekend features. An exception was the case the former Secretary of Defense Karl-Theodor zu Guttenberg who lost his PhD in 2011 as the result of a publicly debated case of plagiarism. The wisdom of the crowd detected, in a joint effort within a few weeks 1218 plagiarized text components on 371 of 393 pages of zu Guttenberg's PhD-Thesis.

The public discussion about the zu Guttenberg case lead to an encouraged effort to address the topic of plagiarism at all levels of academic education. Especially the heads of university libraries initiated a number of local activities to sensitize academia to an increasing problem. Some librarians had already written papers a few years earlier¹ to create consciousness regarding the problem of using the easy to copy and paste options. Other articles highlighted general problems of science and the value of scientific knowledge in an age of a plagiarism epidemic.

In everyday German academic discussion, we talk about cheating as a type of personal insult resulting from students' “poor judgement, weak will, or lack of character.”^[7] Till now the discussion missed various aspects raised in the English publications mentioned in the introduction: Individual or context factors? The teaching moment and the contribution of the professorial performance in class remained unexamined.

1.2 The American or English discussion

Research on academic dishonesty started much earlier in the English academic literature. Davis^[8] gives an overview about the research results beginning in 1941 with reported cheating rates of 23% which grew towards 38% and 49% at the end of the 1950s. Actual numbers are up to 70% and 80% of the students reporting one or another type of academic dishonesty. McCabe et al report 82% in 2003.^[5] Furthermore, we find a body of literature about reasons for cheating which were first recognized in the

psychological disposition of the individual student and later in contextual variables as well.

Gender, age, grade point average, or national culture were typical characteristics to analyze and identify typical students that cheat.^[9] The result revealed changing degrees of influences (strong, some or even none). None of the socio-demographic variables offers a stable and reliable statistical result. Cheating students do not show a uniform character, obviously different situations (classes) lead to different behaviors. We rarely find students or pupil who always cheat and some more who never cheat. In a different approach McCabe and Treviño concentrated especially on the importance of honor codes. Throughout their research, they found significantly lower rates of cheating in those institutions of higher education which strongly implemented honor codes. It is not enough to have an honor code in place, the whole institution has to live according to it, and faculty has to put emphasis on the relevance to comply with the honor codes. McCabe et al report 27% or 17% lower rates of cheating in institutions with honor codes.^[5] However, German Universities don't have a strong culture of honor codes in place, at least they can't rely on a long lasting tradition.

A second line of discussion since the 1990ies is the connection between types of students' learning motivation, individual goals, and cheating behavior.^{[7], [9]} Especially the learning motivation and the goals of the students became one main key aspect of analysis which we focused on in the present research. In the literature, various authors picked up Dweck's ^[10] differentiation of mastery goals or learning (developing ability) and achievement or performance goals (demonstrating ability or avoidance to show a lack of ability)^[2]

"Mastery goals focus the individual on the task at hand and relate especially to developing competency and gaining understanding and insight. Performance goals focus the individual on the self and relate especially to how ability is judged and how one performs, especially relative to others." ^[11, p. 77]

A mastery goal orientation is the ideal for the faculty. Nevertheless not all students adhere to deep learning. The goal to demonstrate ability is often related to superficial learning strategies like rehearsals and memorization to be able to reproduce knowledge while writing a test.^[11] For example, feeding short term memory seems like a reasonable strategy considering particular types of tests. Reproduced isolated facts and numbers (multiple choice) are much easier to mark for the professor than long texts explaining contexts and relations. Therefore, in certain learning contexts these performance goals are suitable "... as long as mastery goals are also high." But how can we guarantee that mastery goals are also held to a suitably high level? ^[11]

While a mastery goal orientation is typically linked with lower rates of cheating, the attitude of performance goals make the use of cheating behavior more likely.^[29] As a type of motivated behavior, the intention is to deliberately violate rules of academic integrity to gain an advantage and to do better than other students. Students can successfully violate these rules of academic behavior due to low detection rates. High rates and greater differences were reported by McCabe et al.^[5, p. 223] They distinguish between cheating on tests and plagiarism and other forms of cheating on homework. Taken together as "serious cheating on written work", 56% (1990-1991) and 58% (1995-1996) of the students in non-honor code institutions reported such cheating activities while 47% (1990-1991) and 45% (1995-1996) of the interviewed students reported "serious test cheating".

2 METHOD

This research project “Academic Integrity: Perceptions of German Students”² is one of few studies in Germany about academic integrity with a reliable sample size. It modifies a prior analysis which was carried out by one of the authors at the University of Applied Sciences Darmstadt (one of the biggest German Universities of Applied Sciences). The previous study in 2016 had a sample of 335 students from engineering, computing and social science courses.^[13] Most of the participating engineering and computer science students answered the questionnaire in courses of the general studies program. The social science students who participated answered it in one of their subject courses. The pen and paper questionnaire was handed to the students in class to be answered anonymously and collected directly afterwards. The response rate was 99% with 684 questionnaires included in the analysis (representing approx. 4.1% of the total student population).

Males (n=390; 57% - females: n=293) are underrepresented in the sample (the university has 63.6% male students). 290 students (43.5%) were freshmen the other 390 were in their second to fourth year of study. Overall 386 students (56.5%) came from technical programs (engineering and computing) while 297 (43.5%) students belong to the social sciences and arts departments. We tried to set up the sample in a way that allows us to analyze by gender, subject area (engineering and computing vs social sciences and arts), and freshmen vs. experienced students. Table 1 shows the distribution of the sample according to these variables. Only one of the combinations of the three variables in the cross-tabulation reveals a weak representation of n=21.

Table 1. Composition of the sample (total: n=684)

	Male		Female		Total
	Freshmen	experienced	Freshmen	experienced	
Engineering and Computing	n=40	n=258	n=21	n=57	n=376
Social Sciences and Arts	n=34	n=49	n=120	n=84	n=287
Total	n=74	n=297	n=141	n=141	n=663

In this paper we will focus on the learning and achievement motivation, the socio-demographic data, and the McCabe/Bowers scenarios^[14]. The scenarios were part of the set of cheating behaviors analyzed by Bowers^[6]. Selection criterion were the overlap with the scenarios used by McCabe et al. Therefore, the scenarios cover not all types of self-reported cheating behavior, but this set of scenarios was adopted in various projects in the past^[13].

The Scales for Learning and Achievement Motivation (SELLMO) were developed by Spinath et al.^[15] and are based on the work by Nicholls et al.^[2]. The 4 scales consist of 31 items asking for three types of learning motivation which are closely related to the work of Dweck^[10] or Midgley et al.^[11]. These orientations are mastery goals (goal to learn and understand), performance approach (good results on exam) and performance avoidance (avoid negative results). The fourth scale measures the degree of work avoidance. These scales developed by Spinath are the only tested scales available in German to analyse goal and motivational orientations. The scales

² The project was funded by the Center of Research and Development of the University of Applied Sciences Darmstadt. The authors thank Anjell Korb and Jessica Nowotka for feeding the computers with the pen and paper data and for doing important parts of the data analysis.

are available in two versions: an often-used version for pupils and a second rarely applied version for students which we choose.

3 RESULTS

Figure 1 gives an overview of the self-reported cheating behavior of all interviewees. Remarkable is the varying number of students reporting no cheating on the nine scenarios. While only 11% reported that they turned in a homework done by a classmate (sc. 7), 80% worked collaborative on an individual task (sc. 8). The scenario obviously describes a cheating behavior that is very widely accepted and not considered a severe form of academic dishonesty, it might be seen as an option to improve one's teamwork experience and abilities. Furthermore, one of the participating students said: If we hadn't worked together we wouldn't have had a chance to accomplish the homework."

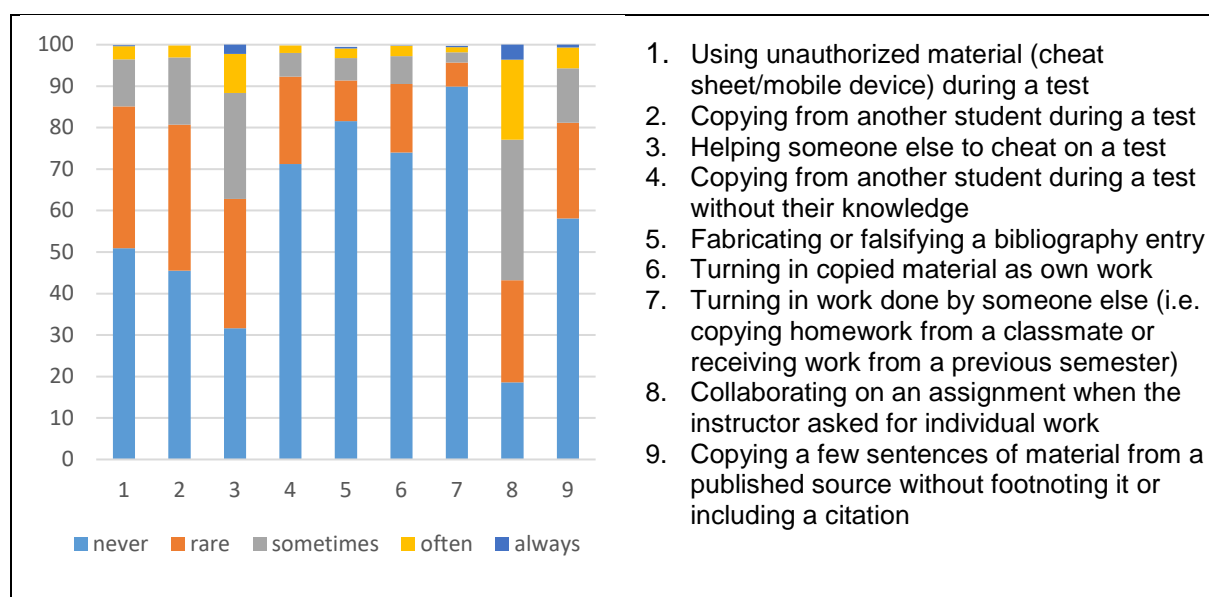


Fig. 1. Share of students reporting cheating activity for 9 single scenarios (n= 680 to 683)

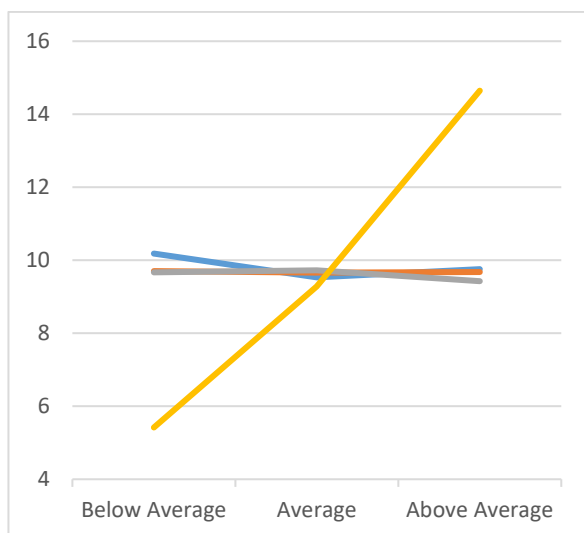
By calculating an index summing up the answer-codes of the nine scenarios, we identified the share of students who reported no cheating at all. With nine scenarios and codes from 1=never to 5=always the index value 9 is calculated for those students answering that they never cheated in the past. The highest possible value is 45. Overall, 92.5% of the students reported at least one incidence of cheating. That is not surprising when looking at scenario 8. Excluding this scenario (it includes a very social and help-oriented component) reduces the number of students who report cheating to 85.4%. About 50% of all respondents rank between index-values of 10 and 15, the next 25% are up to values of 19. About 3% (21 students) report cheating that cumulates to an index value of 25 and more

By a factor analysis (principle component analysis, varimax rotation) we differentiate two factors with an explained variance of 52.07%. Factor 1 encompasses scenarios 1 to 4 (loading values: 0.693 to 0.856), while factor 2 (loading values: 0.638 to 0.786) includes scenarios 5 to 7 plus scenario 9. The remaining scenario 8 loads less strongly on both factors. The factors represent two different situations in the academic life. While the scenarios of factor 1 address the situation of tests or exams while being monitored, factor 2 includes the scenarios that describe academic misconduct when doing homework or writing essays. The scenario seems to be unspecific in relation to the two factors explaining why it loads on both.

Coming back to McCabe's^[5] analysis of cheating rates in exams and in homework we calculated two indices according to the variables of the two factors. While McCabe et al reported approx. 9 to 15% higher cheating rates, the results of this research are more concerning: Only 21% of all interviewees answered the four scenarios in a way that indicated no cheating (index value: 4), 54.5% had index-values between 5 and 8, 2% had values between 13 and 16 (25 Students). Looking at homework 45.9% didn't cheat in the past (index value: 4), another 45% had index values between 5 and 8, with 0.5% of all interviewees with index values above 13.

Checking for socio-demographic differences doesn't indicate strong results: Comparing means of the index values reveals [1] equal values for cheating on tests for both sexes and female students cheat slightly (statistically significant) less on homework. [2] Freshmen report somewhat higher cheating rates in tests. [3] Engineers cheat more on homework than students of social sciences.

Our general assumption was that the learning and goal orientation has a significant influence on cheating rates. Therefore, we analysed the data using a one-way ANOVA-test. We used the four SELLMO-scales and grouped the sample three groups: the overall central 66.6% of the interviewees are displayed as average in the Figure 2 and 3, those 16.6 with low and high values are named as below and above average.



● Mastery Goal ● Performance Approach ● Performance Avoidance ● Work Avoidance

Fig. 2. Cheating on Test

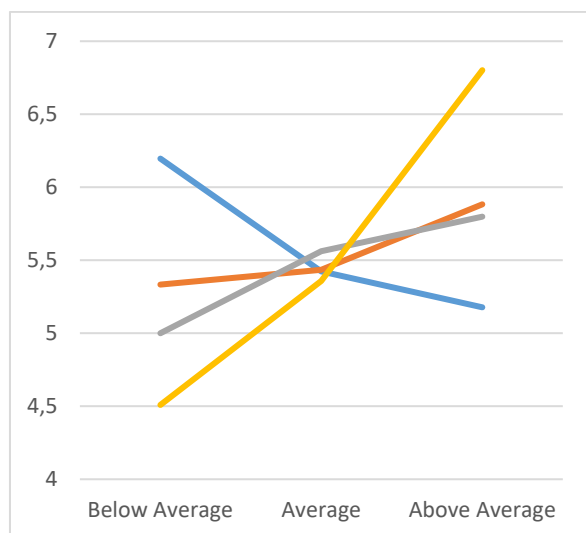


Fig. 3. Cheating on Homework

The two figures reveal a few surprising results. First: Those students who answered the SELLMO-scales indicating a strong tendency for work avoidance show significantly higher cheating rates. Especially tests are the home ground of academic misconduct. The other three goals show no significant differences between the cheating rates. Second: With considerably lower differences (just a 2.3 value-differences on the index for homework in comparison to nearly 9.2 value difference for tests) the degree of work avoidance has still an influence on cheating rates.

Looking at the results for the other scales shows only small and statistically, and in most cases, non-significant differences. For tests the range of the mean values of the cheating-index for all three goal and learning motivations starts at 9.4 and the highest value is 10.2. When it comes to homework the graphs in Figure 3 show a tendency of slightly higher cheating rates when performance approaches are tested. Mastery goals show the opposing trend: The stronger the mastery orientation the lower the cheating rate, a result that follows general expectations.

4 DISCUSSION

The disadvantage of the chosen approach is the missing option to identify clear motivational types. Each participant shows a mixture of all four types evaluated with the SELLMO-scales: we can't say: "Student XYZ is a person who avoids work or who seeks for mastery". The data allows us to identify those persons that indicate with their answers that they have e.g. strong tendencies toward performance goals. v. Yperen et al.^[12] asked interviewees to choose between options in a round-robin mode about their goals and orientations. The four options are shown in table 2. A real mastery approach is rare (13.7%). More than 70% follow an avoidance orientation.

Table 2. Percentages of dominant achievement goal in the domain of education.^[12]

Performance approach: „...to do better than others“	6.8%
Performance avoidance: „... not to do worse than others“	23.1 %
Mastery approach: „ to do better than I did before“	13.7%
Mastery avoidance „ not to do worse than I did before“	48.1%
No dominant goal	8.3%

The four SELLMO-scales^[15] ask for different attitudes: three scales test the learning motivation. The fourth scale (work avoidance) has to be seen differently, a difference that explains the three lines around the index-value 10 in figure 2 and 3 and the completely divergent graph shown with the yellow line. Students act in relation to the context. In some classes they thrive on mastery, in others on performance.^[11] The attitude of work avoidance appears to be a more general and stable attitude. It is not an adjustable trait changing in dependence of the situation.

Universities and their professors have to cope with cheating:

„The first class period of each new college term is a unique occurrence for teacher and students alike. As professors, we hope that these students will find our classes intellectually stimulating and rewarding, if not enjoyable. Standing in front of that sea of faces at the initial class session, another more sobering prediction can be made with no small degree of certainty. Some of these students will engage in, or at least attempt to engage, in actions that are academically dishonest.“^[8: pp.26]

And: Universities and their professors have to keep in mind, that cheating is a deliberate behavior applied in some context but not in all. Therefore, the teaching moment and the expectations we stress as teachers are important. Do we ask for mastery? And ... do we support students and their curiosity?

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Investigating the Dynamics of Authentic Learning in a Project-based Engineering Course

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Conference Key Areas: Engineering Education Research, Engineering skills, Discipline Specific Teaching and Learning

Keywords: authentic learning, enminding model, tension, negotiation

INTRODUCTION

Educational researchers and practitioners have long lamented the chasm between education and real-world experiences or issues. *Authentic learning* has become an increasingly popular means to mitigate this gap and entails “learning knowledge and skills in contexts that reflect the way the knowledge will be useful in real life” [1, p.2]. Authentic learning is thus an umbrella term for a wide gamut of instructional approaches aiming to help students to see the relevance of what they are learning, such as project-based learning and problem-based learning. A salient feature of authentic learning in vocationally oriented courses is the strong emphasis on “preparing students to be practitioners in their chosen field” [2, p. 14]. To this end, students tackle real-world problems, characterized by a high degree of complexity and ambiguity, and more generally engage in professional practices [3].

Much previous work has focused on developing models for authentic learning. Based on a review of this work, Borthwick et al. [2] identified three widespread models for authentic learning: the *apprenticeship* model [1], the *simulated reality* model [4], and the *enminding* model [5-6]. They note that

In the apprenticeship and the simulated reality models, there is an assumption that the “real world” represents the profession and the student needs to be, in some way, placed into this world either through a form of apprenticeship or by bringing in simulated activities to the classroom. In this way the specificity of the student is largely ignored as the authenticity comes primarily from the link to professional activity and the student is expected to move seamlessly from their subjective position into the world of the profession (p. 16).

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By contrast, the enminding model accentuates the importance of the *student* perspective, in the sense that “student learning is given similar emphasis to that of the real-world context” [5]. More specifically,

learning experiences are perceived as authentic when they engage students’ lived experience, and students can find meaningful connections with their current views, understandings and experiences and ‘newer’ views, understandings and experiences they meet as they learn in and about a ‘real-world’ or authentic community of practice (Ibid. p. 240).

Clearly, these “newer” or disciplinary views may challenge students’ prior views, and what students see as *meaningful* activities – a hallmark of authenticity [7] – may differ from the disciplinary view. While the occurrence of such *tensions* between student views and disciplinary views seems to be largely overlooked in contemporary models of authentic learning [5, 8], there are empirical studies showing that students and teachers do not necessarily agree on what they deem authentic [9, 10]. In such a situation, teachers are tasked with finding appropriate ways to bridge the gap between student views and disciplinary views. This involves *dialogue* and *negotiation* [11] to help students to understand why and in what sense activities are indeed meaningful. There is, however, a dearth of empirical accounts of how this negotiation process between teachers and students can play out in authentic learning environments; to wit: what specific strategies teachers use and how students respond to these strategies in terms of being meaningful learning experiences.

The purpose of this paper is to shed light on the *negotiation of authenticity* through a case study based on a course that aims to engage engineering students in authentic software development. Employing an ethnographic approach, we sought to address the following research questions:

- What strategies do teachers employ to manage tensions between ways of working that they and their students deem meaningful?
- What strategies result in students agreeing or disagreeing on what are authentic or meaningful learning experiences?

The findings of this study should therefore be germane to teachers wishing to provide their students with authentic learning experiences. In addition, the study builds on and extends the enminding model of authentic learning by elucidating the importance of tensions and negotiations.

1 METHODOLOGY

The software engineering course studied here serves around 50 bachelor students from two different educational programs, industrial engineering and computer science, at Chalmers University of Technology, Sweden. During the course, students work in teams of 5-6 on software design projects, implementing agile software development methods. In their projects, students launch a software application in collaboration with an external stakeholder. That is, they do not only write code that could be managed and adjusted in a compiler, but actually build a program which work towards a backend integrated in the stakeholder’s software system and provide an interface for users of the application. Scrum methodology [12] is used, and the projects are therefore undertaken in iterative one-week sprints, each encompassing planning, building, reviewing and reflecting upon progression. Five to six such sprints are undertaken. In each sprint review, students present their tentative design and concepts to representatives from the external organization which the students are to deliver customer value to – and get feedback from. This feedback is meant to be used to move forward. The project constitutes the major learning sequence of the course, complemented with three introductory weeks focused primarily on workshops

introducing how to work and how to think when using scrum methodology, and setting up a coding environment to work in. Moreover, the final week is spent on writing a project report.

Data was mainly collected through 23 hours of classroom observations and semi-structured interviews with ten students and the two teachers. The two teachers were interviewed before the course started. From this, a tentative understanding of the course and the teachers' perspective on what makes it challenging for the students was attained. The classroom observations included occasional and colloquial interactions with students regarding their projects and with teachers regarding how the course was moving along. The observations were recorded in field notes. Ten students, spread out amongst the project teams, were interviewed after the course had finished regarding their perception of the learning experience. In addition, formal course evaluation documents were surveyed, including minutes from course evaluation meeting, to gain further insight into students' challenges and how teachers potentially wanted to adapt to these. A follow-up meeting was held with the two teachers eight months after the course had been given, recorded in meeting notes.

The data was analyzed in terms of strands of negotiation between what students and teachers deemed and enacted as authentic. For example, this manifested in teachers talking about what students do which teachers did not consider in line with what was prescribed by the methods they introduced – and students arguing that the tasks or processes set out by teachers were not realistic or meaningful. The analysis of these negotiations was inductive, i.e. no a priori assumptions were made regarding their nature. Rather, a general inductive analysis [13] was used; that is, after coding the data, the codes were sorted and sifted in an iterative way to identify themes in the data.

2 FINDINGS

In this section, a general sense of the course seen through the eyes of the teachers and the students will firstly be given. Secondly, two strands of negotiation are outlined. Both strands describe what strategies the teachers used to manage tensions between what they and their students deemed meaningful ways of working, and whether these strategies resulted in students agreeing or disagreeing.

To the teachers, the stated “core of the course” was to teach students how to deliver real customer value through using agile software development methods. In this, they felt they faced major challenges in bridging students from the habits of mind built up through their previous courses. They talked about how the students had been trained as solitary “hackers” rather than collaborative “engineers”. This included for example students seeking technical finesse rather than solutions that just does the job, being overly fearful of failure and not resourceful in seeking help from others. Accordingly, the teachers used the preparatory lectures and workshops to introduce “newer”, disciplinary, habits of mind, and to let students try these out. They also built in several opportunities for students to engage in structured reflection in order to systematically improve their way of working – which they hope would lead to students developing meta-cognition and subsequently more purposeful choices and priorities when taking on software processes. They expressed further how the external stakeholders were crucial to the course, as without them the students would not be put in the complex and difficult situations where agile methods are most applicable.

In general, the students seemed very excited to (finally) take on a project which was more “real” than they were used to. They talked about meaningfulness and a sense of accomplishment in seeing that they could contribute. Moreover, in line with the teachers' perspective some noted that they could not have learned what they were

supposed to learn if they had worked on a less realistic project. However, they also attested to how the course had been very challenging, which some found rewarding but which seemed to make others quite frustrated. The more frustrated students questioned whether the course was designed in a good way, talked about how they had not learned what was intended and suggested changes that in their eyes would have made the course more meaningful for them.

2.1 Customer orientation

One of the concrete challenges expressed by the teachers was that students tended to take instructions and problem descriptions too literally. That is, instead of trying to inquire, listen and figure out what would be valuable for the customer, they took their first interpretation of what the customer had said and tried to implement that. Instead, the teachers wanted students to develop a habit of trying to understand what the customer “actually” wanted. Furthermore, they wanted students to negotiate customer demands and propose concepts which they believed they could implement with the time and resources they had, delivering something valuable to the customer but not necessarily living up to everything that the customer wished for. The teachers described how this was harder for the computer science students than for the industrial engineering students, who “get the message of customer value much easier”.

In the preparatory lectures and workshops, the teachers explained and argued for this “new” way of working. For example, during a workshop that was meant to simulate the project activity, one of the teachers role-played a customer and told students to ask him “why-questions rather than what to do-questions” and encouraged them to negotiate the demands he put on their products. Moreover, the teachers repeatedly expressed that if the students worked too many hours in order to deliver more than enough, they were lowering their “pay-rate” and the value of their work.

At the end of the course, many of the students expressed that this was indeed a new way of thinking for them. Some, especially among the computer science students, said that they had struggled a lot with understanding what the customer “actually” wanted, but that it had felt rewarding to do so. One student expressed that it had been inspiring and important to be told that they should not work overtime to deliver above and beyond. Another noted that they had had to make difficult decisions regarding what to deliver to the customer in the end, because of the time constraints, and that the introductory workshops had helped in daring to go against wishes from the customer.

Accordingly, even though students could have ended up wanting clearer instructions for what their final software applications were supposed to look like, it seems that the teachers were successful in helping students instead process the information they got about customer demands and arrive upon a solution which they themselves believed in and could motivate. The teachers had argued for a new way of working, which students ultimately seemed to find meaningful.

2.2 Technical concerns

When describing their design of the course, the teachers emphasized how students were supposed to learn the technical tools needed to finish their project self-directedly and how learning to learn technical skills was an important outcome of the course. They also attested to how students found this “hugely frustrating”. Here, a stated difference to students’ previous software development courses was that this course was more focused on applying what they already had learned.

To bring home this point of view, teachers mostly related to technical detail as something that the students themselves had to figure out, often encouraging students to ask each other for advice. For example, at an introductory workshop one of the

teachers explained to the students that many of them had asked him about what database they were supposed to use – and that the only thing he was concerned with was that their product worked. He moreover questioned whether they would actually need to implement a database at all. Technical concerns were generally positioned to only have instrumental value, in how it could deliver value to the customer. In terms of technical content delivered, the course featured a few introductory sessions to some main tools used when launching a software.

As the course progressed, technical difficulties seemed to be the main challenge for many students. Especially some of the industrial engineering students expressed concern over not having the appropriate software skills to take on the project. One student noted that some of them had taken an interest in programming in previous courses, while others “didn’t even know what to google”. More than finding it very difficult, some of the industrial engineering students said that they were not interested in learning more about coding, because they felt they would never use it in their future careers. This challenge culminated in some student groups not being able to present their work live at the final launch event organized by the teachers together with the external stakeholder, because of a version change in the stakeholder’s system.

Some of the students started to question the course design, specifically arguing that it would have felt more meaningful to build an application without integration into a “messy” existing platform. For some, this frustration did not seem alleviated when they were interviewed after the course had ended, one student noting that the technical difficulties had taken all the fun out of the course, and another how it had been impossible to learn anything when nothing worked. The teachers had argued for why self-direction and integration into an existing platform was necessary to properly get the feeling of a real-world project, but here not all students agreed about the meaningfulness of the course design.

3 DISCUSSION

With a view to create authentic and meaningful learning experiences for students, this study set out to explore how teachers manage tensions between ways of working that they and their students find meaningful.

According to the teachers in the case studied here, students come with a set of habits of mind [14] which are inefficient when taking on a real-world software development project. Accordingly, even before the course started, there is potential for conflict between what teachers and students deem meaningful in relation to disciplinary work. Wanting to transform students’ habits of mind, the teachers’ ‘negotiation strategy’ included devising a real project for student to work on, to show the limitations of their habitual way of working. Moreover, teachers pre-empted and prepared students for this confrontation by providing alternative strategies through the introductory workshops – which students could then try out in their projects. In general, this seemed rather successful, seeing that many students found the course challenging, but only a few expressed this in terms of frustration with the teachers or the course design.

The negotiation of authenticity was especially salient in two aspects of the course design. The first, regarding customer orientation, illustrates seemingly successful negotiations, where teachers managed to bridge between the way in which the computer science students had previously worked with software development and the “newer” perspective that the teachers espoused. The bridging attempts designed by the teachers were rooted in a detailed understanding of how courses in software engineering were usually taught, and the way in which the computer science students intuitively acted as they entered the course. Here, the teachers seemed to properly

take into account the “specificity” of this student group [2], in terms of understanding their habits of mind and designing introductory activities to make them explicit and offer alternative ways of working.

The second aspect, regarding technical concerns, illustrates seemingly less successful negotiations, where some of the industrial engineering students were left questioning whether doing a real project was a meaningful activity in relation to their level of competence and interest. To these students, the problem was not that they solved inefficiently, which is what would be implied by the teachers’ habits of mind explanation. Rather, they felt they had no way to solve issues at all and that they were left with too little guidance. Compared to the clear view of what the computer science students struggled with, the teachers did not seem to have an equally deep understanding of what was difficult for the industrial engineering students. The teachers did emphasize that technical tools need to be learned self-directedly, highlighting an important difference between this course and previous ones. They did not, however, seem to provide simulated experiences where alternative strategies could be tried out by the students before taking on their projects. At the very least, what teachers considered to be the proper strategies for learning technical tools self-directedly was not made as clear to the students. Accordingly, one could question whether the teachers sufficiently regarded the specificity of this student group, in terms of their readiness for taking on such a complex task [16].

The tensions highlighted in these two aspects of the course design are different in nature. One regards the way in which students can come to an authentic learning environment as “veterans” of a certain activity (software development), having been taught to use the tools of the trade in a way that is misaligned with what is to be enacted in the new course. The other regards students coming as “novices”, with less proficiency in using the tools of the trade in any way. It seems that in order to achieve perceived meaningfulness in all aspects of the course design, the teachers would have had to better account for the latter perspective.

The study highlights the relevance of two constructs – tensions and negotiations – to models of authentic learning [1, 4, 5, 6, 8]. Accordingly, we argue that agreements and disagreements on meaningful activity should be considered *dynamic* rather than static. This, seeing as students can gain new experience during a course through which *i)* habits of mind are made explicit and/or transformed (veterans rethink), and through which *ii)* learner readiness increases (novices start to participate). Such experiences necessarily impact what students consider meaningful activities.

Accordingly, to further develop models for authentic learning, we call for more longitudinal data on what student and teachers deem meaningful activity in authentic learning environments. That is, rather than studying students’ and teachers’ perspectives on authenticity at a single point in time, future investigations should focus on how they change over time, and through interaction. In this study, students voiced their perspective primarily through interviews after the course was over. Future research designs on this topic should consider also interviewing students before and, more deeply, during an intervention. Furthermore, checking back with students a longer period after an intervention could unveil how and to what extent they find meaning in it after gaining new experiences of disciplinary work.

In the specific course design studied here, *epistemological* tensions seemed more salient than *ontological* ones. That is, rather than disagreeing on whether the project was indeed real (authentic in terms of correspondence with professional software development practices), the cause for disagreement seemed to be whether the activities were meaningful for the students’ learning. Accordingly, while we agree with

previous work highlighting how authenticity is in the eye of the beholder [10, 15], we call for further investigations of differences between teacher-student or student-student perspectives from both an epistemological and an ontological perspective on authenticity – clearly demarcating or integrating the two.

For teachers wanting to employ authentic learning, or struggle with the tensions that emerge as students meet real-world problems, the take-away from the current study definitively lies in the way in which how the teachers managed to understand student habits of mind, how they intuitively reacted to the problems they were presented with. Specifically, they related frequently to the nature of students' previous courses and experiences. Accordingly, apart from "enminding" the course with a disciplinary perspective [6], their successful bridging attempts also entailed enminding the activities with the student perspective. Through this ethnographic study, we have provided one account of such an educational design, and we call for further conceptual and empirical work to elaborate on such a 'dialectic enminding'-model.

While this study was based on a single course, the tensions identified here, pertaining to habits of mind and learner readiness, could occur in similar project and problem-based learning environments. Some of the specific problems discussed by the teachers could be especially prevalent when students are tasked with creating products or solutions in collaboration with an external stakeholder. Organizing learning activities around interaction with external stakeholders seem to make students perceive learning experiences as real and meaningful. However, future studies should elaborate on potential challenges and learning difficulties students face in such learning environments.

4 CONCLUSIONS

This study addresses a gap in the literature regarding how teachers manage tensions between ways of working that they and their students find meaningful in authentic learning environments. Reflecting an epistemological turn in authentic learning research and practice, we conclude that the most effective strategies for managing such tensions are rooted in a solid understanding of students' previous learning experiences, specifically in terms of their habits of mind and their learning readiness. To enhance the value of the enminding model as a practical and explanatory framework, we argue for adding two theoretical constructs to the enminding model – tensions and negotiations – and we call for more and longitudinal research on these constructs.

ACKNOWLEDGMENTS

We extend our sincerest thanks to the teachers and students who have lent the time and engagement that made this study possible.

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Creativity, Invention, Innovation and Entrepreneurship, connected in theory separated in practice

- Can we strengthen engineering education by understanding the overlaps and the differences between the four concepts in an educational context**

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Conference Key Areas:

Teaching Creativity & Innovation

Keywords: Invention, Creativity, Innovation, Entrepreneurship, Engineering Education

1. Introduction

During the past two decades innovation and entrepreneurship have been dedicated much attention both politically and in an educational context across multiple disciplines including engineering. Skills and competences developed within these fields are believed to be essential for continued social and economic prosperity, which is why many governments support innovation and entrepreneurship promoting activities i.e. education. But are we getting the most out of the attention and resources dedicated for this in an engineering education context? Though seemingly connected and linked with creativity, innovation education and entrepreneurship education are most commonly separated in practice and research. Furthermore, technical inventions are essential in all engineering educations, but not always put in the context of innovation or entrepreneurship education, though this is important in order to understand how

inventions can create value for the society and not just explore and challenge technical boundaries. So are we, as educational institutes providing our students with the best possible education within these fields?

The scope of this study is to get a better understanding of the four concepts, creativity, invention, innovation and entrepreneurship, in theory and in the practice of engineering education. With this purpose our research question is;

How are the concepts of creativity, invention, innovation and entrepreneurship defined in theory and in the practice of engineering education in Denmark?

Therefore, this study outlines, compares and contrasts theoretical definitions of the terms; creativity, invention, innovation and entrepreneurship, based on a literature review. Furthermore empirical data was collected from Engineering Programs at five higher educational institutes in Denmark and at a workshop at the Exploring Teaching for Active Learning in Engineering Education 2017 conference (ETALEE 2017) to study how the terms are used in practice in Danish engineering education.

2. Method

A literature review was done where we applied a keyword search in SCOPUS using “Defining” and then the four concepts. The purpose was to find the 5 most cited publications and compare and contrast their definition of the concepts. Proponents of creativity, consider “creativity” and the study of it as a unique and independent discipline and thus it made sense to do a separate literature search on the concepts. However, in practice it is most commonly not taught separately in engineering education but implicit or explicit a part of invention, innovation and entrepreneurship education and for this reason it was excluded in the questionnaire. (However, in hindsight it would also have made sense to ask practitioners to define this seemingly founding concept).

To collect empirical data about definitions of “Invention”, “Innovation” and “Entrepreneurship” a survey was conducted in winter 2016/spring 2017. A questionnaire was made and sent to researcher and educators within the fields of invention, innovation and entrepreneurship in engineering education. The participants were associated with one of the following universities: The University of Southern Denmark, VIA University College, Technical University of Denmark, Aarhus University, Aalborg University. The participant was asked to write their definition of the three terms. Furthermore, they were asked to add name, profession and working place. Totally 24 recipients/participants answered the survey.

At the conference Exploring Teaching for Active Learning in Engineering Education 2017 (ETALEE) held in May 2017, the authors hosted a hands-on session about the topic and during the hands-on session, similar data was collected as in above.

3. Definitions in theory

We have done a literature search in Scopus with the terms “*Defining creativity*”, “*Defining Invention*”, “*Defining Innovation*” and “*Defining Entrepreneurship*” in the heading, key words and/or abstract. The 5 most cited publications relevant within the context of education (broadly defined) were then reviewed with the intent of gaining

an understanding of how each of these is defined in theory. The review yielded the following results for each of the chosen concepts under sections 3.1-3.4:

3.1 Creativity

The scopus research showed that finding a unanimous definition of creativity based on theoretical literature is not possible. Some authors have actually looked at this problem from an educational psychological angle (Plucker, Beghetto, & Dow, 2004). They argue that the problem with defining creativity is harmful to the field of research because without a solid definition the field will lack direction, be object for damaging mythologies and general misunderstanding. This will generally undermine creativity as a field of research and have a negative impact on the development of educational practices. In their study they compare and contrast explicit definitions of creativity based on the inclusion or exclusion of the following descriptive parameters – Unique; Artistic; Psychometric; Usefulness; Stakeholder-defined; Accessible; Divergent thinking; Problem solving.

A large variety of combinations of the descriptive parameters becomes apparent across the definition examples. Then Plucker, Beghetto and Dow suggests the following definition of creativity: *“Creativity is the interaction among aptitude, process, and environment by which an individual or group produces a perceptible product that is both novel and useful as defined within a social context.”* (Plucker et al., 2004)

In this broad definition, creativity is the result of interaction between aptitude, process and environment outlining three important components if the creation process. Moreover, there is a requirement for a perceptible product that needs to be defined as useful and novel according to the social context it is created with in. This means that creativity needs to be manifested and is not confined to a cognitive function. Furthermore, the novelty and usefulness cannot be objectively defined, but must be evaluated based on context.

Rob Pope (2005) wrote a book about creativity, studying the concept through different lenses. First looking at defining creativity historically, then creating definitions theoretically and finally looking at different creative practices. Using different lenses and situating creativity in different contexts results in multiple definitions of the concept. But initially Pope provisionally define creativity as: *“...the capacity to make, do or become something fresh and valuable with respect to others as well as ourselves.”* (Pope, 2005)

With this definition, Pope defines creativity as a capacity and elaborates on the potential out-put of creativity as something you make, do or become, still requiring novelty and usefulness. An example of a very narrow and context specific definition of creativity is offered by Shai, Reich and Rubin (2009) in relation to Computer Aided Design. They define creativity as: *“...a capability that enables the creation of systems that are patentable”* (Shai, Reich, & Rubin, 2009).

In this definition, creativity is defined as a capacity but with a specific purpose, to design a system, and there is a specific requirement for novelty, which is defined by patentability.

With these examples it is established that the definition of creativity is highly context dependent. Broad and general definitions of the concept exist, but they draw on

different descriptive parameters and the more context specific we work with creativity the more specific the requirements for creativity becomes.

In relation to engineering education, Fodor and Carver (200) offers the following definition: *"...students' proposed solutions to an engineering problem ... novelty combined with appropriateness, value or usefulness"* (Fodor & Carver, 2000)

Drawing on the descriptive parameters; uniqueness, usefulness, problem solving and stakeholder defined.

3.2 Invention

Interestingly, the search term "Defining Invention", unlike the other three topics, gave no results. Thus, the search term was broken down into "Invention" AND "Definition". Even here the search yielded 744 results of which only 80 were in the domain of Business literature. The term-use was very discipline-dependent and most articles that were listed related to the legal aspects and especially the patenting literature. Indeed when searching for "invention" alone one would get thousands of papers but very few have actually gone on to defining invention. Only one paper stood out as the one that has attempted to define Invention and Innovation and this paper is by Roberts E, B, first published in 1988 and then reprinted by Research, Technology and Management in 2007. It is interesting to highlight that Roberts already coupled the concept of Creativity with that of an inventor when he stated: *"Prior to our start, academics had concentrated largely on two themes: historical romanticism about the lives and activities of great "creative inventors," like Edison and Bell, and psychological research into the "creativity process." While those writings made interesting reading, in my judgment neither track contributed much useable knowledge for managers of technical organizations"*(Roberts, 2007). In saying so, Roberts claimed that industry did not set a lot of focus on "creativity" as a process and neither did they do it for "invention" – not systematically at least. Furthermore, he set out to tease apart (maybe one of the only few who have attempted this) the concepts of Invention and Innovation. In a section dedicated entirely to the two, he states:

"Roundtable discussions at the 1970 annual IRI spring meeting provide a useful starting point for this review-a set of definitions of the invention and innovation process: Innovation is composed of two parts: (1) the generation of an idea or invention, and (2) the conversion of that invention into a business or other useful application . . . Using the generally accepted (broad) definition of innovation-all of the stages from the technical invention to final commercialization-the technical contribution does not have a dominant position (3).

The invention process covers all efforts aimed at creating new ideas and getting them to work. The exploitation process includes all stages of commercial development, application and transfer, including the focusing of ideas or inventions toward specific objectives, evaluating those objectives, downstream transfer of research and/or development results, and the eventual broad-based utilization, dissemination and diffusion of the technology-based outcomes" (Roberts, 2007).

With these definitions invention is viewed as an important part of innovation, but inventions can stand alone without innovation if the invention is not put to use or

commercialized. Moreover, the invention is described as being the product of a process.

3.3 Innovation

The scopus search on “defining innovation” yielded 30 hits. The most cited publication was on defining innovation networks (Corsaro et al, 2012) . Then a number of publications focused on the definition of innovation in a specific contexts i.e. in surgery ((Rogers et al, 2014) and energy sector (Lee and Lee, 2013). More specifically looking at defining innovation in general Baregheh, Rowley and Sambrook (2009) presents these following definitions based on their literature review.

“Innovation is the generation, acceptance and implementation of new ideas, processes, products or services” T. Thompson’s (1965, p. 2). In their definition West and Anderson (1996) include that innovations must benefit someone; *“Innovation can be defined as the effective application of processes and products new to the organization and designed to benefit it and its stakeholders”*.

Kimberly (1981, p. 108) broadens the term by not only focusing on the product but also include innovation as a process or attribute.

The degree of newness is central in some definitions of innovation. An innovation does not need to be new to the world, but being new to the people involved qualify according to Van du Ven et al (1986). Innovation is also associated with change. Damanpour (1996) provides the following definition of innovation *“Innovation is conceived as a means of changing an organization, either as a response to changes in the external environment or as a pre-emptive action to influence the environment”*. The change does not have to be radical in order to qualify as innovation, incremental innovation also provide newness and change.

Depending on context innovation can be very narrow defined i.e. patent based. But many definitions are more comprehensive one of which is: *“Innovation as the creation of new knowledge and ideas to facilitate new business outcomes, aimed at improving internal business processes and structures and to create market driven products and services.”* Plessis (2007, p. 21)

Based on our review, it is obvious that some definitions of innovation is very close to some definitions of creativity. One might argue that innovation is a creative process, making it difficult to clearly distinguish the two concepts.

3.4 Entrepreneurship

Even the search for *“Defining Entrepreneurship”* had limited results though much more than “Invention”. Of the 13 hits, most papers tended to try and “define” and thereby justify the existence of Entrepreneurship as a field of research and of value in education. One of the most cited papers here was that of Rocha, H, O (2004) where he states that *“Entrepreneurship is defined as the creation of new organizations”* (Rocha, 2004) within a macro-economic perspective of the relevance and impact of clusters. Most papers that tend to define Entrepreneurship tend to do so as Rocha. However, Kobia and Sikalieh (2010) also highlight the problem of “defining Entrepreneurship” and their entire paper is based on the struggle of researchers in trying to define Entrepreneurship which is succinctly captured in this

statement – “...the findings of the literature review showed that none of the approaches used to define entrepreneurship gives a comprehensive picture of entrepreneurship. There is a lack of a common definition of entrepreneurship.” (Kobia & Sikalieh, 2010).

Kao, R.W.Y's definition of Entrepreneurship as: “*Entrepreneurship is the process of doing something new and something different for the purpose of creating wealth for the individual and adding value to society*” (Kao, 1993) can be seen as the precursor to many such similar definitions. One definition that most scholars also cite is that “*Entrepreneurship can be defined as the process of creating something new with value by devoting the necessary time and effort, assuming the accompanying financial, psychic, and social risks, and receiving the resulting rewards of monetary and personal satisfaction and independence*” (Hisrich, Peters, & Shepherd, 2004). For others, Entrepreneurship is “*solely about Innovation and entering a new venture*” (Fooladi & Kayhani, 2003), with the premise that an entrepreneur has to be innovative if he/she should be successful in entrepreneurship. However, studies have shown that most entrepreneurs – loosely defined as anyone who starts a business – often (>80%) build their businesses on someone else's idea and not their own (Bhide, 2000). While there exist multiple perspectives on the definition of Entrepreneurship, the current consensus is that it is the ability to spot/create an opportunity and then exploit that opportunity to create value for multiple stakeholders including oneself (Shane & Venkataraman, 2000).

3.5 sum up of definitions in theory

After researching the definitions of creativity, invention, innovation and entrepreneurship in theory it is apparent that the definitions vary from broad general applicable definitions to very specific context dependent ones. We can conclude that there are similarities but also differences in the definition of the four concepts. However we see that creativity is an important element and part of the definitions for the three other concept

4. Definitions in practice

To gain more insight into how these concepts are defined in danish engineering education, empirical data was collected twice to better understand how the terms invention, innovation and entrepreneurship is understood and used in practice. Defining creativity was left out of the empirical data collection because it is embedded in innovation, invention and entrepreneurship education but rarely taught as a stand alone topic in engineering.

First a survey was constructed asking 24 educators, from 5 different engineering educational institutes, to define the three concepts. Then at the 2017 ETALEE conference in Denmark, three focus groups were constructed consisting of 4-5 members each. The members were engineering educators who signed up for participating in a session about active learning in invention, innovation and entrepreneurship. The purpose with the session was again to construct definitions of the three concepts, but this time based on group discussions.

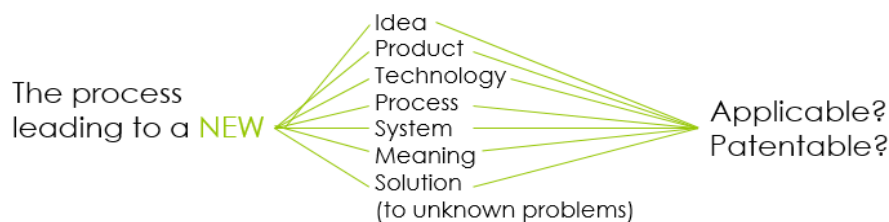
In the following results from our survey and focus groups are presented.

4.1 Empirical data from surveys

Based on the data from the 24 respondents of the survey, the following practical definitions were found (See appendix 1 for survey result).

Invention: It is the act of “creating” something (Idea, product, technology, process, system, meaning, solution) for the “first” time, an invention is something new – i.e. no known prior exists beforehand. The new creation can potentially have a social or economic impact, and it might not be a “completed/finished” creations but something which can be further developed.

Figure 1: Visualisation of definitions of invention



Some respondents argue that the invention should be applicable to someone or something, demanding a sort of value creation for someone. While others define the newness through patentability, an invention is thereby expected to have a degree of “uniqueness” and “unexpectedness”.

Innovation: It is the act of “renewing” or “changing” what has already been invented to something new. It can relate to an idea, product, service, technology or process. Innovation can be defined on a spectre from incremental innovation to radical innovation. Generally, incremental innovation is as improving what is already known, where radical innovation is the creation of something new, which disrupts status quo. It was largely accepted that an innovation should be possible to implement and/or commercialize to give value to someone- i.e. customers, society and companies.

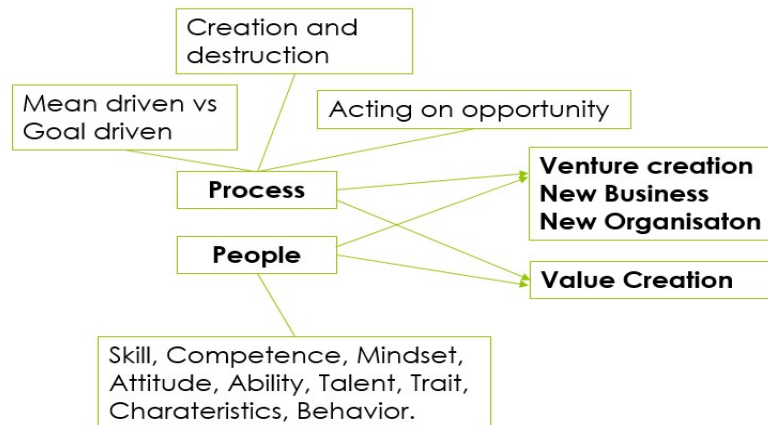
Figur 2: Visualisation of definitions of innovation



Entrepreneurship: It was not as linear defined as invention and innovation. The focus was either on the process of entrepreneurship or the people. The process was described as means-driven (Sarasvathy, 2001) or the acting on opportunity or as a creation and destruction process. All with the result of either building a venture/business/organisation or with the broader term value creation as end result.

In addition, it was seen as opportunities for getting on the market with innovation or inventions.

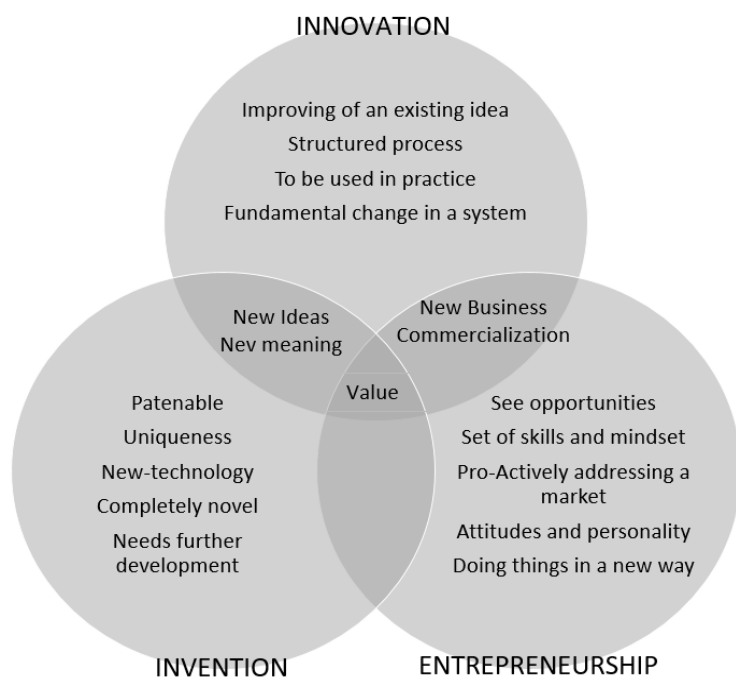
Figure 3: Visualisation of definitions of Entrepreneurship



The same spectre of outcomes was described in the definitions focusing on the people, but rather than emphasizing the process leading to this outcome, the people focused definitions highlighted individual's; Skills, competences, mindset, attitudes, abilities, talents, trait, characteristics and/or behaviour.

In the above the definitions of the three concepts are presented separately. But when comparing the definitions of invention, innovation and entrepreneurship it is found that they are mutually overlapping and presented in figure 4. The figure illustrates what the three concepts share and what is only associated with one or with two of the concepts.

Figure 4: Diagram of unique and overlapping definitions of invention, innovation and entrepreneurship, in engineering education based on a survey



All three concepts have in common to create value/impact - creativity. Innovation and invention share new ideas and to give new meaning, while innovation and entrepreneurship share new business and commercialization. In our survey no sharing only between invention and entrepreneurship was found.

4.2 Empirical data from focus groups

At the 2017 ETALEE conference data was collected from 3 focus groups during our workshop on active learning in engineering education. The purpose of the focus groups was to gain more insight into the definitions of invention, innovation and entrepreneurship in an engineering educational practice. The three groups were asked to discuss and write down the definitions of the three concepts while observed by a member of the research team. In the table (table 1) below the results of these discussions are showed.

Table 1: Definitions of invention, Innovation and Entrepreneurship from the three groups.

	Invention	Innovation	Entrepreneurship
Gr. 1	<ul style="list-style-type: none"> - A thing no one had thought about before - Invention=innovation - To invent and develop (creation) -A new product or service 	<ul style="list-style-type: none"> - Make a new product or service and make a sale (Commercialization) - Something that also have a commercial side (market analysis) - Development of a new solution -Similar to invention, but less a thing- Abstract 	<ul style="list-style-type: none"> - The need to make a product or service a business - to do it in practice - Business, mindset -leads to a business case
Gr. 2	<ul style="list-style-type: none"> - New creation - To invent something new - New produce, service or idea 	<ul style="list-style-type: none"> - Value creation, novelty - Combining existing things in new ways that create value -Bring inventions to use - Clever solutions - Utility 	<ul style="list-style-type: none"> - Making money on inventions -Practical start-up - Creating value with ideas - Not necessarily innovation - From Scratch
Gr. 3	<ul style="list-style-type: none"> - Idea - Invention covers that you as a student invent something new to you...maybe also to others - Scientifically valuable new idea...Creativity 	<ul style="list-style-type: none"> - Methodology/ physical product - Combine theory with practical stuff into new products - the process of creating new things/ideas without existing knowledge - Methodology to bridge the idea into end product 	<ul style="list-style-type: none"> - Outcome/product - The process of putting your inventions into production and making it a live in production -Converting ideas into sustainable and marketable products - Put ideas on the market

The results from the focus groups align with the results from the survey. In relation to invention and innovation there is a focus on creation and novelty, while in relation to entrepreneurship exploitation of a business opportunity is prevalent.

“Creativity, *Invention*, *Innovation* and *Entrepreneurship*” as independent concepts with certain degrees of overlap.

5. Discussion

Our literature review shows that there is no unanimous definition of neither creativity, invention, innovation or entrepreneurship. All definitions were context dependent some wide and other very specific. This finding was supported by our empirical data. So are we building a tower of babel that prevents us from improving education within these fields, when we are using the same terms but not agreeing on their definition or using different terms but in reality talking about overlapping concepts? Deciding on *one* definition of each concept is likely impossible, but could we strengthen engineering education and maybe education in general if we explicitly define the concepts in our theoretical studies and practice? Would this better enable us to pool empirical data, debate, compare and contrast research for the benefit of all research fields? In practices innovation and entrepreneurship research and education are most often separated and invention is not always put in the context of innovation or entrepreneurship. But maybe an educational innovation in all fields can come from sharing best practices?

6. Conclusion and future implications

With this contribution we have researched, how the concepts of creativity, invention, innovation and entrepreneurship are defined in theory and in the practice of engineering education in Denmark. We found that creativity, innovation and entrepreneurship lack a unanimous definition and not much research is dedicated to defining invention. Plucker, Beghetto, & Dow (2004) argue that the problem with defining creativity is harmful to the field of research because without a solid definition the field will lack direction, be object for damaging mythologies and general misunderstanding. This will generally undermine creativity as a field of research and have a negative impact on the development of educational practices. This is likely transferable to the other three concepts. It is clear that some educators use innovation and entrepreneurship interchangeably and it is not clear in educational processes where creativity, invention, innovation and entrepreneurship starts and ends. However, on one hand we have to consider that in education the practical use of these terms is very important. Using them interchangeably can lead to confusion for the students and also affect their motivations. Expectations and perspectives that the students come with into the classroom from the prevailing definitions of these have to thus be taken into account. On the other hand, due to the clear inter-connection between creativity, invention, innovation and entrepreneurship, it may be fruitful in educational development and research not to look at the concepts in isolation. Insight could possibly be gained by cross-conceptual work, solidifying each field. In the future, it is recommended that more work be done in this area and that a larger study conducted in which we can extend the preliminary findings of this paper.

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Appendix 1 (Survey data):

Concept Actor	Invention	Innovation	Entrepreneurship
Participant 1		-Something new that creates value -Doblin's 10 types of innovation.	
Participant 2	A process of creating a new meaning. A meaning could be a tangible product, intangible product (e.g. service), concept/idea, process/workflow/method.	-A process of creating new values from some existing meanings through implementing continuously the principles of "connecting the disconnected", whereas discovering the disconnected is achievable through intense observation into the key aspects including functionality, usability, technology, methodology, aesthetic and user's affection. The principle of "reflection in action" applied through the continuous loop of design-build-test is the key to innovation. Neither disruptive nor sustaining innovation concept is put into the above definition.	
Participant 3			-Behavior related to opportunities leading to value creation for others.
Participant 4			-The start of a business. As a starting point, a company that you want and are able to start.
Participant 5		-The ability to create innovation with a business aim or the ability to create renewal to promote the solution of tasks in both the public and private sectors.	

Participant 6		<p>-Innovation must be value creating, implementable and innovative.</p> <p>-Innovation is transforming creative ideas, mindset and processes into reality - be it products, businesses, workflows etc.</p>	
Participant 7	-The development of a new technology, product or process.	<p>-Creativity that creates value.</p> <p>Creating something new by development or/and adaption new ideas or concepts that gives value to customers, citizens, organizations, society</p> <ul style="list-style-type: none"> - a process - a product - a market segment - a business model - a mindset 	<p>-Ability to search for and undertake new concepts/ideas/projects/technologies/mindsets to create new business</p> <ul style="list-style-type: none"> -to drive the creation and destruction process. -to discover the unknown to make benefits for organization, business, customer, citizens.
Participant 8	-A complete new – never seen before way of doing something or technology – it can be in research or in development, services.	-A combination of know technologies or services or inventions where it is bringing values to the users/customers/citizens/companies.	-The way to see opportunities for getting on the market with the innovation or inventions.

Participant 9	-Something completely new and unexpected, which has an application of some type. It may be patentable, but it is not a demand that it is patentable. It should not just be an incremental change building upon things known to the inventor, but should have a uniqueness and unexpectedness with respect to the environment that the inventor (student) is in and their level of experience and knowledge.	-An ability to create something new or a new value proposition that can have value. In the context of a student and education, this does not have to result in a prototype (but it can) or a finished 'thing', but should result in some kind of product demonstrating the potential of the innovation, for example a report addressing how the innovation can be realized in practice, relevant business models etc. An innovation does not have the same demand of unexpectedness that an invention has.	-An ability to take an invention or an innovation or some kind of value proposition and to actually realize it into a product that creates concrete value of some type (not necessarily monetary), both for the organization (or the entrepreneur themselves) the entrepreneur is in, as well as for the 'customer', stakeholder or end user of the 'product'. The word product is used in a broad sense and does not have to be a device. Entrepreneurship also encompasses intrapreneurship.
Participant 10	-A specific invention.	-A more or less structured process that leads to new products, businesses or services.	-A set of skills and methods that you can acquire and practice depending on talent.
Participant 11	-A game-changing solution for an existing (or assumed) problem.	-A game-changing solution for an existing (or assumed) problem.	-The process to bring any of the two concepts above to real life.
Participant 12	-The process of bringing something completely novel into the world.	-The art of improving an existing idea or technology.	-The process of building a business from an invention or innovation, i.e. commercializing it.
Participant 13	-A new and unique product, service, process etc. Something which can be patented.	-It's the process of generating and implementing ideas that create value for a group of users (therefore focus on users is also a big part of innovation process). - Innovation doesn't have to result in something "novel". It can be "something new to the world", but it can also be	-Entrepreneurship is much about the skills of the person(s) who turns ideas into reality and bring them to the markets where customers are willing to pay for them. They are starting and growing new business' or developing new business' in existing organizations.

		“new to a market” or “new to an organization” etc.	
Participant 14	Something invented as seen for the first time (often a technical feature, a product, a process not necessarily very useful or the use of the invention may be unclear (needs to be discovered).	Developing and implementing new, useful (value creating) solutions.	The actions, attitudes, mindset and personal proactive behavior the individual plays out while conducting or making innovation happen in spite of extreme uncertainty.
Participant 15	An idea or new technology.	Creating new business with an idea or new technology.	Starting a new business.
Participant 16	A new technology.	A new prioritizing, combination, and selection of perspectives that creates new value.	Goal oriented execution of a business through discovery, incubation, and acceleration.
Participant 18	<ul style="list-style-type: none"> - Coming up with proposals for new solutions to known and unknown problems. - Typically relates to technical aspects in product development, e.g. new functionality or new construction principles. Maybe even eligible for a patent (it actually happens sometimes). 	<ul style="list-style-type: none"> - commercial viable product or product-service (student projects are not an innovation, but they may be innovative) - newness criteria (multiple, see e.g. Doblin group 10 types of innovation) - design perspective: creating new meaning. 	<ul style="list-style-type: none"> - pro-actively addressing a market need/opportunity and acting upon it. - attempting to bring a new product/service to market.
Participant 19	Invention er ikke i mit ordforråd. Tænker blot det betyder opfindelse.	Innovation is to do something new that can be used in practice.	Entrepreneurship is the ability to create a new organization, most often business. Business formation is a little bit narrower.

Participant 20	An invention is the introduction of a new idea, often manifested in a new product, service, process or business model. For inventions, the market/implementation success is still unknown and thus inventions may lead to no implementation or commercialization.	An innovation entails a successful implementation or commercialization of a new product, service, process or business model.	A new venture creation or new value creation. The concept of entrepreneurship can often be tied to a "person" or a "process", where the former emphasizes traits and characteristics of the entrepreneur the latter describes the content and the activities which are a part of entrepreneurship.
Participant 21	An invention is an idea, a sketch or model for a new or improved device, product, process or system. Such inventions may often (not always) be patented but they do not necessarily lead to technical innovations. In fact, the majority do not.	An innovation in the economic sense is accomplished only with the first commercial transaction involving the new product, process, system or device, although the word is used also to describe the whole process.	Entrepreneurs are innovators: People who come up with ideas and embody those ideas in companies.
Participant 22	The creative production of an inventor.	The process of making an economic impact based on an original and useful idea.	The process of making an economic impact by means of a new venture creation.

Participants 23	This invention can be further developed into an actual product, but it is still not innovation.	You can talk about innovation as both a process and a "result". The result arises as a result of the process: When a new invention has been developed for a real product (service or other) that the intended recipient has addressed (I distinguish between customer and user, which is not necessarily the same) so that The product changes something (existing ways of doing things or introducing brand new possibilities). It can be shortened to Invention + commercialization + adoption = successful commercialization, which is the innovation performance that a business is looking for. However, innovation may also be non-commercial. If someone invents something new and useful, which changes something for example a good friend - but does not choose to commercialize the product ... yes, it is also innovation, but it does not end with innovation.	It is about building a business by developing and / or commercializing something new. It is associated with some personal characteristics - ie. You can be entrepreneur and thus able to identify, pursue and exploit new opportunities.
Participant 24	Is an idea, a sketch or model for a new or improved device, product, process or system. It has not yet entered into economic system, and most inventions never do so.	An 'innovation' is accomplished only with the first commercial transaction involving the new product, process, system or device. It is part of the economic system.	Entrepreneurship: An organizational structure aimed at bringing a product or service to the market.
Participant 25	The creation of a new idea / invent.	Do new things or do things that have already been done, in a new way, so it creates values.	Realize ideas by establishing a new organization.

Sustainability invisibility: are we hooked on technical rationality?

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Abstract

Education for Sustainable Development (ESD) is regarded as a key enabler for all the 17 Sustainable Development Goals. Higher Education Institutes have been slow in adopting a holistic approach to ESD in undergraduate engineering curricula. The aim of this research is to explore how tertiary subject coordinators understand and envision sustainability and how that subsequently manifests in their teaching curriculum design.

A qualitative inquiry approach was adopted to explore the rationalities of ten academics within the School of Civil and Environmental Engineering at an Australian university. In a previous study in the School, the researchers identified a low percentage of ESD integration across the curriculum. The interviews showed that these academics perceive sustainability as a technical concept, presumably taught by someone else in the curriculum. As a result, sustainability is mostly invisible within undergraduate engineering curricula.

Results elsewhere show that for ESD to be effectively implemented at a tertiary level, academics must come to understand and accept what ESD aims to achieve, which is to educate engineering students to encourage them to integrate sustainability decision making in their future engineering practice. Engineers Australia's Code of Ethics requires: *Balance the needs of the present with the needs of future generations.*

The difficulty is that these behaviours are difficult to detect in engineering curricula, which are strongly focused on technical problem solving. This research will identify and

disseminate good practice in curriculum design for sustainability at both unit level and program level. This paper represents an early part of the research program.

Conference Key Areas: Curriculum Development, Sustainable Development Goals in Engineering Education, Educational and Organizational Development

Keywords: Education for Sustainable Development, Qualitative Inquiry, Undergraduate Engineering Curriculum

INTRODUCTION

Education for Sustainable Development (ESD) is regarded as a key enabler and achiever for all the 17 Sustainable Development Goals (SDG) [1], [2]. Nevertheless, Higher Education Institutes (HEIs) have been slow in adopting a holistic and transformational approach to Education for Sustainable ESD [3, p.392-393], [4, p.341].

Results elsewhere show that for ESD to be effectively implemented at a tertiary level, academics must come to understand and accept what ESD aims to achieve, which is to educate engineering students to encourage them to integrate decision making for ESD in their future engineering practice [5], [6]. Additionally, Engineers Australia's Code of Ethics requires that professional engineers: *Balance the needs of the present with the needs of future generations* [7].

The difficulty is that these behaviours are difficult to detect in engineering curricula, which are strongly focused on technical problem solving. Indeed, in a previous stage of this project, the authors identified a low level of ESD integration across the curriculum in all engineering programs at this Australian university [8]. The low level of ESD in the curriculum and inconsistencies between claimed and achieved learning outcomes led us to question how subject co-ordinators understand sustainability and how that subsequently manifests in their teaching through curriculum design. In addressing this question, we focus on subject co-ordinators in the Civil and Environmental Engineering program.

1. BACKGROUND

In a previous study, an ESD assessment framework was established to analyse the engineering curriculum at an Australian university. The framework was developed through a meta-analysis, which identified twelve highly-cited articles recommending different sets of Education for Sustainable Development competencies. Individual competencies were given a frequency of occurrence. Similar competencies were grouped together under an overall competency. Finally, overall competencies were ranked according to the overall occurrence of each of the competencies. The resulting set of seven Education for Sustainability competencies is shown in Table 1. For more details on the framework and curriculum assessment process please see [8].

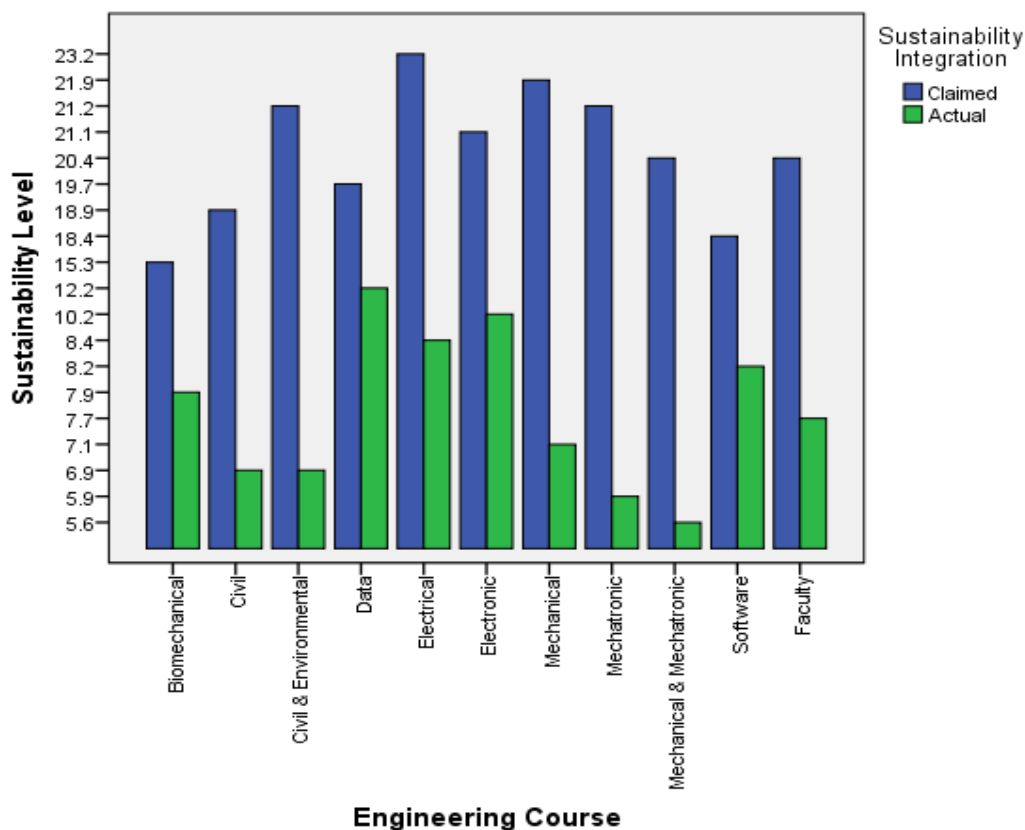
The set of seven ESD competencies complies with the holistic approach towards a sustainable education. It engages the head, heart and hands as recommended by [9]. Moreover, critical thinking was incorporated into each of the seven collective competencies within the set. Brown and Keely [10, p.3] state that: '*Critical thinking consists of an awareness of a set of interrelated critical questions, plus the ability and willingness to ask and answer them at appropriate times*'. Subsequently, critical thinking is essential to any type of thinking or acting [11] [12]. The set of seven competencies incorporating critical thinking was then used in a framework.

The framework was used as a tool in a document analysis of subject outlines to investigate where ESD was integrated into the curriculum of engineering programs. An initial assessment of the engineering curriculum showed that ESD learning outcomes made up around 25% of the overall claimed course learning outcomes. A more detailed evaluation showed that ESD related learning outcomes were included in subject assessment task criteria in only a third of the claimed outcomes within the curriculum. Figure 1 illustrates both claimed and actual sustainability integration. The low level of sustainability related learning outcomes and the differences between claimed and actual sustainability learning outcomes led us to wonder how subject co-ordinators thought about sustainability and hence to the study reported in this paper.

Table 1. Sustainability of 7 learning outcomes incorporating critical thinking

Competency	Overall Frequency
Change management and Envisioning a better future	18
Value-based thinking, self-awareness and global responsibility	18
Complexity & Systems thinking (TBL)	17
Stakeholder Engagement & Collaboration	16
Life-long learning and continuous reflection	13
Lifecycle Analysis	12
Decision making for sustainability in an interdisciplinary setting	11

Figure 1. Engineering Courses percentage of sustainability evident in the curriculum



2. DATA COLLECTION

The undergraduate Civil and Environmental Engineering program was the focus of the study reported in this paper. This program offers 32 subjects which are coordinated by 24 academics. Of these 24 academics, 10 agreed to be interviewed for this study. Participating in this research was voluntary and the authors acknowledge that this means that participants are likely to be those subject co-ordinators who are interested in the research since the interview was expected to take up to one hour. Given their busy schedules this could be a major consideration for the subject co-ordinators who chose to opt out.

Consequently the authors were sensitive to the risk of bias and considered this in the analysis of interview transcripts. Participants were categorised into four groups according to the claimed and achieved sustainability in their subjects, based on the results of the previous analysis referred to in the Background section [8]. This included content analysis of Subject Outlines associated with each subject coordinator's subject to determine whether they were claiming and achieving ESD learning outcomes or not. The four groups are listed in Table 2 below:

Table 2. Group numbers and description based on ESD outcomes

Group	Description
1	Subjects that claimed and achieved at least one ESD learning outcome
2	Subjects that did not claim but achieved at least one ESD learning outcome
3	Subjects that claimed but did not achieve any ESD learning outcomes
4	Subjects that did not claim and did not achieve any ESD learning outcomes

In the Civil and Environmental Engineering program, subject coordinators were categorised according to which group they belonged to. As a result;

3 subject co-ordinators were categorised in group 1, another 3 in group 2, 12 were in group 3 and 6 were in group 4. It is worth noting that some subject co-ordinators co-ordinate more than one subject within the school. However, their subjects did not belong to more than one of the four groups. This emphasised consistencies between subject co-ordinators' perceptions and ESD integration within their subjects. Keeping in mind the diverse subject-Coordinator groups, the researchers carefully designed an interview protocol.

The interview protocol included open-ended questions to allow for a wide exploration of participants' attitudes towards the inclusion of sustainability related learning outcomes. The advantage of such questions is that they lead researchers in new directions. Some of these outcomes will be highlighted at a later stage of this research. All subject-coordinator interviews were recorded and the audio files were transcribed so that the text could be used for analysis.

3. DATA ANALYSIS

A qualitative inquiry approach was adopted to analyse the collected data. This approach is defined by [13] as *"a research process that uses inductive data analysis to learn about the meaning that participants hold about a problem or issue, by identifying patterns or themes"*. The authors then triangulated the analysed data from

the interviews with the overarching group the participants belonged to. Participant groups were highlighted in Table 2.

In this preliminary analysis we focus on participants' responses to the following two questions and triangulate the data with existing subject-coordinator groups:

Question 1: Do you think that the engineering curriculum sufficiently covers sustainability?

Question 2: Can sustainability education be applied to your subject?

Several themes were highlighted through the analysis and triangulation of the subject-coordinators' interviews.

Analysing **Question 1** of the academic interviews led to the following themes:

There was an overwhelming consensus amongst participants (8 out of 10), that belonged to groups 1, 2, 3 and 4 that sustainability is not adequately integrated into the Civil and Environmental Engineering program:

Personally, no; I think as a whole, everyone has a slightly different definition of sustainability. Often it comes down to people thinking about the environment, but it's a lot broader than that now. (Academic 1)

I believe we're still lacking. That's my belief. I'm not sure how much of the fact is there. (Academic 2)

Honestly, no, at the moment. Honestly. We should work on that, and I would say I'm very fan of that part, really (Academic 7)

One of the Two subject co-ordinators in both groups 3 & 4 i.e. subjects that do not achieve ESD learning outcomes, responded that they did not have the expertise to make the judgement:

I don't know. I know my subject covers this topic but I'm not sure others because I think most of the other subjects - so the coordinator defines sustainability in different ways. Yeah, so for me it's quite a technical term so I defined based on the content in what I teach, so like that (Academic 8)

I'm not in the field of sustainability directly - it's not my expertise. (Academic 10)

Overall, it is worth noting that all six subject co-ordinators that coordinated subjects which achieved at least one ESD learning outcome (Groups 1 & 2) agreed that the engineering curriculum does not sufficiently cover sustainability. In Contrast, a similar consensus could not be achieved in Groups 3 & 4.

Analysing **Question 2** of the academic interviews led to the following themes:

Group 1: Three participants co-ordinate subjects that both claim and achieve ESD outcomes. These academics were able to describe how sustainability is manifested in their subjects with responses varying from:

Sustainability is built within the design of the subject. (Academic 3); to

Students are actually assessed with their projects with a sustainability lens. (Academic 1).

Although traces of sustainability were found in all three subjects, only one subject provided a strong holistic focus on sustainability.

Group 2: Three participants co-ordinate subjects that do not claim sustainability related learning outcomes but achieve aspects of them in the criteria used in assessment tasks. In their responses these subject co-ordinators claimed that either they were not interested in implementing it:

So, although I might have elements of that - of those in there, that was not my intent (Academic 5);

or faced resistance from students:

I constantly try and embed it but there are so many challenges. My challenge is more so about convincing the students that this is something they need. That's where I get stuck. (Academic 4).

Group 3: Two participants co-ordinate subjects that claim sustainability related learning outcomes but did not assess students on the related skills. One of these subject co-ordinators demonstrated a flawed understanding of sustainability by limiting it to consideration of environmental issues:

Sure, sure. Both of them, closely. Both of my subjects closely involved with the environment. (Academic 7);

While the other claimed to be integrating sustainability in their subject because they taught “advanced technologies” (Academic 8).

Group 4: The two participants that did not claim sustainability learning outcomes nor did their subjects achieve them perceived that education for sustainability should be implemented in other contexts.

Not the subject. It's part of the design thread (Academic 9).

When it comes to being able to resist environmental aspect, then it comes down to maybe material science (Academic 10).

4. DISCUSSION

All subject co-ordinators from Groups 1 and 2 participated in this study. This points to an interest in sustainability and Engineering Education for Sustainability Development within Groups 1 & 2. On the other hand, Groups 3 and 4 had the lowest participation rate amongst academics. 2 academics out of 12 (Group 3) and 2 out of 6 (Group 4) were involved in the interview process. Overall, 4 out of 18 participants had no sustainability integration within their subjects (group 3 & 4). These results emphasise the diversity in academic perceptions towards sustainability. For any future interventions within the School of Civil and Environmental Engineering to be successful, there is an undeniable need to take into consideration the wide range of ESD perceptions held amongst subject-coordinators. This finding re-emphasises the same concepts discussed by Barth and Rieckmann [6].

Combining Group 1 & 2 answers, we can see that participants are equipped with the appropriate sustainability perceptions. However, these perceptions do not necessarily lead to deliberate sustainability integration within the curriculum. Moreover, the holistic approach to integrating sustainability within curriculum is only visible in one of the undergraduate engineering subjects. An institutional ESD intervention within the two Groups (1 & 2) could build on existing sustainability perceptions to promote a holistic approach in Engineering ESD. This concept is discussed within literature; Sipos, Battisti and Grimm [9] argue that for ESD to succeed it must be transformative whilst adopting a holistic approach.

Combining groups 3 & 4 answers, we may say that sustainability is missing as it is either being envisioned as a technical aspect commonly mistaken for environmental considerations or assumed as being addressed by someone else leaving room to emphasise technical considerations.

4.1 Engineering Technicality

25 out of the 32 subjects which belong to groups 3 & 4 did not cover sustainability. It was argued by academics that these subjects cover “technical” aspects of Civil and Environmental Engineering. This concept emphasises the overwhelming subjective approaches to current engineering education [14]. In most cases, these approaches remove the social and environmental aspects of engineering problems.

Social and environmental aspects make up two of the three pillars of sustainability. Without considering the social and environmental aspects of engineering problems fails sustainability education generally and the goals sustainability education sets out to achieve. As a result of the dominant technical rationality within the undergraduate engineering academics, the civil and environmental engineering curriculum lacks Education for sustainable development integration.

5. CONCLUSION

The interviews showed that the vast majority of academics perceive sustainability as a technical concept, presumably taught by someone else in the curriculum. As a result, sustainability is mostly invisible within this undergraduate engineering program. Academics that implement sustainability within undergraduate engineering curricula do not necessarily adopt a holistic approach. Curriculum assessment results showed that a holistic approach to ESD was adopted in only 1 out of 32 subjects.

Academic views varied on Education for Sustainable Development. However, general consensus was achieved around one question. Eight out of ten participants agreed that the current engineering curriculum within the Australian university does not sufficiently cover sustainability. This consensus can be used as a conversation starter for curriculum change towards ESD within the program.

Finally, for a tertiary engineering ESD intervention to be successful, it needs to take into account the wide range of academic perceptions. A major hurdle to overcome lies within current academic perceptions of sustainability. For adequate ESD integration within the engineering curriculum academics must move beyond technical rationality.

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PATTERNS OF STUDENT'S CURRICULUM ENGAGEMENT IN AN ON-DEMAND ONLINE CURRICULUM

An exploratory study at Charles Sturt University

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Conference Key Areas: Innovative Teaching and Learning Methods

Keywords: Engineering education, on-demand education, learning analytics

INTRODUCTION

Charles Sturt University (CSU) Engineering is a new programme established in 2016. This programme was established from scratch in a university that had not previously taught engineering. This was taken as an opportunity to build an all-new programme structure and philosophy [1]. Students at CSU Engineering complete a sequence of three semester-long PBL-style challenges across the first three semesters; after this point, they commence work placements in industry. The underlying technical curriculum that supports the projects is broken down into fine-grained learning

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activities called ‘topics’ that are offered online using the Realizeit platform [2]. Each topic is intended to take a typical student around three hours to complete. Although topics are arranged into a tree structure where the recommended learning order is made explicit [3], see Figure 1, the curriculum is based on a philosophy of self-directed learning; students have a considerable amount of freedom in deciding how and when they engage with the topics in the online environment.

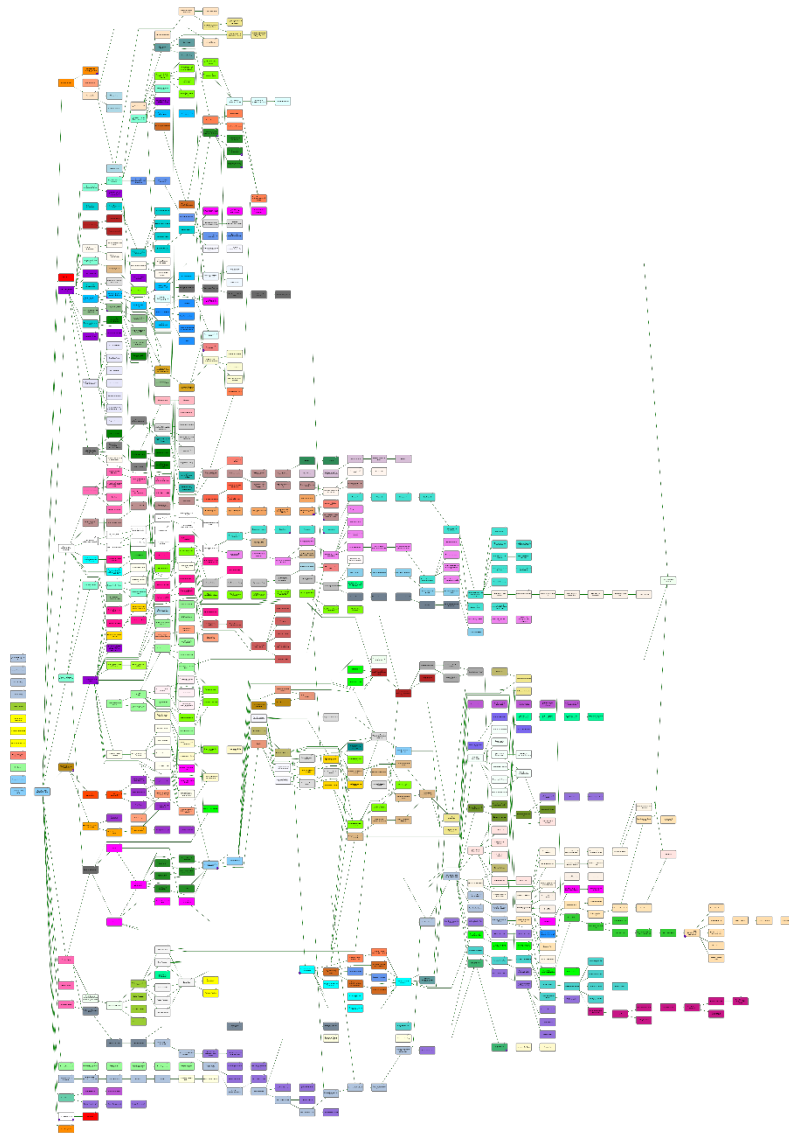


Figure 1: The CSU Engineering topic tree.

In this way, the students engage with theory at the point at which it is required in their work, rather than in a synchronous syllabus driven manner. This has the advantage of ensuring the content is relevant at the point at which it is learnt; however it also introduces the risk of how the students manage their progression through the tree. In this paper, we present exploratory research in which the authors attempt to understand student engagement in this online environment.

1 ORGANISATION OF THE ON-DEMAND CURRICULUM

1.1 Topic Acquisition and progression

Students are required to complete a total of at least 240 topics from the tree before they are eligible to go on industry placement in their fourth semester. While 80 of these topics are compulsory, selected after a process of engaging with industry partners [1], the students are free to choose the other 160 from throughout the tree. The topic tree consists of multiple branches comprised of sequences of topics which are strongly related and scaffolded on top of the other. Although there is no required order in which to students should complete topics, the structure of the tree provides clear guidance as to the recommended learning path. Each topic in turn consists of a number of learning activities.

Progress is first and foremost the responsibility of the students as self-directed learning is an important element of the programme. There are essentially no immediate consequences for an inadequate rate of progression through the topic tree. Where the PBL challenges have mid- and end-of-semester milestones, the topic tree has only two requirements, and neither of them manifests until the very end of the three-semester subject. Lindsay and Morgan [3] observed that this effectively leads to the emergence of two sub-cohorts – one who was up to date, and one that was well behind and unlikely to complete.

While some measures have been taken to signal adequate progression to encourage students to stay on track [4], some students still lag behind. A challenge with learning in online environments is that while all behaviour is logged, it is not straightforward to determine how this data captures effective study behaviour, and how to interpret it in the light of potential interventions.

1.2 Student behaviour and student success

Student success is among the most widely studied topics in higher education, however, little is known about effective study behaviour in online and blended environments. Carroll [5] postulated that the basis of all student success is rooted in effective study behaviour, which consists of time on task and the behaviour itself. He states that students with a great aptitude do not automatically pass their exams: even strong students have to open their books and use their time in a meaningful way to learn the materials. A weaker student can achieve the same outcomes by spending more time on the materials and/or in a more effective manner. There is never just one way of being successful as a student, according to Carroll, there are however many ways not to be successful. These two elements of effective study behaviour were taken as starting points to explore behaviours in the online environment, as they were previously used in similar settings of research [6].

1.3 Logging student behaviour in the online environment

The analysis of data that is logged in online systems with the aim of understanding and improving learning is often referred to as learning analytics. This has been a trending topic for the past years, but understanding the data that is logged and interpreting it, is more complicated than it may seem. The data that is logged by the Realizeit system includes all timestamped attempts at the topics in the tree, as well as detailed metrics capturing what happens within these attempts, and the context within which the attempt was made. Through this data, it becomes clear how students navigate their way through the topic tree, how much they do in a set period of time,

etc. It is up to the researchers and teachers to try to understand what kind of behaviours this data reflects and what that means for learning.

Van den Bogaard and De Vries [7] showed that by just using data mining techniques, or even AI, we can predict success easily, but we often end up with predictor variables and algorithms that are almost impossible to conceptualise and use as a starting point for meaningful interventions. Additionally, the data shows only what happens within the platform, but can't log data on what happens on other screens. While working on a topic, a student may be doing something else on a different screen on their computers, or they leave a topic open while they take a break. The data continues to get logged, but it is not clear what it represents. Actual time on task is therefore difficult to calculate. Research at the University of Central Florida [8] examined metrics from the Realizeit learning platform and found that differences in student performance are an effective predictor for who will succeed and who will not. However, the use of the platform in this study does not reflect the unique manner in which it is being used at Charles Sturt University. The challenge for the teachers at CSU Engineering is to develop metrics of behaviour that support understanding effective study behaviour in this unique curriculum.

2 METHODOLOGY

2.1 Research questions

As there are many different ways of looking at behaviour and defining it, we took the topic tree as our starting point. The tree is the main structure of the online environment, so this seems like an obvious starting point. The research question for this study is:

How do the students move through the topic tree in terms of actual behaviour and time spent in the Realizeit system?

2.2 Dataset

For this study, we used the data from the first two student cohorts of the programme, cohorts 2016 and 2017 that was available in the first quarter of 2018. Cohort 2016 contains 29 students and have started their industry placements. Cohort 2017 contains 26 students who are in the initial phase of their programme. Some of the topics at CSU contain several sub learning activities for which data is logged, others only contain an assignment to wrap the topic up at the end. In this exploration we therefore only consider data at the level of the topics, not on the level of sub learning activities.

2.3 Approach

As this concerns exploratory research, in an iterative process we started out with raw data from the system and tried to combine data and structure data in such a way it would present different kinds of behaviour related to the topic tree. We ran analyses using these metrics and find out if we could somehow describe this in terms of effective study behaviour. The team of researchers consisted of a data scientist, an learning analytics researcher and two engineering education researchers who teach at CSU, so different ideas and frameworks informed the decisions. In this paper, we present some of the strongest metrics regarding ease of interpretation and their predictive value.

3 RESULTS

3.1 Order of the activities and time between them

The first question to be addressed is how far do students move with the topic tree on consecutive learning activities? In Figure 2(a) a histogram of the distance between topics is plotted for all students. We can see that by far, the most common distance is zero. This means that after a student completes a topic, the most common next thing for them to do is another topic within the same branch. Students tend to see the series of related topics through until they have done everything within that neighbourhood.

We can see that the distribution is positively skewed meaning that students tend to stay local. However, there are some large distances between consecutive learning activities on topics with some that are 10 to 30 connections apart. Some large jumps are inevitable given the shape of the topic tree; students who finish out a branch will be required to make a large jump across the tree to commence a new branch.

Figure 2(b) shows the time in days between consecutive topics. In this figure the bar at position 31 represents all time gaps of 31 days or more. Again, we can see the distribution is positively skewed meaning that students typically do not leave much time between learning activities. In fact, the most common time between topics is zero days meaning that students attempt multiple topics on any days that they are active. This suggests that students allocate time to go through a number of topics on a single day. From the perspective of study behaviour this is an effective strategy as it allows students to spend as much time on a topic as they feel they need to learn to master it. In regular programmes students often complain about the fragmentation of their time to sit down and work on difficult topics, as by their programme they are required to participate in multiple educational activities on a given day.

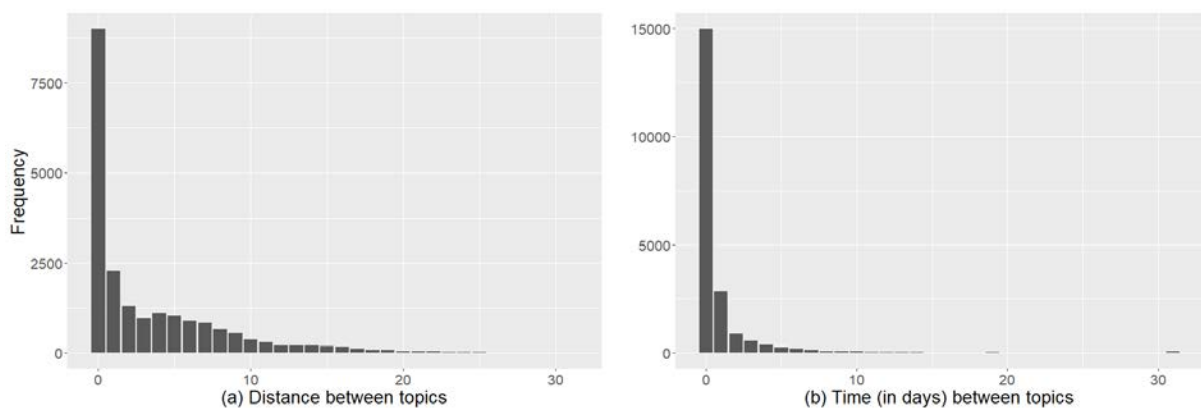


Figure 2: Frequency of distance (a) and time in days (b) between topics.

These two insights, students stay local and complete multiple topics on that same day are further highlighted by Figure 3. The joint distribution of the two-previous metrics is plotted with frequency on a log scale. The peak of the distribution is clearly at (0,0) and represents 38% of all activities. This is nearly an order of magnitude larger than the next largest distance-time combination and suggests that some level of bingeing on topics is taking place.

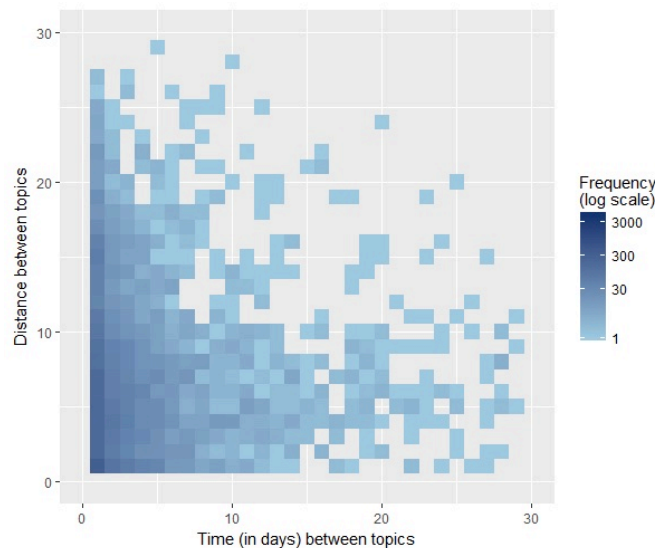


Figure 3: A heatmap showing the joint frequency distribution of distance and time in days between topics. Frequency is plotted on a log scale.

One interesting subset of consecutive learning activities to examine is the next activity directly after they complete a topic. In other words, when a student completes a topic, what is the next thing they do? How far away do they move on the topic tree? As suggested by the above analysis students tend to stay local and attempt the next learning activity on the same day. It has been observed that this seems like a Netflix effect, where students ‘binge’ on topics on the same branch before they do anything else [3].

3.2 Activity after completions

From 3.1 it shows how all students binge to a certain extent, however, there are two interesting, and in some ways opposite, subsets of students that are worth pointing out that were identified based on visual inspection of the data. Both subsets are displayed in Figure 4, where Cohort 2016 students are shown in red and Cohort 2017 students are shown in blue. The numbers in each graph represent a single student. Figure 4 shows a selection of students who show the pattern in behaviour.

For the first subset, shown in Figure 4(a), the distribution of their distances to the next topic after completing a topic is positively skewed, meaning they stay local. This is in line with what we have seen before. However, with a peak at zero, this means that after they complete a topic, the most common next activity for them to do is to revise that topic. In a sense these students are bingers, as they stay local, but they revise topics before they move on. These students are revisers.

The second subset, shown in Figure 4(b), generally have the same shaped positively skewed distribution. What is notable about these students is that, while they generally stay local, they have no consecutive activities with a distance of zero after completing a topic. This means that they never go directly back into a topic after completing it, they always attempt a lesson on a new topic. They may, however, revise the topic at a later date. These students may still binge, but they also jump.

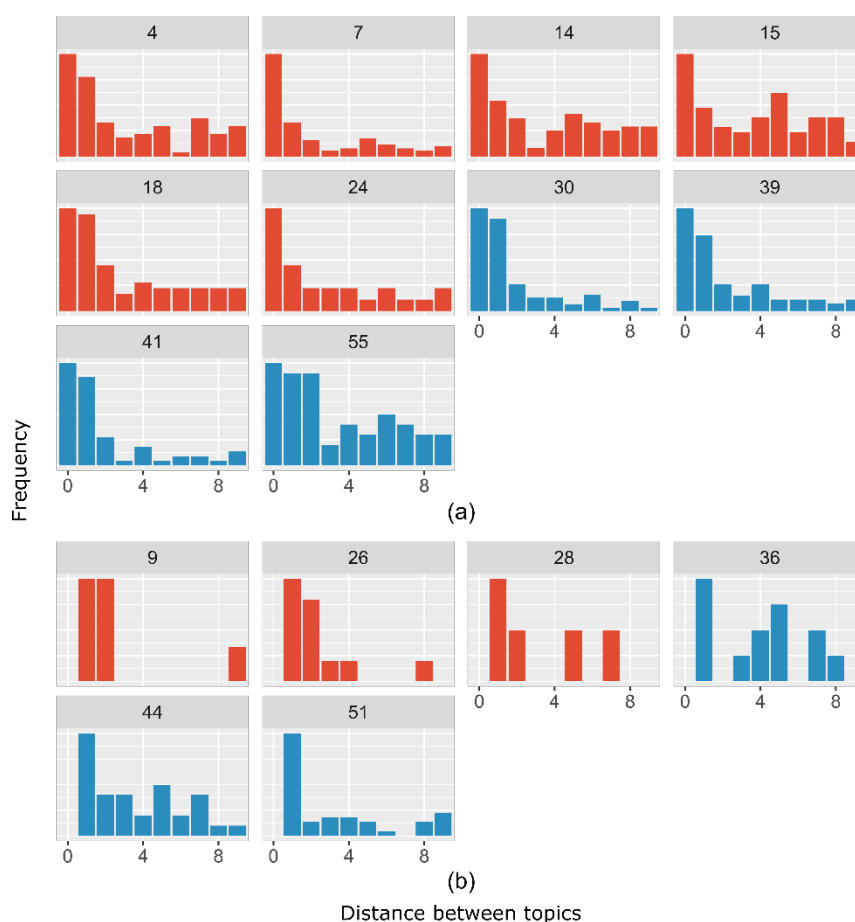


Figure 4: Distance to the next topic after completing a topic for two subsets of students (a) who revise a topic upon completion straight away and (b) students do not.

In general we discern between three major patterns of behaviour that overlap to some extent:

- Bingers – these are students who stay on the same branch in the topic tree and do all topics within a certain branch within a certain time.
- Jumpers – these are students who go through the topic tree seemingly random. They finish a single topic, tend not to revise the topic and tend not to see through all topics within a single branch. There may also be more time between the topics these students engage in.
- Revisers – these are students who will go back to revise a topic as soon as they finish it.

As these behaviours overlap to some extent, it is hard to discern clearly delineated groups based on it.

4 CONCLUSIONS AND DISCUSSION

Lindsey and Morgan [3] observed that students move through the topic tree in a similar way as many people watch series on Netflix: they tend to stay within in the same series and watch all episodes of a series in a short amount of time. Some students revise: the first thing they do when they finish a topic is to start all over again with the same topic. Some students do not revise right away, but they move to the next topic which may be the next topic on the branch but does not have to be. Bingeing seems like an

effective strategy to study, as it would help the students to spend a considerable amount of time on task and to stay focused. Revision and self-testing are well established and effective study behaviours. Jumpers do not revise right away and do not always come back to all topics. These observations fit in well with Carroll's model for school learning: some students need to spend more time on a topic to master it than others and some students have more effective study behaviours than others. From the data we studied it is not possible to make any claims on how the students spent their time exactly and how much time they spent on their studies of the topics, but we are able to discern a number of behaviours that seem striking based on the data. Although these findings may not seem significant, we believe they are: in these innovative learning environments we do not know how students deal with the materials, how they move through the curriculum. In regular education we have a good grasp of principles of design to support student success. In this innovative curriculum it is up to the students to make decisions regarding their study behaviour, but it is still important to understand student behaviour to monitor the effectiveness of the environment, but also to be able to spot students who may be at risk and think of interventions that are appropriate in this unique context.

Next steps in this endeavour are to explore the dimensions that are underlying for this behaviour, to create a link with student performance, but also to start a dialogue with the students about these study behaviours: what motivates them to study in this way, what do they feel they gain through these behaviours and how does that tie in with their other educational activities in the curriculum? We intend to pursue this questions further in future research.

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**Socialization and Curriculum Integration:
Emergent premises in student experiences of a first-year electrical engineering
course**

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Conference Key Areas: Innovative Teaching and Learning Methods, Curriculum
Development, Recruitment and Retention

Keywords: First-year students, Project-based learning, Socialization, Curriculum Integration

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INTRODUCTION

The integration of project based learning (PBL) into engineering curriculums has received growing interest in the engineering education research literature [1]. One particular area of interest is the first year in engineering programs [2], as it establishes the cognitive, affective, and conative foundation for students and is also closely linked to student retention and academic success [3]. At the same time, many engineering programs remain focused around theory heavy courses that provide little coupling to actual engineering practices in the first year. Balancing engineering science and engineering practices is challenging, and students often find it difficult to establish connections between different concepts, practices, and areas of engineering [4]. Furthermore, first year engineering students at today's universities often are enrolled in large anonymous courses on e.g. math, mechanics, and electronics with hundreds of other students across different engineering disciplines. Within this environment, it is difficult for the students to identify themselves as engineers in making, and be part of a disciplinary socialization process right from their first semester [5].

The context for this study is a re-designed electrical engineering program that aims at providing students with opportunities to learn engineering practices right from the start, while at the same time maintaining some of the traditional large, theory heavy, courses. Here, we explore how first year students perceive their learning environment and their transition to university. Using a national student survey as an entry point, we briefly compare the program to other electrical engineering programs in Norway before exploring the *how* and *why* of students' experiences in detail through in-depth interviews. A thematic qualitative analysis approach leads to the identification of two emergent themes that are central for the students: socialization and curriculum integration.

1 RESEARCH CONTEXT AND DESIGN

The context for this study is the five-year *Electronic System Design and Innovation* (ELSYS) integrated master study program at the Norwegian University of Science and Technology (NTNU). The program curriculum was re-designed in 2014 by introducing the *Electronic Engineering Ladder* [6], an integrated sequence of four courses during the first four semesters. The aim of this ladder is to strike a balance between integrating PBL and engineering practice, with traditional engineering science course, and transform an existing program through targeted modifications, improvements, and adjustments, without the need to change the entire curriculum.

In the first semester of the ELSYS program, an introductory project-based course (ELSYS GK) was added to the curriculum, where the students get the opportunity to work on an engineering project. The second and third semester were changed by adding an engineering science course on circuit design and analysis, and signal processing, respectively. Finally, the curriculum was adjusted to include a final course in the fourth semester, where students continued to work with the project from the first semester. Here, we focus on the ELSYS GK in the first semester.

The central aim with introducing a project activity right from the first semester is to illustrate how engineers work and give students the opportunity to work in teams. Students are divided into groups of 6-8 by the teachers and there are around 15 groups each year. The general project theme is similar for all groups and defined through a collaboration with an external partner, typically a company, organization, or public institution with an authentic engineering problem. Within this general theme, the

students define and work the details of the project themselves and solve the problem within their groups.

The ELSYS GK course is organized as a full day (8-16 o'clock) over a period of 13 weeks. The day is structured around a general skeleton of different activities as shown in Figure 1. Each day starts with an introduction session called *Cross-Talk* where problems related to the current project situation are discussed and relevant theory from other parallel courses is brought in. Following the plenary session, the groups work individually, before the class has another plenary session around lunch. In this session, called *Today's Guest*, students meet an invited guest from industry who talks about their work and how electrical engineering is important for their company. After lunch, the group work continues, until a final plenary session at the end of the day, where selected groups present problems they have encountered during the day. In addition, focus sessions are held throughout the day, where one or two students from each group with similar challenges or project tasks can share experiences and learn from each other.

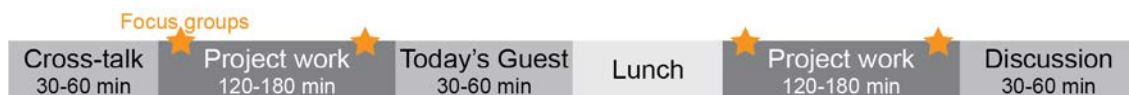


Fig. 1. A typical ELSYS GK day

In order to get a general understanding of the effects that the redesign of the ELSYS program has on students' experiences, we used data from an independent national student survey called Studiebarometeret administered by the Norwegian National Agency for Quality in Education (NOKUT) [7]. The survey asks students about their perception of quality in study programs at Norwegian universities and covers a wide range of topics including questions on the learning environment, professional relevance, and student involvement, amongst others. All questions are aimed at study program level, not course or institution level. The Studiebarometeret allows the comparison of the ELSYS program to other electrical engineering programs in Norway on a general level.

Using this quantitative evaluation as a starting point, we used a qualitative case study approach [8] to explore students' experiences in the first semester of the ELSYS program further. Six students volunteered and gave their informed consent to be part of the semi-structured in-depth interviews at the end of the ELSYS GK course. The students were selected to cover different levels of pre-knowledge in electronics, as well as being part of different project groups. The interviews lasted 20-45 minutes each and covered topics about students' pre-knowledge, their perception of the learning environment, and experiences coupled to their first semester curriculum. All interviews were audio-recorded and transcribed.

For the analysis, the interviews were pooled together and a thematic analysis approach [9] was used to identify, analyse and describe patterns and themes within the data. The material was read and re-read to explore what factors in the course the students described as central for their experiences. Through this iterative process, we identified different themes that emerged from the interviews. These themes were further explored by considering relevant literature and using it as an additional perspective to develop and deepen the thematic analysis. In this study, we will focus on two themes from the analysis: socialization and curriculum integration, other themes included: pre-knowledge, group work, peer-learning, and drop-out.

2 RESULTS

The ELSYS program differs from more traditional electrical engineering programs in Norway, as briefly described above. Overall the teaching approaches used in the program seem to be well received by the students. Table 1 shows a comparison of the ELSYS program with an average of other electrical engineering programs in Norway for 2015 to 2017 for four selected areas. Regarding the learning environment, the ELSYS program scores slightly higher with respect to the academic environment among students, and considerably higher on student satisfaction with the environment between students and academic staff. Furthermore, students in the ELSYS program feel slightly more that the program contributes to their motivation and say to a larger degree that their program has a good collaboration with industry.

Table 1. Comparison of ELSYS with other electrical engineering programs in Norway

NOKUT Studiebarometer [7] (1=dissatisfied/disagree; 5=satisfied/agree)	ELSYS – 5-year program at NTNU			Average of all 5-year study programs in Electronics		
	2017	2016	2015	2017	2016	2015
The academic environment among the students in the study program	4.5	4.5	4.2	4.2	4.3	4.2
The environment between the students and the academic staff in the study program	4.5	4.5	4.4	3.7	3.8	3.8
The study program contributes to your motivation for studying	4.1	4.1	4.2	3.8	3.9	3.8
The study program has good collaborations with industry	4.5	4.5	-	4.0	4.0	-

Building upon this general program evaluation, we will, in the following, focus on two themes that emerged from the qualitative analysis of the interviews: socialization and curriculum integration.

2.1 Socialization

The first theme that emerged from the interviews with the students is how the ELSYS GK course contributes to the socialization process. One important aspect that the students highlight in the socialization process is to get to know each other and feeling that they belong to the study program. They emphasize that ELSYS builds a community, where you learn each other names, get to know each other, and have teachers to relate to:

We build a very nice community in ELSYS. You learn many names, you get to know your classmates... we have a number of teachers that we meet continuously and can relate to.
(Student 2)

The students experience building this type of community as the main point of the ELSYS GK course. They believe that the disciplinary learning is not at the center of the course, but that the overall goal is to have a good start at the university and get some basic ideas about group work and different working approaches:

I do not think the main point in the course is to learn so much about electronics, just to use it a bit, try it a bit, play with it. But the point is to learn a little more about group work and different working approaches and to have a very nice start in the ELSYS program ... (Student 2)

The students value this approach and the focus on building a community within ELSYS, as they feel that it helps them beyond the ELSYS GK course. By emphasizing to get to know each other and establishing a community, the students feel that they belong to something:

For me ELSYS made it much easier to get to know people. You start to recognize faces and then when you see someone later at the university you feel - It feels friendly and familiar. You feel that you are part of a community even though we are so many students. (Student 5)

This is not necessarily always the case at a large university with over 40.000 students like NTNU, especially as not all students feel comfortable or want to participate in social activities organized outside the disciplinary context of their study program. Some students pointed out that the community they found within ELSYS was enough for them:

It has been very good to get this community in the ELSYS program. I'm not very active in student association and do not enjoy social happenings very much, so I have not gotten to know a lot of other students, but the ELSYS community is enough for me. (Student 2)

While the project work and general design of the ELSYS GK course play an important role in the socialization process and community building, the students explicitly also highlight a kick-off trip at the beginning of the first semester. This trip plays a significant role, as it changes the learning environment and enables students to interact with each other and the teachers differently. The students value the possibility to talk to the teachers in a safe and relaxed environment and pointed out that this made their start at the university feel easier and less dangerous:

In the beginning, we had a trip to Munkholmen and all the professors, all the lecturers and engineers from the program joined...We sat in groups on the grass and talked together. This made it a little bit less dangerous to start at university. Also when we sat to eat, there was a professor at each table so we could talk a little. (Student 2)

The socialization process is further strengthened, as the students start to see people within the community as role models. The students point out the importance of teachers connecting concepts to authentic engineering tasks and how the multifaceted interactions with the teachers help them to identify themselves with the community:

Because [the teachers] have engineering degrees and they know what engineering actually is. They always draw parallels and make comments to what it is in the engineering world. I think this helps very much. And to feel that there is a community and something to identify yourself with. That we are going to be engineers and that [the teachers] are with us. (Student 1)

While many students do not reflect upon that their teachers are academics and not necessarily practicing engineers, some students do point out the important role that guest lectures from industry play in the socialization process. They highly value the possibility to listen to and interact with practicing engineers and learn more about how engineering work looks outside of academia:

Today's guest, I think it's been what I've been looking forward to most on Wednesdays because you can see how things are at different workplaces. [At the university] you can see professors and so on. But many of us want to go to work outside academia and here we can see what professional engineers are doing. (Student 5)

Overall, the students emphasize how the first semester in the ELSYS program contributes to their socialization process into a community and that this is something that they feel is important and valuable for them.

2.2 Curriculum Integration

The second theme that emerged from the interviews as important for the students is how the ELSYS GK course contributes to integrate different aspects of the curriculum during the first semester of the ELSYS study program. One central activity in the ELSYS GK course are Cross-Talk sessions. The students feel that this really helps

them to see how different ideas, theories, and concepts can be used and how they link to practical implications:

The teachers are very good at the Cross-Talk sessions. They help you to see that “OK you have had that in the circuit theory and this in math. Then we can use these two things to do this.” Even if there is nothing we can do immediately, it shows at least what we have learned will be needed later... It becomes more meaningful. So I think the ELSYS GK course is very good to connect the entire program together as a whole. Because everyone has math and a couple of programs have circuit theory. But in ELSYS [the teachers] show exactly what you can use it for. I think that is very good. (Student 2)

In this way, the ELSYS GK course helps to situate theory and connect it to practice by showing concrete examples that the students more easily can relate to. As the students point out, this also helps them to differentiate their own study program from other programs and contributes to the community building presented before.

By connecting theory and practice in the course and integrating aspects of the entire study program, the students also experience that the course helps them to gain a better understanding of how the different courses contribute to the ELSYS study program:

At the beginning of each Wednesday [the teachers] tend to go through what we are doing in the other courses and show how it is related to the ELSYS GK course. So, it helps me to gain an insight into why we need all the other courses and see that it is useful to what we will learn in the future. (Student 3)

The Cross-Talk sessions help the students to see more clearly the relevance of what they are learning, how it can be used in different settings, and where they might need it in the future:

I really appreciated the Cross-Talk sessions. Seeing that what you do in other subjects is useful and relevant for something - that everything is related. I think that was good. (Student 4)

The students also point out how seeing the relevance and usefulness of the different ideas, concepts, and theories help them with their motivation. On a more general level, the ELSYS GK course connects many different elements together and the students feel that this helps them in their motivation towards becoming engineers:

What I might feel is that this course really helps me to be motivated to become an engineer... You see that the theory you learn is very useful in practice. And the course is in a way a link between all the other subjects. There is a circuit technology course, a programming course, and then you have the ELSYS GK course that just ties everything together. And that's awesome. (Student 1)

In addition, some students mentioned how the positive experiences and the satisfaction from working with the project helps them with their motivation not only for the ELSYS GK course, but has cross-motivational effects for their other courses:

I think it has been fun working on the project and really the whole course I think was awesome. And it has helped a lot with my motivation to work in this course and the other courses actually. (Student 3)

Overall, the students experiencing that the ELSYS GK course strongly couples together the entire ELSYS curriculum and greatly helps them to see the relevance and usefulness of different concepts and theories. For the students, it is critical that the teachers help them to see the connection between different parts and support them in their personal development of a more holistic view on the field, which the students describe as important for their motivation.

3 DISCUSSION

Curriculum integration was highlighted in the interviews as an important part of the ELSYS GK and as having a substantial effect on students' motivation. One of the core ideas with PBL is linking theory and practice by situating concepts and theories into practical applications [1], [4]. The ELSYS GK implements this idea through the projects, but at the same time adds an additional layer through Cross-Talk sessions, which the students valued highly. One important practical consideration for Cross-Talk is that teachers have access to the learning management system (LMS) pages of the other courses. In this way, it is possible for the teachers in the ELSYS GK to follow the progress of the students and readily adapt the Cross-Talk session to be relevant and connected to the other courses.

By making the connection between theory from other courses and students' own work explicit, the teachers *cognitively model* and make their thinking visible for students [10] on how to link theory and practice. This method helps the students in the short-term to see the relevance of the other courses that they have and contributes to their overall motivation. In addition, we argue that it also has long-term benefits, as the student learn the importance and approaches how to connect theory, concepts, and practice from different areas. Furthermore, it is through this integrated approach that the students perceive the ELSYS GK as holding the entire program curriculum together.

The second theme that emerged from the interviews with the students was the students' socialization process into a community. The students value being part of a disciplinary community and the close contact that they have amongst each other, as well as with the teachers. By considering the survey data, this appears to be something that separates the ELSYS program from many other electrical engineering programs in Norway.

The ability to build meaningful relations and belong to a community are widely recognized as important factors for human motivation and central for the learning environment [11]. However, much less is known about how first-year curriculum design decisions can support processes that lead to a sense of belonging for students [12]. The interviews in this study enable us to see glimpses of how different activities like PBL, Cross-Talk, Today's Guests, and study trips in a single course can contribute to the overall socialization process. The students relate to the teachers and see them as role models. By building these student-teacher relations, the students feel that they belong not only to a community of students, but a disciplinary community coupled to their study program. Today's Guests further contribute to this process and add a professional engineering dimension to the community.

The re-designed ELSYS program described here does not take PBL integration as far as other programs [2], but it combines PBL with approaches like Today's Guest and Cross-Talk session, as well as kick-off to provide students with a meaningful and developing environment when they start university. One advantage of this approach of targeted modifications, improvements, and adjustments is that they are easier to implement than larger curriculum changes. We argue that the approach described here provides a template to significantly improve first year engineering programs with relative simple and manageable changes, while retaining most of the existing courses.

4 CONCLUSION

Overall, the ELSYS program strikes a balance between keeping old structures and courses in place and at the same time integrate new approaches and ideas that change first year students experiences. The empirical data shows that disciplinary socialization and curriculum integration are two main areas that the ELSYS GK has a strong impact on. The course binds together the program through the integration of theories and concepts from the entire program, helps the students to build a disciplinary community, and provides them with opportunities to build engineering identities. Based on the ideas presented here, and supported by the empirical findings, we provide a case example of how targeted modifications can have program wide effects, which we hope can serve as a starting point for other educators.

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Evolutionary Trends of Global Engineering Education Policy and Its Enlightenment: 2000-2017

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ABSTRACT

In order to cope with the new characteristics of the new industrial revolution industry and the new talent demand, it is essential to analyze the characteristics and trends of global engineering education policy evolution and to innovate the engineering talent training model. This paper selects 51 typical engineering education policies of the US, Germany, China, Russia, and Japan from 2000 to 2017, uses content analysis method, determines key words based on the contents of various policies and their changes, and analyzes the themes of major industrial countries' engineering education policies. Based on the frequency and changes of words, the common characteristics and evolution trends of global engineering education policies are summarized. The research finds that: (1) the US values STEM education and cultivates new engineers with computing power; (2) Germany leads the reform in engineering education through digitalization and intelligence; (3) China emphasizes the cultivation of diversified, innovative and entrepreneurial Engineers; (4) Russia focuses on engineering practice and promotes the transformation of the engineering talent system in response to industrial demand; (5) Japan is driven by innovation strategy and is committed to developing a composite engineer to solve social challenges. Based on this, we try to build a new generation of engineer capability model and put forward some countermeasures.

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Conference Key Areas: Engineering Education Research

Keywords: Engineering Education Policy; Evolutionary Trends; Policy Implications

INTRODUCTION

The new industrial revolution takes place under the combined effects of the technological revolution, the energy revolution, and the communications revolution. It will have a far-reaching impact on the existing technology paradigm, manufacturing methods, industrial forms, organizational forms, and business models. In the wave of the new industrial revolution, a large number of smart industries, intelligent equipment, and intelligent products with clear signs of information age have emerged. The new industrial system led by information and intelligence will be the new industrial form. Engineering education is an important part of higher education and plays a very important role in promoting the development of national science and technology. Engineering education provides a steady stream of emerging forces for the country's engineering and industrial sectors by cultivating trained laborers and innovative engineers. Since the new industrial revolution, in response to new industrial characteristics and new requirements for talents, major industrial countries in the world have issued a series of important engineering education policy plans and research reports to promote the reform of engineering education and cultivate a new generation of engineers.

International engineering education is dominated by two types of countries[1]. One category is industrial powers that have solid foundations in industry. Such countries are at the helm of the development direction of engineering education. Their development is the frontier of engineering education. The United States, Germany, and Japan are such categories. The other category is the emerging industrial powers. Such countries have unique advantages in scale and a solid personnel training system. They want to take advantage of the new industrial revolution to seize manufacturing advantages and develop new industries. Russia and China are representatives of such countries. Extracting the characteristics of engineering education policies in two types of countries is crucial for judging the state of engineering education in the global countries.

This research uses content analysis method to analyze 51 engineering education policies in the United States, Germany, Japan, Russia, and China since the 21st century, and summarizes the characteristics of engineering education policies in major industrial countries. On this basis, the global engineering education is summarized. Policy evolution trends, and finally build a new generation of engineer models based on policy trends. The evolving trend of education policy, and finally building a new generation of engineer models based on policy trends.

1 RESEARCH QUESTION

The purpose of engineering education policy is to serve the training of engineering science and technology personnel. This study aims to analyze the global engineering education policy since the 21st century and summarize the characteristics of global engineering education talents. Specifically, the research questions of this study are:

1. What are the themes of global engineering education policy focusing on talent training?
2. What are the characteristics of engineering science and technology personnel training in major industrial countries in the world?
3. What kind of enlightenment has been brought to us by the evolutionary trend of global engineering education policies?

2 METHODOLOGY

The essence of the content analysis method is to convert documents expressed in language rather than quantity into data expressed by numbers by identifying the key features in the target text, and describe the results of the analysis using statistical data, based on further "quantity" of the content of the text[2]. To identify features that can reflect certain essential aspects of the content of the literature and are easy to count, Clarify its laws and conduct Inspection and interpretation. In order to reduce the subjective bias of coders and influence the research results, the classification and coding rules in the identification analysis framework need to be verified through reliability tests to ensure the scientificity of the analysis process and results. Therefore, we need to choose different appraisers to compare the coding results of the same analysis sample, and the consistency between the two coefficients is >0.8 . [3]The reliability test results of this paper reach $\alpha = 0.9$, which proves that the classification and coding rules are scientific and reliable.

3 PROCEDURE

This study uses the content analysis model of Chou and Chang's (2010) and the study is divided into 4 steps [4]:

1.Sampling (content selection): The study focused on the engineering education policies of the United States, Germany, Japan, Russia, and China. The target policy is an important policy plan and research report issued by the Ministry of Education, the Academy of Engineering, and related departments. Through the direct search of the official website of the above-mentioned departments, the Key words such as "engineering education", "engineering talents", "sci-tech talents, and "engineers", backtracking related documents, policy planning, and retrieval of publicly issued policy texts and research reports. In order to ensure the accuracy and representativeness of the policy text, the policy of closely related to the main content engineering education (The engineering education policy must be the subject of a report or a chapter, otherwise it will not be collected.) . In the end, 51 typical policy documents at the national level were categorized from three aspects: the introduction of time, the introduction of institutions, and the policy name. (Appendix 2).

2. Conceptualization: Corresponding to the issues raised previously, this study focuses on the following three aspects: (a) Global Engineering Education Policy Focuses on Topics, (b) Characteristics of Engineering Education Policy in Major Industrial Countries, (c) Global engineering education policy evolution trends.

3. Operationalization (Variable identification): Based on research issues, a code book for inductive coding strategies was created.

4. Coding Verification (Confidence Check): This study uses the triangulation method[5] of Miles and Huberman (1984) to obtain research data from multiple sources of information such as the official website of the Ministry of Education, the Academy of Engineering report, and the website of the Industry and Information Commission. At the same time, during the coding process, more than two doctoral students jointly handle the selected policies and reports. Subsequently, the completed code is submitted to a highly experienced professor of engineering education.

3.1 CODING BOOK

The coding manual, as a research guide, describes the classification principles of the first three research questions. The policy texts and reports collected will be systematically processed in accordance with these principles.[6] In the above, the key words for the training of engineering talents are: A-emphasis on multidisciplinary integration, B- highlighting engineering practice, C-cultivating engineering innovation ability, D-oriented industry demand, E- focused STEM education, F-STEM education, G- Engineering ethics. In coding, the policy coding range is from 1-51, and the global engineering education policy focuses on A-G changes.

3.2 Engineering education personnel training

Table 1 summarizes the operation description of the text encoding classification.

Table 1. Coding Strategies for Engineering Talent Cultivation

Coding	Category	Description
A	Multidisciplinary integration	Cross-convergence requirements in various fields, reviewing and solving problems from an overall macro perspective.
B	Engineering practice ability	With engineering professional skills, knowledge application capabilities and engineering conception.
C	Engineering innovation and entrepreneurship	With innovative engineering thinking, he has the intention and ability to engage in entrepreneurial activities in related fields such as engineering, technology development, production and service.
D	For industry needs	The skills possessed by engineering graduates match the needs of the industry and can meet the needs of the society and promote the development of the industry.

E	STEM education	STEM education relies on project practice and real situations to cultivate students' ability to solve problems using the four aspects of science, technology, mathematics, and engineering, and cultivate students' cross-knowledge structure. The coding needs to explicitly mention STEM education and be separated from the discipline.
F	Respond to social challenges	Cultivate new engineers who can solve the economic and social problems facing society in this century.
G	Engineering ethics	Establish the concept of symbiotic development of industrial development and eco-environment, the concept of integration of professional ethics and engineering practice.

3.3 Text frequency statistics

On the basis of collecting and arranging related policies, 51 policy texts are coded according to "text numbering - specific clauses/chapter". If there is a case where policy texts contain policy tools for comprehensive use, serial numbers are assigned sequentially according to the contents of the extracted policies, and a form of "text preparation—specific terms/chapter-serial numbers" is formed, and finally a coding table of policy content analysis units is formed. Based on the frequency and proportion of the seven keywords in five major industrial countries, draw a two-dimensional map of policy texts (Figure 1).

G	1-6; 6; 12	21-3;	37-2		
F	10;10-3	18-3;	30-4;37-4;32-1;25-1;26-3	40-3	
E	2-3;4;11-6;10-1		38-3		
D	7-3;8-4	13;14-1; 15-2;18-2;19-5;21-1	22-3;28-3-2;29-4;36;37	40-4;41-1;43-1;43-2	48-2;49-2-1;50-3-3;51-2-5;52-3;53-1;54-4
C	2-2; 6-4;7;8;9-3	15-1;18;19-3;20;21-2	23-2;24-1;26-2;27-7;28-3-4;29-3;31-3;34-4;35-4	42-3;44;45;46-3	49-1-3;51-2-8;53-3
B	5;11-3;10-1	17	31-1;34-2	40-2;41-2;42-1;43-3;45-3	49-2-2;50-3-4;51-2-7;54-3
A	1-3;2-1;8-3;9-1;10	21-5; 14-2;16	36-2;38-2	42-2;43-2	49-1-2;50-3-5;51-2-6;52-2

United States Germany Japan Russia China

Figure 1 Two-dimensional distribution of policy texts

4 FINDINGS

4.1 Analysis of policy texts

Since the 21st century, the number of global engineering education policies has steadily increased. Especially since 2008, engineering education policies have exploded, and engineering education has become an important part of higher education. This study collected 51 engineering education policies from 2000 to 2017, including 12 US engineering education policies, 9 in Germany, 16 in Japan, 8 in Russia, and 6 in China. Among the 51 engineering education policies, the keywords “for industry demand (D)” and “engineering innovation and entrepreneurship” (C) accounted for nearly half of the total, indicating that major industrial countries pay particular attention to cultivating innovative engineering talents for industrial needs. “Multidisciplinary integration” (A) and “Engineering practice ability” (B) accounted for 15.84% and 14.85%, respectively, reaching an average of the proportion, indicating that countries are paying more attention to interdisciplinary and engineering practice when cultivating engineering talents. In addition, “STEM education” (E) accounted for 6.93%, “respond to social challenges” (F) accounted for 8.91%, and “engineering ethics” (G) accounted for 4.95%. Among them, STEM education became a hot spot in American engineering education policy, responding to social challenges. To become the focus of Japan's engineering education policy formulation, Germany and the United States are also increasingly concerned about engineering ethics.

4.2 Characteristics of evolutionary trends in major industrial countries

The core elements of national engineering education policy texts can be extracted from Figure 1:

1. The United States: Emphasizing STEM Education, Training Innovative Engineers with Cross-knowledge Background

From the data point of view, STEM education and multidisciplinary integration accounted for the highest proportion of engineering education policies in the United States (all accounted for 4.95%, followed by engineering innovation and entrepreneurship (3.96%), engineering ethics (2.97%), engineering practice ability (2.97%), for industry demand (1.98%), and response to social challenges (1.98%). In general, the U.S. engineering education policy has the following characteristics: (1) Emphasizing STEM education, attempting to build a large system of engineering education based on the learning of interdisciplinary projects; (2) Advance design, dedicated to training future-oriented engineers and technology talents. Propose the "2020 Engineers Plan" report, and on this basis, formulate action plans for innovative engineering talents; (3) Strengthen the intersection of disciplines and explore the multiple modes and innovative approaches for engineering talent training; (4) Emphasis on engineering practice requires students to connect theory with practice.

2. Germany: Focusing on Industrial Needs, Emphasizing the Development of Digital and Intelligent Talents

From the data point of view, Germany pays special attention to the cultivation of industry demand and innovative engineering talents. The industry-oriented demand

(4.95%) and innovation engineering talents (5.94%) have the highest proportion of their engineering education. In the rest, multidisciplinary integration accounted for 2.97%, and engineering practice ability accounted for 0.99%. Generally speaking, the German engineering education policy has the following characteristics: (1) Transforming the engineering education system for industrial needs, and the policy is tilted towards digital and intelligent engineering talents; (2) The institutionalization of industry-university cooperation provides policy guarantees for the smooth implementation of engineering education practice. Adopt the “dual system” and “double-training” personnel training methods. Schools and enterprises jointly undertake the cultivation of talents. The school is responsible for theoretical teaching, the company is responsible for practical teaching, and improves engineering students' practical ability and innovation.

3. Japan: Driven by innovation strategy, dedicated to developing composite engineers to solve social challenges

From a data point of view, Japan placed the training of engineering talents in innovation and entrepreneurship at the top of the list, accounting for 8.91% of the total. In addition, Japan emphasized the importance of cultivating engineers who can cope with the major social challenges, the “responding to major social challenges”. accounted for 5.94%. In the rest, multidisciplinary integration accounted for 1.98%, engineering practice ability accounted for 1.98%, STEM education accounted for 0.99%, and engineering ethics accounted for 0.99%. In general, the Japanese engineering education policy has the following characteristics: (1) Actively develop innovative research and strive to cultivate composite engineers that solve social challenges; (2) Build an open and innovative talent training system and call for interaction between technological innovation and society; (3) Actively invest funds in the engineering field, focusing on Investment in engineering talents in areas such as internet of things, energy, and information technology.

4. Russia: Focus on engineering practice and promote the transformation of engineering talent system for industrial development

From the data point of view, engineering practice ability accounted for 4.95%, engineering innovation and entrepreneurship accounted for 3.96%, facing the industry demand accounted for 3.96%, multidisciplinary integration accounted for 1.98%, to deal with social challenges of 0.99%. In general, the Russian engineering education policy focuses on engineering practice for industrial needs, and its engineering education policy presents the following characteristics: (1) Legalization of internal and external cooperation mechanisms in engineering education, internal cooperation with universities and large-scale enterprises, and resource sharing measures to improve the practical ability of engineering talents; (2) Actively fostering innovative talents through universities, Science and technology parks, university business incubators and other training professionals; (3) Based on cross-disciplinary, develop comprehensive talents that meet industry needs.

5. China: Promoting the New Engineering Paradigm and Developing a New Generation of Engineers Facing Industry Needs

The development of engineering education policies in China has seen an explosive growth in the last two years. From the data point of view, the industry-oriented demand accounted for 6.93%, multidisciplinary and engineering practices ability accounted for 3.96%, and engineering innovation and entrepreneurship accounted for 2.97%. In general, China's engineering education policy has the following characteristics: (1) Cultivate diversified, innovative and entrepreneurial engineers, and implement discipline professional construction to adapt to industrial transformation and upgrading; (2) Build a new engineering talent system and implement an excellent engineer training program; (3) Promote the integration of production and education, and strengthen the transformation of scientific and technological achievements.

4.3 New Generation Engineer Model Construction based on policy trend

Through the analysis of 51 major industrial countries' engineering education policies, it can be seen that global engineering talent cultivation shows the general direction of demand practice, innovation, compound, and international vision. The topics of engineering talent training focus on: interdisciplinary integration capabilities, engineering practice capabilities, innovation and entrepreneurship capabilities, facing industry needs, addressing major social challenges, STEM education, and engineering ethics. Combining the extracted key words and the core characteristics of engineering education policies in major industrial countries, and comprehensively considering the research literature on future capability of engineering science and technology talents at home and abroad, this paper exploratorily builds a new generation of engineers' core competencies model, as shown in Figure 2.

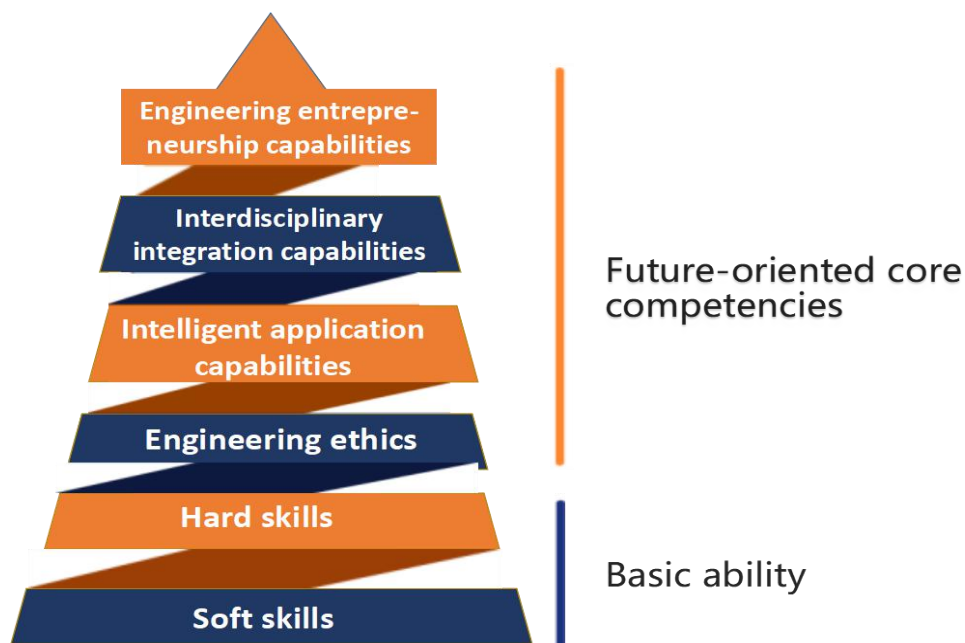


Figure 2 New Generation Engineer Capability Model

In the framework of a new generation of engineers' capabilities, engineers are weighted toward future-oriented core competencies such as basic skills and engineering ethics, intelligent applications, interdisciplinary collaboration, and engineering entrepreneurship. Hard skills refer to professional knowledge and

capabilities. Basic skills are equal to the sum of hard skills and soft skills such as engineering practice and communication and leadership skills. Above basic skills is the core competence for the future, which is the difference between the new generation of engineers' capability framework and the traditional engineer's capability framework. This paper will focus on the future of the core capabilities are divided into four levels, engineering ethics, intelligent application capabilities, cross-disciplinary collaboration capabilities and engineering entrepreneurial capabilities.

5 CONCLUSIONS AND RECOMMENDATIONS

By analyzing the engineering education policies of the major industrial countries in the world, it is found that countries have significant commonalities in the field of concern and the cultivation of engineering talents. The engineering education policies of various countries are obviously inclined in the cultivation of artificial intelligence, internet of things and big data engineering talents. At the same time, countries have reached a consensus on training a new generation of engineers and engineers with engineering practice capabilities, innovation and entrepreneurship capabilities, and interdisciplinary collaboration capabilities. From the perspective of policy trends, the future engineering education reforms in various countries can be broken through four aspects: (1) speeding up the integration of education and information technology; (2) Strengthening the connection between engineering talents and industrial needs; (3) training model for innovative engineers; (4) Strengthen interdisciplinary collaboration.

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SELF AND PEER REVIEW TO ENGAGE STUDENTS WITH ASSESSMENT CRITERIA, DEVELOP THEIR JUDGEMENT AND CRITICAL EVALUATION SKILLS AND EXTEND THE BENEFITS OF INSTRUCTOR FEEDBACK.

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Keywords: self and peer assessment, Collaborative learning, Academic standards

1 INTRODUCTION

While assessment may shape students' perception of learning [1], to be effective learners, students need to understand the assessment processes, criteria being used and the learning outcomes being assessed [2]. Many activities have been designed to assist students to engage with and understand assessment processes including providing written criteria and grade descriptors. However, this is frequently not sufficient to make what is often tacit 'knowledge' visible to students. It could be argued that this is particularly relevant for students new to higher education who are yet to have become familiar with the learning culture and expectations of the institution in which they are studying. We suggest that for students to be socialised into these tacit assessment standards and practices they need opportunities to practice and receive feedback.

This paper reports how students behaved and responded to a self and peer review activity aimed at developing student's judgement, appreciation and understanding of academic standards to increase the benefits from assessment in a first year engineering program.

2 BACKGROUND

Boud [3] argues that learning is socially and culturally constructed by the learner. But a social construction requires a language allowing students to think about, understand and discuss their learning. The same attributes are also required for students to develop their professional judgement.

Many activities have been designed to assist students to engage with and understand assessment processes ranging from the arguably mandatory written criteria and grade descriptors linked to learning outcomes through to providing summative feedback tasks and collaborative discussions. However, this is often not sufficient to make academic standards, which are often tacit 'knowledge', visible to students [4].

Many academics and universities assume that a students' ability to make academic judgements will automatically develop as they compare their assessments with those of expert instructors and tutors. However, academics often use holistic judgement which they subsequently justify by resort to criteria [5]. Sadler recommends that students should move beyond 'teacher-supplied feedback to learner self-monitoring' requiring instructors to design explicit opportunities for students to develop and evaluate their expertise. He suggests that self-evaluative skills need to be developed 'by providing direct authentic evaluative experience for students' [5] (p. 119) such as making judgements about work they have completed. Rust introduces the analogy of developing 'connoisseurship', which is largely about socialisation and experience "involving observation, imitation, dialogue and practice" [4] (p. 152).

Self-regulation as described by Nicol and Macfarlane-Dick [6] requires students to be able to effectively judge their own work. Without such ability students learning will be less effective and they will be unable to judge whether their approaches to learning and chosen methods of study are effective and appropriate [7]. This development of judgement is extremely important not only for students learning but in their professional practice. For example, using judgement and being able to develop judgement is required to evaluate if their contribution, work, analysis et cetera is sufficient to meet the requirements of workplace tasks undertaken [8].

Sadler identified three conditions for feedback to effectively influence learning:

1. a knowledge of the standards
2. having to compare those standards to one's own work, and
3. taking action to close the gap between the two [5] (p. 138).

In this paper we focus on using self, peer and academic review to improve student's judgement. The University of Sydney reports the main aims of self and peer assessment are to [9]:

1. increase student responsibility and autonomy
2. strive for a more advanced and deeper understanding of the subject matter, skills and processes
3. lift the role and status of the student from passive learner to active learner and assessor (this also encourages a deeper approach to learning)
4. involve students in critical reflection
5. develop in students a better understanding of their own subjectivity and judgement.

Learning activities should be also scaffolded to reduce undesirable anxiety, promote engagement and ensure students understand and hence can benefit from the learning opportunity provided. Willey and Gardner [10] recommend that academics should explain to students:

- why they designed the assessment activity the way they did,
- what learning opportunities the activity provides the students,
- how students can evaluate their learning from the activity, and
- how it is going to impact on their reality (enable them to see the world differently).

The last step being arguably the most important. If students are not gaining something from our learning activities that enables them to see the world differently, provide a different perspective or new awareness then we are only confirming what they already knew.

We suggest that for students to be socialised into the often tacit assessment standards and practices, they need opportunities to practice and receive feedback and that, it is important to commence this socialisation in the first year of their studies.

This paper reports on the impact of a self and peer review activity in developing student's judgement, developing an appreciation and understanding of academic standards and increasing the benefits from assessment in a first year engineering subject.

3 STUDY

The described activity involves student's self and peer reviewing their own and each other's assessment artefacts. Students are required to grade the artefacts against criteria and provide feedback explaining their decisions. Typically, students self-assess their own work and peer assess the work of two others. This reduces what I call writing for the tutor, a process by which a student's work is only ever seen by them self and the tutor and the tutors feedback only has an impact on the student who submitted the work. In the described self and peer review process students get to see the judgements and feedback from them self, two peers, and the tutor for three (their own and two peers) submissions.

In the reported instance aliases were used to provide students with anonymity while still identifying whether the feedback and ratings were provided by a student or an instructor. For example, the aliases for students were assessor 1, assessor 2, assessor 3 et cetera and for the instructors, tutor 1, tutor 2 et cetera (in previous trials students were identified). The same alias was used for all three reviews (self and two peers) allowing the ratings and comments provided by a particular student (assessor) or instructor (tutor) to be recognised (see Fig 1). This facilitated students identifying the different standards applied, for example, some students were characterised as being hard or easy markers. The activity was designed to build

students professional skills including judgement and critical evaluation while simultaneously building their understanding of academic standards.

Facilitating self and peer assessment can result in significant academic workload and is almost unsustainable in large classes without the assistance of some form of educational technology. SPARK^{PLUS} [11] [12] is used to support the self and peer review process discussed in this paper.

4 CONTEXT

A large (>500 enrolments) multidisciplinary first year engineering subject was chosen for this study.

As part of their assessment students had to undertake a group design project. The narrative used to scaffold the design project had student working as teams of interns for a fictitious company. At the end of the semester students had to apply for a part time design engineer position with the company. This required them to write a cover letter and respond to two of the selection criteria. The selection criteria were taken from actual advertisements for engineering positions and were chosen to reflect the professional development required by the discipline and recognised in accordance with Engineers Australia level I competencies [13]. To assist them in preparing their application students were required to maintain a portfolio within which they planned, monitored and evaluated their development of the skills listed in the selection criteria.

While the student peer reviews had no impact on the grade a student received for their submitted job application (this was determined solely by the tutor) students were given marks for each of their peer reviews.

Awarding marks for the quality of the peer reviews fits well with the subject learning objective to develop critical evaluation and assessment skills. It also motivated students to engage, participate and provide quality peer reviews. We felt this was particularly important being a first year unit. In later years when students have become familiar with self and peer review processes and the learning opportunities they provide these review activities are formative.

4.1 What students see

The results screen allows students to compare their ratings and written feedback/reasoning against each of the assessment criterion to that of their student peers and tutors for each submission they assessed (Fig 1)

Participants can also view a summary of their ratings for different submissions to compare their ratings (grades used FA: Fail, P: pass, C: credit, D: distinction, HD: high distinction) with those of their fellow assessors. This comparison can be self against all the other assessors or just against student peers, tutors/instructors or any other category using the drop-down menu (Fig 2).

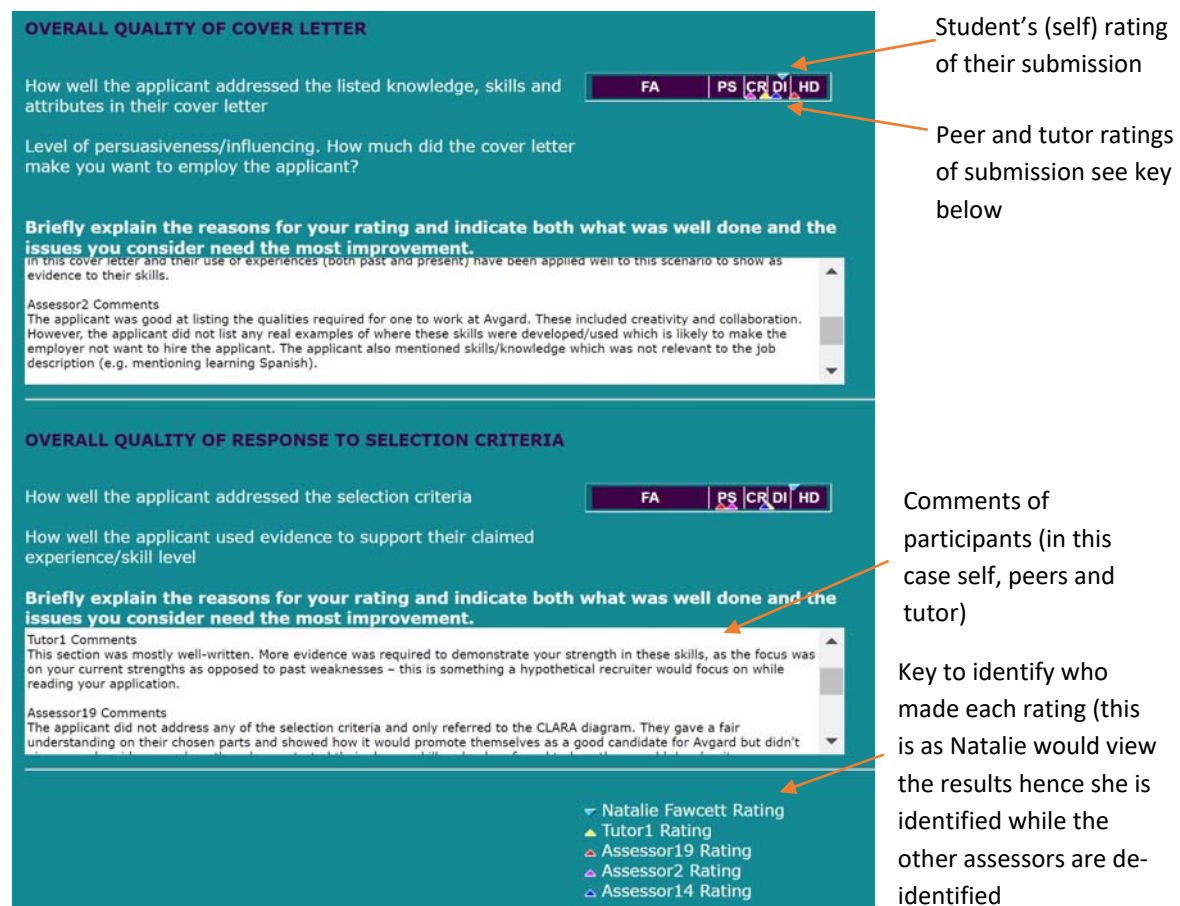


Fig 1: Multiple Assessor results screen. Students enter their ratings and feedback individually before viewing the results (SPARK^{PLUS} also facilitates the assessors to be identified).



Fig 2: Multiple Assessor comparative summary screen.

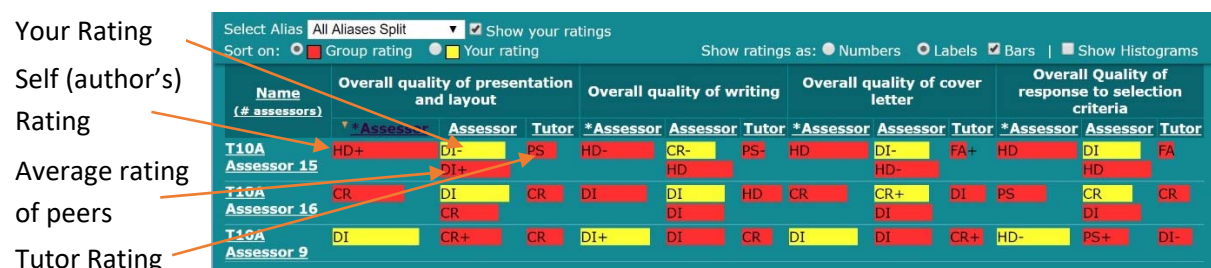


Fig 3: Multiple Assessor comparative summary screen.

Alternatively, it is possible to split the summary screen to compare your ratings to the average rating provided by each of the assigned assessor groups. In this case we categorised students as assessors and instructors as tutors (Fig 3)

5 RESULTS

92 students from a cohort of 520 agreed to answer a series of questions and describe their learning experience from the self and peer review process. 78% of these students reported that having to peer review job applications of other students and subsequently being able to compare their own, their peers and their tutor's assessments and feedback had improved their capacity to write as a professional. 77% of participating students said the process improved their understanding and awareness of how to improve their professional skills through:

the opportunity provided by the activity design;

"THIS WAS ALSO A VERY WELL structured component of the Job Application. It was very effective in developing critical evaluation and feedback skills. It enabled students to examine how other applications had pros and cons and where each application could improve aspects they lacked in".

"It helped me find out what I need to improve, and gave me a chance to compare myself with others".

The reviews *"told me where I should improve and some professional advice was also useful"*

comparing one's own submission with other students;

"I think that the peer reviewing was helpful to see how other people write and seeing where they went wrong to improve in those areas for the future".

"I saw some mistakes in other people's writing and then thought back to my own work and realised some of the mistakes I had also been making in my work so it was an eye-opener to not only the flaws of my peers but also to my own".

having to assess and provide feedback on someone else's submission;

"I found writing the feedback more helpful than the feedback itself. It allows you to contrast someone's work to your own and make judgement on things you did well and ways you could both improve".

the tutor assessment and feedback,

"By comparing with others and get feedback from them and tutor, I can directly see the weakness of my job application.

Despite the fact that tutors also provided assessments in line with findings by Sampson and Cohen [14] some student's perceived peer learning as having little value as feedback is often not given by a recognised expert.

“Not many peer students actually know what is a good cover letter including myself, so it is hard to make judgement and comments as to evaluate others comment and make an improvement”.

“I found that the feedback from my peers differed wildly - both from themselves and from the tutor. This meant that I became more uncertain as to how I did”.

This activity has been run for a number of semesters on some occasions both the person who submitted the work and the reviewers were anonymised on others the identity of both the submitting student and the reviewers was known. The activity was successful in both instances although some students did appreciate the anonymity when it was provided.

A preliminary analysis also uncovered evidence to support Boud's study [8] that found compared to instructor judgements lower ability students significantly overestimated their ability in self assessments, while higher ability students often underestimated their grades. This supports our belief in having assessment groups made up of students of different abilities. It allows the lower achieving student to receive feedback from higher achieving student and an opportunity for higher achieving student to articulate their judgement, critical evaluation and understanding (if a high achieving student is assessing a high achieving student there is often less opportunity to provide critical evaluation).

5.1 Improving Learning Culture and Practice

A variation of this activity to assist students to make the most out of learning activities is to ask students to answer a number of questions and provide feedback about how they have engaged with and/or approached a learning activity. Once the results are published students are encouraged to compare their experiences using the result histograms and view the comments of students who have rated the activity at different levels of satisfaction. For example, a student who rated a learning activity as poor often finds a more beneficial way of engaging with, and learning from, these activities by reading the comments from students that rated the activity as good or excellent. This student feedback also helps instructors to improve both the design and scaffolding of their learning activities.

6 CONCLUSION / FURTHER INTEGRATION

The self and peer review activities involving students and instructors provided a valuable opportunity for students to evaluate, receive feedback on and develop their critical evaluation and assessment skills and their understanding of academic standards. We have now incorporated into our second, third and fourth year subject's formative opportunities to undertake this type of assessment. In these subjects we have also included opportunities for groups to collaborate to assess other groups and extended the assessed activities to include in addition to written submissions, oral presentations, engineering designs and critical evaluations.

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Concept Papers

(Re)integrating long term unemployed engineers through innovation projects

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Conference Key Areas: University-Business cooperation, Continuing EE and Lifelong Learning, Recruitment and Retention

Keywords: Long term unemployment, dual learning, engineering, Flanders

INTRODUCTION

The Flemish labour market for engineers is marked by a striking paradox of both scarcity and growing unemployment. Looking at numbers provided by VDAB (Flemish Service for Employment and Vocational Training), we see that on the one hand an increasing number of vacancies for engineers is not filled (at the end of August 2016, 3942 vacancies were open [1]), while on the other hand more and more engineers are registered as job-seekers (in the same period there were 2248). In three years' time there is even a tripling of the engineering shortage (from 2214 vacancies at the end of 2013 to 4120 at the end of 2016). The actual shortage is probably even larger, as not all vacancies are registered with VDAB by companies.

Especially over-50s and immigrants are having a hard time (re)integrating into the labour market. For both groups the chances of recruitment are higher when competencies can be demonstrated through workplace learning or internships. Add to this the fact that long-term unemployed engineers need a knowledge update (as their knowledge is obsolete and/or because they have to look further than the domain in which they have specialized for many years), and the principle of dual learning emerges. That concept of dual learning can be applied to all long-term job seekers.

In September 2016 a follow-up project for the Postgraduate Programme in Innovation & Entrepreneurship in engineering was approved by VLAIO (Agency Flanders Innovation & Entrepreneurship). One of the additional goals of the project was exactly this (re)integration of unemployed engineers. The programme is a cooperation between all Flemish universities, and very early during the process, a partnership agreement with VDAB was signed for this project. Representatives from all universities and VDAB formed a project team and named the pilot project WINWIN ("Werkzoekende INgenieurs Werken aan INnovatie"). The pilot project took place in academic year 2017-2018.

1 GENERAL

1.1 Dual learning in Flanders

The large discrepancy between increasing scarcity of engineers and increased unemployment in the engineering sector calls for a solution that better matches supply and demand. A possible answer is contained in the concept of dual learning.

With the Concept Note bis [2], the Flemish government decided in 2015 to focus on dual learning as a fully qualified learning pathway in secondary education. Through dual learning, i.e. a learning trajectory that deals with work experience and a related learning component, education and the professional field are brought closer together. This movement enables a qualification process that is closely in line with the reality of the workplace, thus facilitating competency matching in the labour market. With the decree concerning dual learning [3] the Flemish government explicitly states the ambition to extend the dual learning line to be extended to higher education in order to further bridge the gap between education and the labour market.

1.2 Dual learning and unemployment in Flanders

For the (re)employment of specific target groups in unemployment, workplace learning, whether or not in combination with customised further training, can also be a suitable approach. Several recent initiatives illustrate how this is already being done in practice among the lower educated. For example, the VDAB concept of “Intensive Workplace Learning” offers long-term unemployed people vocational training within the social economy; WELT, a VOKA initiative in collaboration with VDAB, tries to fill bottleneck vacancies within the framework of corporate social responsibility by means of work experience and learning pathways; and finally, VDAB also sets up entry placements for young unemployed people without a higher diploma. These concepts can, subject to adaptation, be transferred to a highly educated target audience.

In the context of job-seeking engineers, such a programme can consist of a combination of a work placement, in which knowledge is updated in line with the latest technological developments, and a supplementary course, in which both (broad) technical competencies and soft skills are central. This training course will enable job-seekers to fill certain skills gaps and, in addition, to gain up-to-date workplace experience that will make it easier for them to (re)find a job.

1.3 Dual learning for long term unemployed engineers

Flanders, and by extension Belgium, is obviously not the only region where the labour market for engineers is characterised by the apparent contradiction between a serious shortage of engineers and an increasing group of job seekers with precisely that qualification. It is therefore also worth looking beyond national borders when seeking a suitable approach to resolving this discrepancy. In Germany, for example, the cradle of dual learning, three different (re-)employment projects were rolled out in the period 1991-2009, one by one based on the principle of cooperation between university institutions and industry.

A first project is mentioned in the article 'A practice-based model for continued engineering education' (1991) [4]. The model described here combines a company-based, interdisciplinary team project with technical courses that fit within an individual training programme.

In the period 1999 - 2002, another rehabilitation project, ‘Arbeitslose Ingenieure in den ersten Arbeitsmarkt’ [5], was launched. Here three actors (the University of Magdeburg, the employment service in Magdeburg and the company Bosch in Feuerbach) joined forces to coordinate demand (a large engineering deficit in the mechanical engineering sector in the Stuttgart region) and supply (a historically high number of unemployed engineers in the Magdeburg region). Engineers specialising in mechanical engineering initially followed a four-month course in the automotive sector, while simultaneously acquiring soft skills, computer skills and technical English via workshops. This was followed by a 6-month internship at Bosch (Feuerbach, Stuttgart). Over a period of 3 years, 50 to 60 engineers were reemployed in this way.

A third and last German project, return2job [6], (2008-2010) aimed to reintegrate engineers who, due to family commitments, had not been active for many years into the labour market, through technical and scientific training via distance learning (40 - 60 ECTS), soft skills seminars and three months of work experience. The companies that offered an internship evaluated the internship well to very well, and half of the participants were employed within six months of the end of the internship.

Also further away, dual learning projects are developing. Canada, which has an active immigration policy, offers an 'Engineering and Technology Upgrading Program' [7] in the state of Alberta for engineers trained abroad who do not yet have Canadian work experience. The programme includes soft skills training for the Canadian context, an upgrade of technical/technological competencies, an AutoCAD training course and a workplace experience within an engineering company in Calgary. According to the own data of this programme, 97% of the participants succeed in being employed as engineers at the end of the programme.

2 WINWIN PROJECT

2.1 Project design

In September 2016, VLAIO approved a follow-up project for the "Postgraduate Programme in Innovation & Entrepreneurship in engineering". This postgraduate programme [8] is a joint initiative of faculties of the five Flemish universities that offer programmes in industrial sciences, biosciences, bioengineering and engineering sciences, and it aims to ensure that students are better prepared for the practice of their profession by focusing on the development of innovation, entrepreneurial and professional competences, aside from technical engineering skills. Within this follow-up project, a number of new objectives were formulated, of which involving job-seeking engineers was one.

VDAB is the public employment service of Flanders, and thus functions an important partner in the project. Very early during the process, a partnership agreement was signed between the universities and VDAB.

During the WINWIN-project, the unemployed engineer participates in a so-called 'innovation project'. An innovation project is a company project aimed at the development and implementation of a product, process, service or concept that is new and innovative for the company. This is done under the guidance of a company mentor, and a university coach.

Based on the present and desired competence profile of the individual participant, the mentor can decide on maximum two additional courses that have to be followed at the universities. Naturally, this decision is made in consultation with the participant, the company mentor and university coach.

Depending on the individual upgrade process, the duration of the project is between 12 and 16 weeks, with approximately 60 working days (3 to 5 working days per week). During the duration of the project, the unemployed engineer still receives his unemployment benefits.

2.2 Selection procedure

The postgraduate programme has a lot of experience with the coordination of innovation projects and can thus count on a large corporate network. Companies from the internship database of the postgraduate programme were contacted and asked about their interest in WINWIN. After mostly positive responses, the project team started the recruitment procedure for candidates.

The target group consists of all job-seeking engineers with a master's degree in Flanders who have been job-seeking for at least one year and are registered with VDAB. A targeted mailing was carried out by VDAB and flyers and posters were distributed. Additionally, a brand new website was launched (winwinproject.be [9]). By June 2017, these marketing efforts led to a total of 43 candidates that applied for the WINWIN pilot project through the website.

The selection process that followed consisted of three steps, namely a pre-screening procedure, a round of interviews and finally a finalising selection meeting. The pre-screening and selection interviews were intended to provide clarity about a candidate's attitude, soft-skills, and technical competencies. After all, a suitable candidate must have a minimum of competencies. There are therefore initial terms that must be fulfilled.

The pre-screening of suitable candidates was carried out by local VDAB consultants who, on the one hand, had to check whether a candidate met the hard criteria (engineering diploma at master level and looking for work for at least a year) and, on the other hand, could assess the attitude and potential of the candidate, regardless of his/her technical knowledge. Following this pre-screening process, the number of candidates was reduced from 42 to 35.

For the round of interviews, those 35 people were invited for an interview of half an hour, with the aim of selecting 10 suitable candidates. Each selection committee consisted of at least four people, namely a HR professional specialised in the recruitment of engineers, a lecturer with a background in engineering education, the regional coordinator of the postgraduate programme and a representative of the VDAB. The interviews were conducted in accordance with a common script. In the end, 32 interviews were held, from which 12 people were selected.

2.3 Participants

For the twelve selected candidates, the search for a suitable business match commenced. An overview can be found in *table 1*.

Table 1: Overview of the participants of the WINWIN project

No.	Sex	Age	Region
1	M	41-50	East Flanders
2	M	31-40	Antwerp
3	M	31-40	Antwerp
4	M	51-60	East Flanders
5	M	51-60	West Flanders
6	M	51-60	Antwerp
7	M	51-60	Flemish Brabant
8	F	31-40	Limburg
9	F	31-40	East Flanders
10	M	41-50	Antwerp
11	F	51-60	Flemish Brabant
12	F	51-60	Flemish Brabant
13	M	51-60	Antwerp
14	M	51-60	Limburg

For three participants (order no.: 1-3), the WINWIN project was already a success before they started the innovation project. During the search for a suitable project these participants already found a job. Two of these contacts came about as a result of the WINWIN project.

For two other participants (order no.: 4-5), the search proved to be a lot more difficult. It became clear that there were motivation and/or attitude problems that had not come to the fore during the selection procedure. For them, the WINWIN project was therefore terminated. Two new participants were then picked up from the reserve list (order no: 13-14). Unfortunately, we were unable to find a suitable innovation project for them in time, so they did not complete the project.

A match between a project and the profile of the participant was found for the other seven participants (order no: 6-12).

3 EVALUATION PROJECT

3.1 Main findings

Of the seven participants who started the WINWIN project, two have currently found a job, approximately three months after the end of the internship. One of the participants was offered a contract with her internship company. Furthermore, even before the project started, two candidates were able to work through contacts made by the WINWIN coach. A total of four long-term job-seeking engineers were put to work by the WINWIN project.

3.2 Conclusions

3.2.1 *Attitude, motivation and professional skills*

There is a clear need for coaching on attitude, motivation and professional skills, but the current set-up of the programme does not sufficiently meet these needs: experience learns that there are almost always underlying reasons why the participants can't find a job (attitude, psychological, communication, etc.). As an additional complication, it turns out that job seekers are often very reluctant to undergo attitude training because they themselves do not see the need for it.

The current partnership of engineering faculties, assisted by the VDAB, reflects this initial choice: it can rely on assets such as a large industrial network and the capacity to provide a (bio)technological knowledge update, but the expertise needed to work specifically on the listed problem areas is lacking. To overcome these hurdles, a next edition will take this double solution into account:

1. Not let all (potential) candidates immediately participate in the internship, but to provide the option for some of them, after the first intake interview, to first follow a general "skills" trajectory;
2. Expand the consortium with additional partners (e.g. career centres, outplacement agencies...) who can complete this person-centred coaching.

3.2.2 *Role of the coaches*

From the start of the project it became clear that the supervision of WINWIN participants required a different approach than regular postgraduate students: the selection of suitable candidates (intake interviews) proved to be time-consuming, and during the course of the project they needed a much closer and more intensive follow-up - both by the coaches and by VDAB. The topics that had to be discussed with the candidates were often different from those that were discussed with the regular students. Moreover, it was much more difficult to find a good business match for the candidates, so more time needs to be set aside for this in the future.

And finally: a relationship of trust between coach and coachee is very important. Experience shows, however, that some candidates - certainly in the beginning - are suspicious of the coaches of the universities, perhaps because of the close link that exists with the VDAB. As a result, important information is not shared with the coach, or is shared only at a late stage. That is why in the future it is important that the roles remain effectively separated but also that they are communicated more transparently to participants.

3.2.3 *Knowledge update via courses from the university offer*

Participants of the WINWIN project often take one or two university courses (n=5). Although the participants are very enthusiastic about the courses and indicate that

they can immediately apply the content of the courses in the internship, they indicate that passing the exam is too difficult. For a follow-up project, examinations should be more encouraged or even made compulsory.

3.2.4 Internship

The project foresees that participants in the WINWIN project as well as those in the postgraduate programme in principle participate in an 'innovation' project. In practice, however, the internships of the WINWIN participants are often of an operational nature: an innovative path is, in this phase of their career, often too ambitious. In the future, the project should therefore explicitly allow for operational internships, while ensuring that they remain 'engineering' projects.

Whereas in the initial pilot project this was not yet well enough coordinated and in some cases led to frustrations, in a new project the employment possibilities in the future will have to be taken even more into account in the search for a suitable internship. For example, concrete vacancies can be used, or there will have to be clear communication between the internship company and the participant about possible employment afterwards.

3.2.5 Information flow within the consortium

The partners each have a very partial view of a candidate's competence profile - and their skill gaps. In the future, it should be possible to exchange information on this subject in a more structured way, taking into account, of course, the principles of privacy.

3.3 Future

In September 2018 a second pilot phase ("WINWIN project 2.0") will be launched, based on the conclusions reached in the initial project. It will give the project a new interpretation, while retaining its original objectives. In order to reach these objectives, a preparatory phase will be built into pilot project 2.0. This means that not all participants immediately partake in the company internship, but rather that some participants will first follow a general skills track, consisting of attitude, soft skills and business readiness training. A special focus will be given to career coaching, self-reflection and life skill coaching. An external partner will be in charge of this preparatory track and it will consist of individual coaching, supplemented by group coaching. Whether or not the participant will have a need for this track, will be decided after the first intake interview and after a obligatory three-day workshop organised by VDAB, are completed.

Furthermore, participants will no longer be required to work on an "innovation project", but as of now can also opt for a more operational project. The internships will be chosen with a special focus on the employment possibilities in the future.

The pilot project has provided everyone involved in the WINWIN project with better insight into the complexity of problems that come with long-term job seeking engineers. There is clearly a gap in guidance for these engineers, and many of them would not find a job without help. This again indicates the social importance of the project. The insights gained from the pilot project and the additional insights that will still follow, must be put to practice. It is clear that dual learning and lifelong learning are indispensable for graduate engineers, which should be reflected in the education and organisation of universities and governments.

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Evaluation of students' capstone software development projects

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Conference Key Areas: Education, Engineering Skills, Discipline-specific Teaching & Learning

Keywords: Capstone project, evaluation, software development, software product

INTRODUCTION

Capstone projects are important part of engineering education studies in software development field. In the project, a student team implements a software product usually for a company. Because of group work, complex project topics and external

stakeholders, evaluation of students' work is challenging. Our studied project course is aimed for Master's students, during their last year of studies. It is compilation of all information and competence, what students have learned during their studies in computer science so far.

In this paper, we introduce a new detailed evaluation model for software engineering capstone projects. The model has the following three main dimensions; project team implementation, customer feedback and individual level performance. We have tested the evaluation model with over 25 projects and 146 students during two academic years, and the benefits of the model are clear and transparent requirements in addition to fair credits to students. There may be variation within a project group both on the credit units and on grade.

The rest of this paper is organised as follows. Next, we give an overview to engineering education capstone projects, and evaluation of group work. Section 2 gives a detailed description of a capstone project implementation at Tampere University of Technology (TUT). In Section 3, new project evaluation model is given and analysed.

1 CAPSTONE PROJECTS IN ENGINEERING EDUCATION

1.1 Capstone projects

Project work skills are recognised widely as core knowledge in software engineering [1]; [2] and also in other engineering fields. In software engineering capstone projects, students have a possibility to apply all their knowledge and skills from earlier studies to implement a software product.

The following issues characterise academic software engineering capstone projects: i) The project is done during the last study years before graduation. ii) Group size varies between 4-7 developers, often one team member acts as a project manager. iii) Outcome from the project is a software product. iv) Customer comes from a company or some other external organisation. v) Size of the project is relatively large, students can receive up to 10 ECTS and the project may last 4-6 months. vi) The team must follow widely recognised software development models and good project working practices. vii) Teachers supervise the team. viii) Traditional project constraints, like scope, schedule and quality are important, but usually there is no real budget.

Exact learning goals of capstone projects vary between disciplines and organisations, but for example, ACM's Software Engineering Curricula [1] guideline describes content of a project course as follows: *"Group software engineering project requiring completion of a software system for an approved customer. Tasks include project planning, risk analysis, use of standards, prototyping, configuration management, quality assurance, project reviews and reports, team management and organisation, copyright, liability, and handling project failure."*

1.2 Evaluation

Assessment refer to evaluation of learning outcomes, but it can also refer to activities that teacher use to help students to learn, and to measure student's progress. If assessment is shown to students, it works as a feedback. All aspects that are related to teaching should be aligned to support students' learning, understanding and professional development.

Assessment can be formative, when it happens during the course, or it can be summative, when it happens at the end of the course. Formative assessment helps

students to know whether they are on a right track or not, and it aids and motivates to improve activities during the course. Summative assessment is used to summarise what the student has learned. The summarisation can be a grade or it can be just passed or failed evaluation. In self-evaluation, student assesses his/her learning by him/herself, while in peer feedback, evaluation is done by other students. In addition, a group can evaluate together the group's learning.

Pickford and Brown [3] have identified several key questions for the evaluation process itself, when evaluating students learning and performance: 1) Why are we assessing? 2) What it is we are assessing? 3) How are we assessing? 4) Who is best placed to assess? 5) When should assessment take place? Pickford and Brown [3] also raise up challenges in assessment. Learning outcomes can be difficult to assess, if they are vague, over-ambiguous, expressed with complex terms, or inappropriate in terms of level, scope or extent.

Group work brings even more challenges to assessment because group's performance must be mapped into individual grades. When discussing about weights of different evaluation components, teacher is recommended to consider the following aspects [4]: i) What percentage of the student's total project grade will be based on the group's performance vs. individual components? ii) What percentage will be based on assessments of product vs. assessments of process? iii) How much weight will be given to peer evaluations or self-evaluations? iv) Will feedback from external customers also be incorporated into teachers' assessment of the group's work?

2 CAPSTONE PROJECT COURSE AT TUT

The project course has over 26 years' history [5]; [6]; [7]. From the very beginning in 1990s, project work topics from companies have been accepted. Some topics from university research projects (from different faculties) have been done occasionally. Non-profit organisations and individuals (e.g. researchers, hobbyists or entrepreneurs) could also have been customers. Previously students could also suggest their own project topics (for their personal use), but those are not accepted anymore as there should be an external customer.

Evaluation of projects in 1990s and early 2000s was based on project Demo meeting (Product Check), Final Presentation, documentation, inspections (a few documents and code), and weekly reports. At evaluation product's quality and usefulness to customer was considered, as well as the process quality (including deliverables in time). Customer's feedback was not systematically asked.

Learning goals of the course are: Implementation of a software project. Planning, tracking and executing of a project of several people, made to some customer. Professional contribution of own technical skills to the project. Controlled process of project work with quality activities. Teamwork with different roles. Technical documentation and reporting.

Actual project size varies depending on the technology and students' motivation. Sometimes students make over 250 personal working hours, which equals 10 ECTS.

TUT project course is aimed at Master's studies last year, and it has been respected very much among local ICT companies, and students themselves. Course's current process model is in Appendix A.

3 EVALUATION MODEL

3.1 Evaluation model

New evaluation model for Project Work on Pervasive Systems course in Tampere University of Technology (TUT) has been created, among other things, to improve the quality of grading. Grades achieved by students are based on points given in different parts of the evaluation. Total points can be varied from zero to 60. Student need to have at least 30 points to pass the course (see Table 1).

Table 1. Project work course grade/points table.

Points	0 – 29 p	30 – 36 p	37 – 42 p	43 – 48 p	49 – 54 p	55 – 60 p
Grade	0	1	2	3	4	5

Other drivers for new evaluation model were to improve fairness and professionalism. Evaluation model is divided to three different parts (see Table 2 and Appendix B). Each of those parts have several viewpoints how evaluation is established. **First and main part** is evaluation of **project implementation** and it is done by course staff. The evaluators need to use their intuitions and judgments to subjective evaluation criteria for different quality factors of the projects. Maximum points for this is 30. This part of evaluation has three viewpoints. **First**, end result of project is evaluated and key evaluated elements there are quality of implementation, usable user interface, quality of documentation and reasonable architecture. This evaluation is done based on common project practices and comparing different projects to each other. Quality of end product is carefully evaluated based on these criteria to ensure that the students' projects are rated fairly.

This part of evaluation is done as staff effort to achieve the objective of fair and accurate evaluations. **Secondly**, quality of work in project is evaluated and key evaluated elements there are implemented SW development framework, quality of work split and effort estimation in planning, risk management, established meetings, quality of delivered reports and product quality assurance activities and finally perfectness of delivery. Furthermore, project related presentations (mid and final presentations) are evaluated from quality point of view. **Thirdly**, project schedule related issues are evaluated and important deadlines there are delivery of Project Plan, Testing Plan, final product, bi-weekly reports and Final Report. Keeping schedule and acting accordingly for delays is one of key elements for any project. All these deliveries will left timestamp to course learning platform called Moodle with one exception on bi-weekly report, where timestamp will be found from e-mail system. In this part of evaluation points from all three viewpoints are added together.

Second part of the evaluation model is **customer feedback** for project and project team. Customer feedback is collected from customers by sending feedback request to customer's key contact person after one to two weeks actual project result has been delivered to customer. Usually one customer's key contact person give feedback to project, but if there are several of those average of given points are calculated. Maximum points for this is 15 points. Customer give points from three viewpoints, as well as give free written feedback. Those viewpoints are product itself, quality of delivered result and co-operation with the project team. **First**, customer is evaluating delivered product and key elements on that are implemented features, fulfillment of

requirements given by customer, layout and capability to develop it further as well as transformability. Customer evaluate these issues by evaluating and using the delivered product during couple of first weeks. **Secondly**, customer is evaluating quality of results, delivered product and related required documentation. Key elements in this evaluation are implemented functionality, logicity of implementation, easiness to maintain as well as quality and usefulness of related documentation. **Thirdly**, co-operation with project team is evaluated and key elements there are quality and level of communication, usefulness of meetings held, quality and timing of reporting as well as customer contact availability. Also, in this part of evaluation points from all three elements are added together.

Table 2. Project work course evaluation model.

Evaluation model	Viewpoints	Key elements in evaluation	Points
Project team implementation together (0-30p)	End result quality	Usability, architecture, documentation, implementation, user experience, etc.	0–10 p
	Quality of work	SW development process, work split, effort estimation, meetings, reports, planning, QA, etc.	0–10 p
	Schedule related	Keeping deadlines; plans, delivery, reports, meetings, etc.	0–10 p
Customer feedback for project results and team (0-15p)	End product itself	Features, requirements, layout, capability develop further, transformability, etc.	0–5 p
	End result quality	Functionality, logicity, easy to maintain, documentation, etc.	0–5 p
	Co-operation with team	Meetings, reporting, availability, communication, etc.	0–5 p
Individual level performance (0-15p)	Self-evaluation	Students make self-assessment themselves (performance, importance)	0–10 p
	Peer-evaluation	Giving peer feedback to other project team members (performance, importance)	
	Staff evaluation	Project course staff giving feedback for individuals (performance, professionalism)	0–5 p

Finally, third and last part of the evaluation model is evaluation of individual level performance of each project member (students). Maximum points for this is 15 points. Students are receiving points from three viewpoints, as well as some free-form written feedback. **First**, in the end of the project work course, called Final Meeting is established for every project. Last item on that meeting is self- and peer-evaluation. Every project member of the project team is filling a form, where they are giving

feedback (written and points) to every team member. Furthermore, they are giving feedback to themselves as points, how well they have performed during the project. Result from these evaluations is average points (0-10p) to all students. **Last viewpoint** of this evaluation model is individual level feedback given by course staff (project coach and other staff). Key elements in this evaluation are performance in course and specifically in project work and quality professionalism in SW engineering.

Two most important **evaluation events** for creation of presented project evaluation model are called “Final Meeting” and “grade meeting”. **Final Meeting** is established about one week after end of the project to evaluate one project at a time. Content of that two hours meeting consists of review of project, Final Report content and self- and peer-evaluations. Project is reviewed by going it through from early phase with help of a comprehensive checklist, project team creation, to its later phases delivery and final presentation. Main method used is discussion between project team members and course staff to review of key learnings, problems, realised risks and other key elements of the implemented project. **Grade meeting** is established when all information related to evaluation model (usually waiting for customer evaluation results) has been collected. In this meeting, course staff is doing final evaluations and discussions related evaluation model and grades. Best project is also selected based on evaluations and discussions and the best project team is rewarded by grant, which will be granted in some suitable conference or theme day established at the university.

3.2 Assessment of the evaluation model

Evaluation of the evaluation model is done by applying Pickford's and Brown's [3] key questions. **First question** (what) you need to answer is that is your theory and practice in balance. Students need to have knowledge to solve problems during the project. Our project course have several lectures in the beginning of the course, so that all related knowledge and information is available for students to use. Learning of theory is currently yet evaluated, but we are planning to improve process of evaluation to that direction as well. Our course content and process (see Appendix A) are presented to students in the beginning of the course. We also present key points for our evaluation model in that process. Furthermore, we go through all objectives for students in learning and project development point of view.

Second question (Why) is mostly related to motivation as well as giving and receiving feedback. Students are more motivated, when they know both course learning objectives and how their learning and achievements are evaluated. In project work course, we take care that all students have that information during the first lecture. Evaluation model and results from previous years are gone through with students. Motivation of students getting up during last two years and one reason for that can be seen in evaluation model and its visibility to students. Reflection of higher motivation can be seen in grades (Figure 1) and credits (Figure 2) during last two years. There in the pictures can be seen year 2012-2013 as a baseline. During years 2013-14, 2014-15 and 2015-16 grades scale 0 to 5 were not in use, evaluation results was only pass or fail (which was later considered very bad for students' motivation).

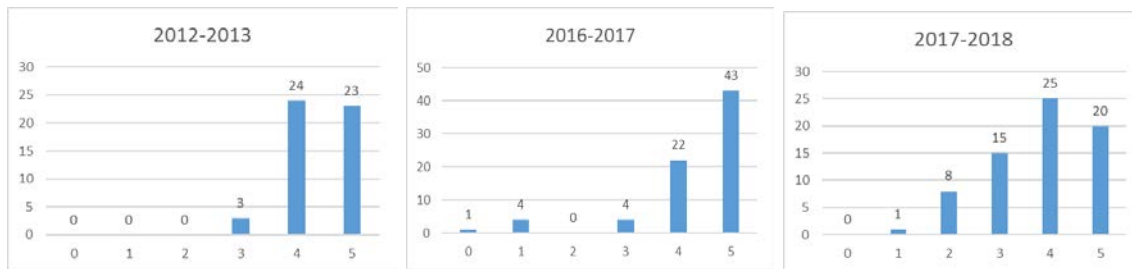


Fig. 1. Course grade distributions 2012-2013, 2016-2017 and 2017-2018.

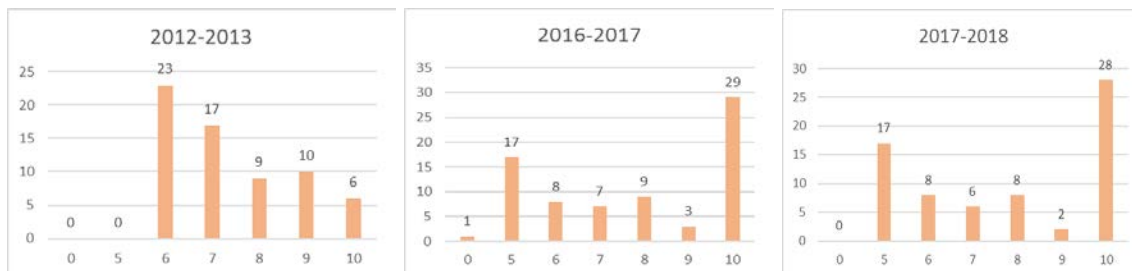


Fig. 2. Course credit unit distributions 2012-2013, 2016-2017 and 2017-2018.

Third (How) question is related to evaluation methods and how evaluation data is collected. In this course, also students know this process. Focus and weight is on course staff evaluation of result and process to get there. Last year customer feedback weight was increased as result of feedback from students. As projects are all customer projects, students think and staff think that also weight of customer feedback needs to be higher. To reward individual excellence and to get difference between students from performance point of view, individual part of evaluation data have also impact to given grade. One part of learning what needs to be improved is evaluation of theory of project work learned in this course. Of course, theory is used to solve problems in project and so been evaluated as part of project results and way of work.

Who should be part of an evaluation? As a summary of evaluation model, manner of an approach is to get evaluation data from all relevant stakeholders for this course. Those are course staff review data, customer feedback data, peer evaluation review data and self-evaluation results. Quite often end users can be seen stakeholders of course project as well, but also almost every time production usage of implemented product is not yet started before course is in the end. End users feedback can be and has been quite often collected as part of usability or other testing activity established during the project.

When evaluation should be then done? Best practice is to evaluate all learnings and doings during the course. In project work course focus is in the project itself, process and end-result. In this evaluation model, part of the evaluation data is collected during the project (e.g. schedule, documentation, communication, etc.). Also in the Final Meeting project will be evaluated from its early phases to the delivery of ready product. Other part of evaluation will be done in the end of the project, when e.g. end-result and Final Report can be analysed. Projects also need to present their doings and results in sprint reviews, mid-presentation and final presentation. Those are excellent opportunities for course staff and customer to analyse project achievements. Self and peer reviews are done in the end of Final Meeting after project has ended. Furthermore, customer feedback will be collected one or two weeks after delivery, so that customer has opportunity to use and analyse the product.

3.3 Conclusions and future improvement

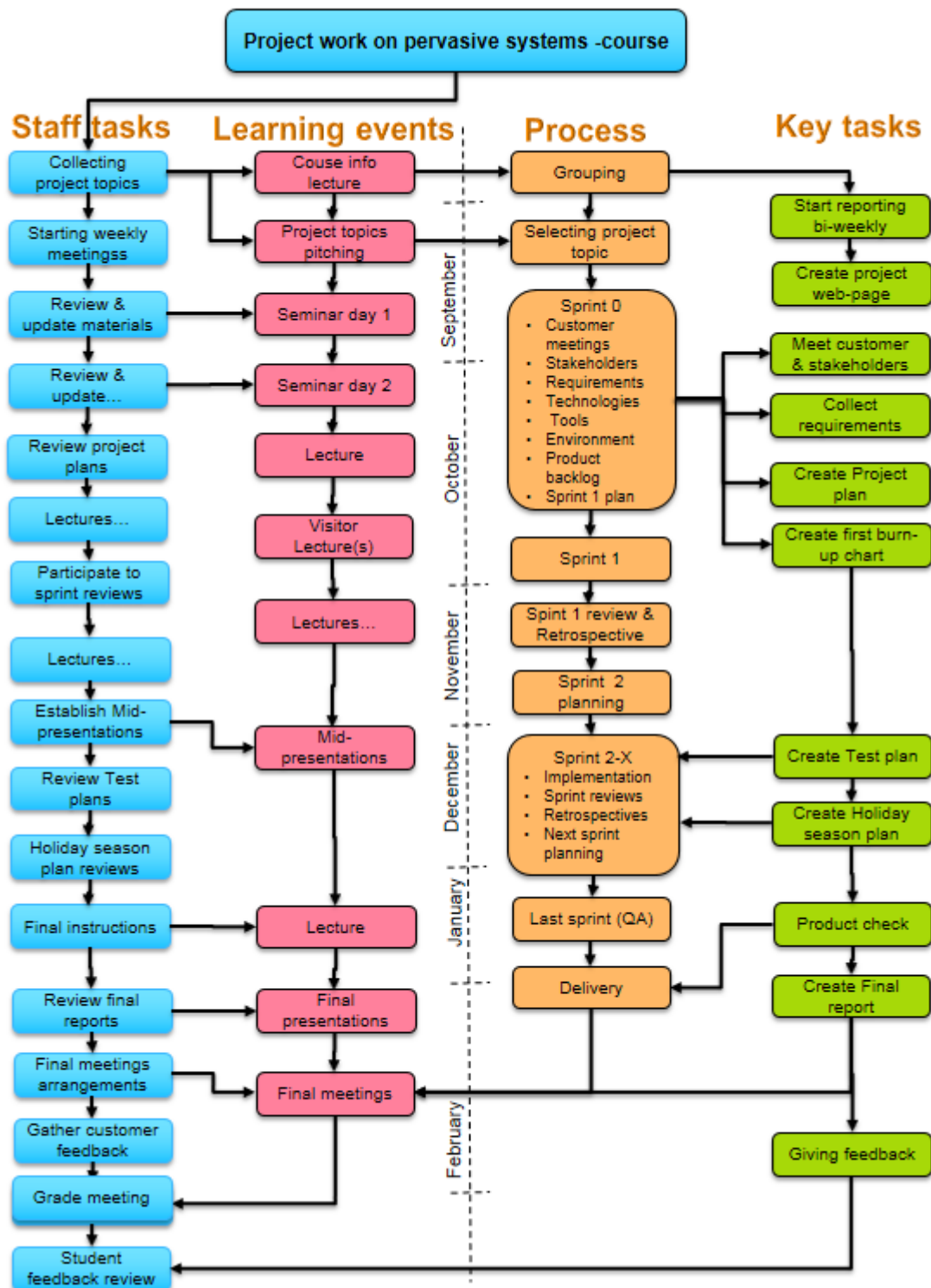
Evaluation model introduced in this paper gives wider view on evaluation of customer projects and how it is part of an university course evaluation. This model establishes one useful tool for that kind of evaluation based grading. Students have not complained about this model. Positive educational point is that it teaches also peer feedback and self-assessment to students.

However our model still leaves some room for improvements during coming years. To be really equal between all students, e.g. technology coefficient would be needed.

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Appendix A. Project course process at TUT.



Appendix B. Example of Project course evaluation matrix at TUT.

Student	Role	Team implementation together (0-30p)	Schedule (0-10p)	Process / Quality of work (0-10p)	Quality of end result (0-10p)	Customer feedback for project (0-15p)	End product itself (0-5p)	Quality of end product (0-5p)	Co-operation with the project	Individual performance (0-20p)	Comparative feedback (0-10p)	Coach / Other staff evaluation (0-5p)	Total points	Grade	Working hours	Credit points
XXX	PM	19	5	6	8	11	3	4	4	11,17	8,17	3	41,17	2	160,5	6
XXX	PO	19	5	6	8	11	3	4	4	14,67	9,67	5	44,67	3	230,0	9
XXX		19	5	6	8	11	3	4	4	10,33	7,33	3	40,33	2	149,5	6
XXX		19	5	6	8	11	3	4	4	12,17	8,17	4	42,17	2	151,0	6
XXX		19	5	6	8	11	3	4	4	12,50	8,50	4	42,50	3	183,0	7
XXX		19	5	6	8	11	3	4	4	13,17	9,17	4	43,17	3	202,0	8
Average		19	5	6	8	11	3	4	4	12,33	8,50	3,83	42,33	2,50	179,33	7
XXX	PM	26	9	8	9	14	4	5	5	12,17	8,17	4	52,17	4	145,0	5
XXX	PO	26	9	8	9	14	4	5	5	11,17	7,17	4	51,17	4	153,5	6
XXX	QA	26	9	8	9	14	4	5	5	14,83	9,83	5	54,83	5	181,0	7
XXX		26	9	8	9	14	4	5	5	12,33	8,33	4	52,33	4	178,5	7
XXX		26	9	8	9	14	4	5	5	14,00	9,00	5	54,00	4	151,0	6
XXX		26	9	8	9	14	4	5	5	11,00	7,00	4	51,00	4	136,0	5
Average		26	9	8	9	14	4	5	5	12,58	8,25	4,33333333	52,58	4,1666667	157,5	6

International Innovation as the context for engineering education

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Conference Key Areas: Ethics EE, Engineering Skills, Curriculum Development

Keywords: Innovation, Competencies, Humanities, International Collaboration

INTRODUCTION

1 GENERAL

There is a growing awareness within European education that learning, innovation skills is a requirement in order to prepare engineering students for their future career in developing creative and innovative technological solutions.

Some of innovation skills are: the ability to function in international teams (to which communication skill is key), the ability to interact with people from other cultures, and the ability to work in interdisciplinary teams. This paper describes a common innovation engineering project, developed for students from Technical University of Denmark (DTU Diplom), Denmark, and students from Fontys University of Applied Sciences, Eindhoven, The Netherlands. The collaboration of engineering students in such project is vital to their education, as it provides them with the international setting, very similar to what they will face when working on innovation development in companies. The goal of the project was to prepare engineering students to excel on their innovation skills. The aim of this paper is to present different aspects of how innovation skills are being developed, within the context of an international innovation engineering project. The following items are described in this paper:

- The Key Role of Humanities in Innovation Engineering.
- Required Competencies in Innovation Engineering.
- Best Didactics to Create a Learning Environment in Innovation Engineering.
- Setting and Main Findings on Current DTU-Fontys Innovation Engineering Project.
- Lessons Learnt and Future Developments.

2 THE KEY ROLE OF HUMANITIES IN INNOVATION ENGINEERING

2.1 Innovation concept

Different stakeholders have different perceptions of what an innovation is. For some, it is a process of finding a creative new idea. For others, it is a research for a market opportunity. It is paramount to have a common perception on what innovation is as in company processes, innovations are developed from a market pulling side as well as from a technology pushing side, but there are also several other aspects that influence the process.

Humanities as the Determining Factor

Innovations are made by people, to people who have needs and wishes. It sounds logical but often the role of Humanities, here understood as the study of how humanity processes the human experience (via arts, history, philosophy, language, etc.) [2], is neglected. Humanities is the driving force, the determining factor in innovation engineering as it explains the causes, motivations, needs, and wishes of people. Therefore, when properly studied, Humanities provides not only the background to an innovation, but it also enables innovative engineers to assess the ethical impact of their innovations in society.

3 REQUIRED COMPETENCES IN INNOVATION ENGINEERING

3.1 What competences and why?

A variety of competencies is required from an engineer in order to fully develop innovation. Creativity and awareness, for example, are known to be key driving competencies but have already been developed elsewhere, e.g. in literature e.g. in

literature [3,4]. For the purpose of this article, however, an exclusive set of competencies called the **i⁵**-competencies will be presented, see Fig 1, as the competencies an innovation engineer must have:

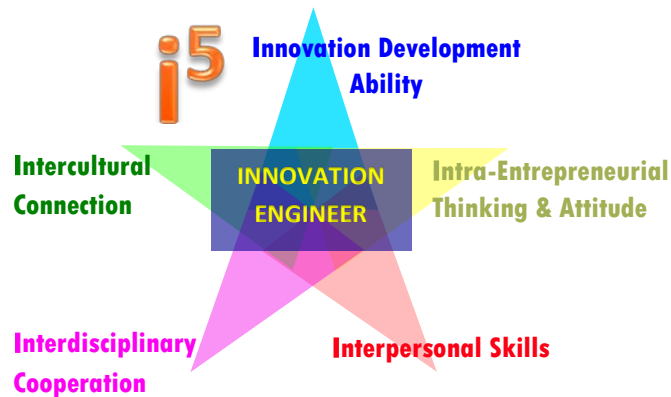


Fig. 1. Competences of an Innovation Engineer.

1. Think and Act i**ntra/entrepreneurially**: think independently, intuitively and in a consumer-friendly way. Take calculated risks, take responsibility, and foster a network in order to maximise corporate opportunities.
2. Develop i**nnovation**: incorporate different relevant aspects in the process of product and process innovation. The development of innovative products requires that engineers acquire basic knowledge on ethics, patents as well as appropriate methodological approaches on designing.
3. Cooperate i**nterdisciplinary**: cooperate with other disciplines. Face the opportunities and challenges of other disciplines, while recognising opportunities and challenges of one's own discipline, and effectively employing this mutual set of unique capabilities in teams. Modern technologies are also typically interdisciplinarily and involve the combination of knowledge and technologies from several fields.
4. Connect i**nter-culturally**: cooperate respectfully with different cultures, establish and maintain international contacts, and identify the relevance of the opportunities of several cultural environments in developing innovation. In an increasingly globalized world, engineers need international experiences to be able to communicate with customers and project partners all across the globe and to respect the cultural differences in order to maximise the possibilities of innovation.
5. Have i**nterpersonal skills**: To possess certain leadership capacities, to be able to set up discussions with peers, to analyse the best choice, to use convincing reasoning, to be able to be a chairperson in meetings, to use project management methodologies, and to be an efficient team player. Interpersonal skills include also advanced knowledge about ethics and communication within teams, whether in a company environment or in relation to customers.

4 LEARNING ENVIRONMENT IN INNOVATION ENGINEERING

4.1 The learning environment (Introduction to Project Collaboration DTU-Fontys)

The collaboration to develop an innovation engineering project for students from Technical University of Denmark (DTU Diplom) and Fontys University of Applied Sciences in Eindhoven was firstly effective in September 2017, but preparations were on the way around a year prior to that. The aim was to provide a learning environment in which, besides main stream engineering and technological knowledge, also international skills, communication skills, humanities overall knowledge, ethics, and cultural awareness were developed. Within the project, there was an ongoing effort to expose engineering students to challenges such as:

- Different professional cultures, as students in Mechanical Engineering and also from Marketing programs from Eindhoven work together with students in programs in Electronics and Software Engineering program from DTU.
- Different nationalities/cultures (Danish, Dutch, Brazilian and Polish)
- Communication only in English, as being non-native language for all students
- Differences in academic demands and calendars
- Working together as a team while maintain geographical distance
- Communication via email, phone and other electronic media

This is the setting which sharpens required skills to innovative engineers as engineering students are expected to develop themselves in unfamiliar areas. They are required to broaden their worldview and abilities, by embracing and acting upon a complete new set of circumstances. The place of curiosity, risk, mistake, cooperation, vulnerability and discovery becomes therefore paramount to the innovation engineering learning environment.

At the start, students were given information about the project. Teachers of Eindhoven and Denmark needed to find proper themes where each student of each discipline could use their different capabilities in a common project. Students had to find an invention that could lead to an interesting innovation for a company. However, Educational programs from Eindhoven and Copenhagen have different educational agendas, which became another pressing issue for the project. Thus, although project started in September 2017, only in October 2017 students from Copenhagen visited Eindhoven students. The three days visit, allowed for them to know each other and start growing into a real team. Following that visit, students worked on finding interesting inventions and, in collaboration with Marketing students, they investigated possibilities for their invention to become an innovation that could be marketable and, whereof, a business plan was set up. In January 2018, the Dutch students went to Copenhagen and together with their Danish counterparts presented their final results to the teaching staff of Copenhagen and Eindhoven. Students developed an inflatable compression stocking for people with circulatory problems. Usually, people with this difficulty need to wear elastic stockings, which are hard to put on, especially for elderly people, because it requires the help of

nurses to put on these stockings. An inflatable compression stocking does not require help from others and make a person more independent, this could be an interesting innovation for companies.

4.2 How to develop Key Competencies

There are different factors, described in literature, which help international and interdisciplinary teams to function [6,7 and 10]. They include various levels of technical expertise, motivation, social skills, but also cultural norms and expectations of team members. Teachers need to investigate and facilitate for students to understand a variety of cultural values in different countries, which is very important for teams to successfully accomplish their project. This facilitation includes, for example, the analysis of specific cultural behaviour of team members in terms of:

- the tradition of working individually or collectively in teams;
- leadership behaviours and patterns; norms for communication and interaction, direct or indirect communication;
- obstacles due to inadequate language or cultural skills.

The learning of competences cannot be obtained out of a book. Competences are complex structures of knowledge, skills, attitude and experiences. Students need to be given as real as possible environments in which they can experience what it means to act according to a certain competence. These real environments can be provided in different levels by applying appropriated mixed approach didactics. For this project, Copenhagen and Eindhoven educational programs employed different didactical approaches: a combination of lecturing, discussing groups and self-learning elements were used. However, an international innovation project-based context has been set as it provides the best conditions to learn engineering by experiencing it. Based on the five basic innovation competences mentioned in chapter 3, a realistic project was setup for students from DTU and Fontys. Students could experience the process of developing an innovation that can be used entrepreneurially, within a working context that was interdisciplinary and intercultural.

5 SETTING AND MAIN FINDINGS

5.1 Danish-Dutch Innovation Engineering Project Collaboration

Undergraduate engineering education, in many countries, has as one of the goals to prepare the engineering students to work with practical engineering tasks, improving company's products by innovations and even with technological inventions [5]. At the same time, many companies work globally and need engineers with abilities and skills to work in international teams, with engineers and technicians from other countries and cultures [6,7,8]. The industry in Europe and European Union supports international cooperation amongst universities in order to train students' skills to work in multicultural and interdisciplinary teams. Combining innovation based projects with international teamwork, significantly contributes to develop students' skills [9,10] in areas which also include communication skills in English, for example. These were

the main reasons for us to start our cooperation, the cooperation between DTU and Fontys, with the common project: International Collaborative Innovation Project. A student who has met the objectives of this common course/project will be able to:

- Function effectively in multidisciplinary teams;
- Perform with successful project planning;
- Take a project from design requirements to final working proof of concept;
- Synthesize, integrate and apply technical engineering course content to a real-world engineering project;
- Apply creativity in the design of systems, components, or processes;
- Ability to assess how Invention adds value to society by understanding people-planet-profit aspects.
- Communicate effectively in a multicultural, multidisciplinary way.
- Interact with and collaborate on a joint project with students from a different culture/nationality.

Overall content of course/project is: Project Management and Ethics; International/Intercultural and Interdisciplinary Teamwork; Planning, Designing and Implementing Technical Engineering Knowledge to a real-world engineering project, and Verbal and Written Communication with team members from other cultures and nationalities.

5.2 Main findings: Students Account on Innovation Engineering Project

The cooperation between DTU and Fontys run for the first time in fall semester 2017, and after 6 weeks of work (during the DTU students visit to Fontys Eindhoven) a survey was conducted in order to uncover students overall perceptions. Main findings are listed in Table 1:

Question	Students' answer
What are the most positive aspects you have experienced, up to now from the common project?	<p>We've got a bigger picture/knowledge on:</p> <ul style="list-style-type: none"> • International engineering and education • Other country's culture • Contacts with students from abroad • How to cooperate from a distance • Differences in teaching and programs at other universities • Interdisciplinary problems and challenges • How to deal with real-world engineering tasks/problems • That marketing is an important part of engineering projects • That communication with all team members is very important
What are the most negative experiences you have from the project?	<ul style="list-style-type: none"> • Time schedule must be decided very early • Difficulties to communicate because of misunderstanding of professional communicating language and English • Lack of personal contact, face-to-face meeting has to be solved at the very beginning of the project • It was difficult to find the proper idea for common project
What is needed for successful	<ul style="list-style-type: none"> • Finding the proper interdisciplinary project to work on • Making a time schedule and plan for the project early in the

cooperation and project work?	<ul style="list-style-type: none"> process for students in DK and NL with exact same requirements • Project which motivates both groups of students (mechanical and electronics/software) to work efficiently • Money to have the possibility to buy materials necessary to develop the product • Manual and/or template given by supervisors for project plan and schedule
Is there any cultural obstacle you experienced?	<ul style="list-style-type: none"> • Dutch students work more directly, and want, from the beginning, to decide specific tasks • Danish students want to investigate all possibilities and discuss all students' wishes • Different expectations, especially in the beginning, according to which day to communicate (differences in week schedule and other courses) and how often we should have Skype-meetings
What can be done better to plan visits?	<ul style="list-style-type: none"> • Coordination and whole plan of the visit in NL. It should be students' task and approved afterwards by supervisors/teachers

Table. 1. Questions and answers of students on their experience of the project.

6 CONCLUSION: LESSONS LEARNT AND FUTURE DEVELOPMENTS

6.1 Usefulness for Society, Students and Companies

It has been highlighted at the first edition of the innovation engineering collaboration project that society and companies must and can play a bigger role in the project. Nonetheless, students were consumed by the intense demand the project set upon them and, for that, perhaps they were unable to fully develop the experience the project aims to provide them with. For the coming years, efforts will be put not only so that society and companies have a bigger saying, but also that they equally benefit from the project as main stakeholders. Concerning students, it has been learnt that regarding to team work, there has to be a better understanding of each other's cultural behaviour, which directly affects communication amongst team members. These two areas require further improvements.

6.2 Required Improvements on Project execution Approach

Students have pointed out that, at least, two face-to-face meetings (part of a visit to each other's universities), followed by a social gathering (for example a dinner), are very interesting to bind teams together and to better understand each other's cultures. Perhaps, another possibility is the development of a template with which students can set up a communication plan. Cards on which basic rules of communication will be written can possibly be adopted in order to support students to develop in an effective manner. For most of the students, the international project was the first time they encountered what it means to execute an internationally co-operation project. Although students were given enough information to start up their project, they were not fully capable to organize a smooth collaboration process. Cultural differences and differences in the timetables of each university were causing delay in schedules. In addition, it was seen that students were not using meetings in a professional way. This implies that it is important that universities help students to

start up their collaboration, by giving helpful templates and instructions. Lastly, it was observed that meeting personally, at the beginning of the project, adds tremendous value to the entire process.

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The interactive whiteboard supports joint focus in collaborative learning

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Conference Key Areas: innovative teaching and learning method, how learning spaces support innovative teaching & learning, the teacher as a supervisor

Keywords: innovative learning space, collaborative learning, student perspective, student activity, interactive whiteboard

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INTRODUCTION

The interactive whiteboard (IWB) has been an important educational tool at our institution for a long time, and since 2010, an innovative learning space consisting of group stations with IWBs, suited for collaborative learning has been available [1]. In the present paper, the term collaborative learning describes a specific kind of group work, in which students actively work together on the same task, where the intention is for the students to learn together [2]. The potential of collaborative learning is explored extensively in the literature [3] [4].

Throughout two terms of fall 2016 and spring 2017, students at a preparatory physics course for engineering education attended weekly collaborative learning sessions in an innovative learning space. The intention was to use the IWB as a joint focus for both the students and the teachers, thus facilitating a collaborative learning process. One study has indicated three ways in which the IWB may facilitate collaborative learning processes in physics: Exploratory processes, characterised by collaborative brainstorming and sketching on the IWB; Explanatory processes, where one student takes on a teacher's role towards the rest of the group, using the IWB; and Clarifying processes, which were characterised by inquiries or clarifying questions to what had been written on the IWB [5]. The same study also indicated a fourth work process, which did not facilitate collaborative learning: Insertion, which was characterised by one student inserting a solution on the IWB already sketched on paper, while the rest of the group either sat quietly observing or were busy working individually. In the present study, a paperless work procedure was introduced, with the intention of minimising this latter work process, i.e., to have the students work as a group and not just *in* a group.

Although collaborative learning represents a student-centred learning context, the involvement of the teacher(s) plays a crucial role in the success of the students' learning process and their learning outcome [6]. This calls for careful considerations regarding the intention of the group work, the design of the group work and the tasks that are to be solved, the assessment of the group work process and product (i.e. solutions). The teacher also needs to consider how to provide support and guidance during the group work. Regarding the latter point, the success of teacher interventions depends on the teacher's ability to adapt his or her feedback to the students [7], which furthermore depends on the teacher's insight into the students' needs [8]. In this case, the IWB may facilitate easy insight, due to its sheer size.

In this paper, we present results from focus group interviews with students participating in these collaborative learning sessions. The results reflect the students' perspective, concerning the role of the IWB, how the IWB may affect the collaborative learning process, and the teachers' role as perceived by the students.

1 BACKGROUND

1.1 The preparatory physics course for prospective engineering students

In the preparatory physics course, the description of learning outcomes states the importance of carrying out experiments, doing measurements and interpret the results. Another aspect is the importance of oral skills, stated as: "*The candidate can communicate with others about natural science issues using physical concepts and sizes*" [9]. In traditional classroom teaching the learning outcomes mentioned above have been an important part of the course. However, to extend and develop the student activity even further, new innovative teaching and learning methods were

introduced. An important part of the changes was an extensive use of collaborative learning.

In this context, it was crucial to increase the “teacher density”, i.e. double the amount of supervisors present when the students were active and needed feedback. This was done without adding extra resources, but through a change of how the classes and the course were organized. Instead of giving two student groups, at approximately 45 students each separate lectures, they received joint lectures from one of the two teachers, followed by separate student-active learning sessions where both teachers were present. Each week the students had two lectures that were followed by student-active sessions. One of these sessions was held in the innovative learning space, which is the focus of this paper. Participation in these sessions was voluntary.

As a consequence of the structural and pedagogical changes that were introduced, it was natural for the teachers to work collaboratively. This collaboration included not only the planning of the time schedule, but also the planning of the active learning sessions and the lectures. The teachers together reflected upon the design of the activities, how they were perceived, and to what degree the intended learning outcome was realised. Through this collaboration, new innovative teaching and learning methods were developed throughout the year.

1.2 The innovative learning space

The innovative learning space consists of group stations, each equipped with an IWB that supports electronic data logging, typing and handwriting. This makes it easy to write formulas and do calculations similar to how one would do it on paper or on an whiteboard, but with the possibility of saving it. Sound reducing curtains form separated work stations for up to four students, see *Fig. 1*, where the innovative learning space is shown with and without use of the curtains.



Fig. 1. The innovative learning space with and without curtains around the group stations.

1.3 Collaborative and active learning

The lecture and the subsequent session in the innovative learning space dealt with the same physics topic. The constellations of the groups were decided by the teachers, and were changed frequently. Two teachers were supervising and facilitating discussions within the groups.

The regular working routine in the innovative learning space consisted of the students: logging into the pc at the work station, downloading the file of the day from the learning management system, and performing the tasks. At the end of the

session, the file was uploaded in order to be shared with the teachers and the group. The tasks were written in the same software as used in the lectures.

On the IWB, the students read the task, monitored the experiments, calculated, and wrote their comments and results. This lead up to the IWB as a joint focus for the group and made it possible for the students and the teachers to work completely paperless. During sessions, the only “papers” present were textbooks and formulas. *Fig. 2* shows examples from these student-active learning situations.



Fig. 2. Students working in the innovative learning space.

2 DESIGN OF TASKS FOR THE INTERACTIVE WHITEBOARD

Through the design of the tasks, it is possible to facilitate use of the IWB as a joint focus for collaborative learning. Every session included practical exercises and measurements of physical quantities, which were mostly done by use of sensors and a data logging software. The experimental graphs and results were copied into the file and subsequently discussed, or calculations were done based on the measured values.

An example of how a practical task may look like is shown in *Fig. 3*, where Newtons first law is explored in two-dimensions by decomposition of three forces pointing in various directions. The picture to the left in *Fig. 3*, shows a page in the downloaded file, while the picture to the right shows the uploaded file. In this task, a photo is inserted to illustrate how the practical exercise should be done. In addition, short itemized sentences explain the idea. The group has copied a segment from the data logging software and done further calculation on the measured values in order to accomplish this task. The results are written by hand into the file.



Fig. 3. A task before and after the students have answered using the interactive white board.

Another way of facilitating for use of the IWB is shown in *Fig. 4*. Here an ordinary textbook exercise has been modified into an IWB version. The task has been rewritten from “What is the spring constant?” to the more open question “Investigate whether the spring obey Hooke’s law. If so, estimate the spring constant”. The more open questions are intended to induce discussions of concepts, instead of merely calculating answers.

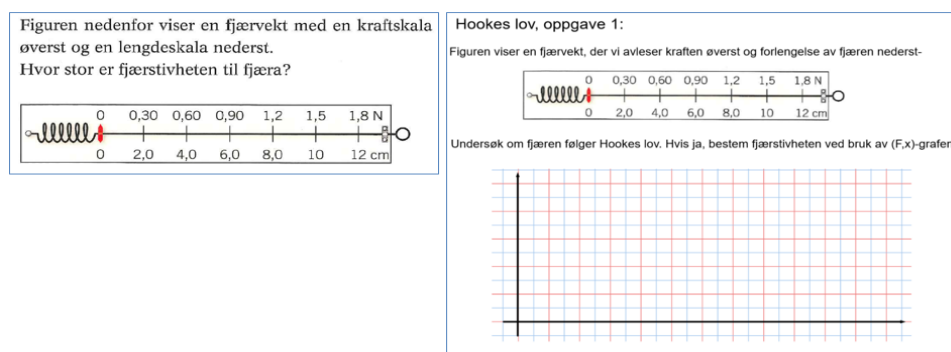


Fig. 4. A textbook exercise to the left changed into an interactive white board version to the right.

The reason for the changes done was to prevent the students from solving the task individually in their own notebooks instead of together as a group. By preparing ready-made graphical backgrounds, tables etc. in the task files, the intention was to make it more attractive for the students to use the IWB instead of paper.

Furthermore, open spaces are left in the files making room for the students to write their answers. In *Fig. 4* for example a system of coordinates has been prepared, in order to provide an effective learning session, where the focus is on the physical problems and concepts, not on technical details.

3 THE STUDENTS' PERSPECTIVE

Data was collected through three focus group interviews with some of the participating students, towards the end of the last term (two male student groups and one female student group, in total ten students). The students were interviewed about their perceptions and experiences with the sessions in the innovative learning space with an emphasis on the following themes: the IWB, the group work process, and the teachers' role. An independent researcher conducted the interviews, which each lasted between 70 and 100 minutes. The transcribed interviews have been read by all authors through several iterations, in order to obtain a consistent impression on the themes described above. Overall, the students perceive the learning sessions as valuable, albeit for different reasons. Some students emphasise the importance of practical tasks, while others put emphasis on the conceptual problems. Most of the students seem to appreciate the collaborative aspect of the learning sessions.

3.1 The interactive whiteboard

From the teachers' perspective, the intention with the IWB was to facilitate a joint focus for the students, thus contributing to collaborative learning. The students very much seem to have recognised and appreciated this:

Male1Group1: Everything takes place on the board, the board is crucial. It is somehow the whole point of being there.

Female1: You look at the same thing, you are working together. Remove it, and you only have a regular group room with students who work on their own task. [...] it makes people work together.

Male1Group2: [...] everyone is paying attention to what is happening on the board, nobody is sitting at the corner of the table and calculating on their own. It «sticks» the group together.

Male2Group1: [...] the big board helps to see what is going on. Yeah, and that everyone sees it. We do everything together.

All student groups mention experiences with technical difficulties writing on the IWBs. However, while this has been a cause for some frustration, the students seem to have gotten accustomed to these difficulties.

3.2 Group work process

The students seem to perceive the IWB as an important part of the group work, due to its affordance as an area of joint focus. As we see it, this has some positive effects on the students' group work process. Several students mention that the group-work situation makes them endure difficult physics problems longer, compared to situations where they work alone:

Male2Group1: If you meet a problem at home, it's easy to give up and do something else. The threshold is a little higher when you are here and can get help from the teacher or other students.

The main point of working collaboratively is to learn together, which is also reflected in the students' perspectives on the group-work situation. A key aspect here is an emphasis on conceptual problems, rather than mere calculations:

Male2Group1: [It] can be easier to understand when someone at your level talks about it rather than the teacher. Also if you sit there and do not understand something, there are three "teachers" who can teach you in three different ways.

Female1: [...] you learn so much by explaining to others what you have understood, and to get an input on what you have not understood yourself. So you get a complete picture, as long as everyone participates.

When it comes to solving problems on the IWB, all student groups mention the role of the student who is doing the actual writing on the IWB, albeit with various emphasis. On some occasions, this student is taking on a teacher's role, guiding the rest of the group through the problem solving. Opposite examples are also mentioned, where the group tries to guide the student writing on the IWB. If the student writing is somewhat informed about both the problem and elements of its solution, taking the role as a "secretary" is not seen as problematic. On the contrary, if everyone in a group is on the same level, this situation can cause fruitful discussions among the students. However, in the case where the student writing

feels uncertain or unknowledgeable about the problem altogether, the “secretary” role is seen as quite uncomfortable and not very fruitful for neither party in the group.

3.3 The teachers’ role

The students value the presence of two teachers, simply because it makes the teacher resource more accessible. The IWB plays a role with regard to teacher interventions, in the sense that the students’ solutions are immediately available. For the teachers, this availability helps providing concise feedback. The students seem to value the teachers’ approach when it comes to teacher interventions:

Male2Group1: [The teachers] are becoming a bit like a supervisor. When we ask for help, they do not only tell us how to do it, but say how we must think.

Female3: They spend more time with us in the innovative learning space [...] [Here] they have to sit down and ask themselves: “Why don’t they understand this?” [...] They use more time on each of us and I think they have started to see what people know [...] They are very good at remembering names [...] and have started picking up on how people work and how to approach them.

4 DISCUSSION AND CONCLUSION

The intention of the sessions was to increase the student activity, where the IWB was a tool to facilitate effective collaborative learning, supported by the design of the tasks and the paperless work procedure. Experiences expressed by the students support the notion that this intention was realised. The IWB’s affordance as a joint focus for every participant in the student groups seems to yield some positive effects with regard to how the students structure their work process.

When the students referred to writing on the IWB they used the terms “teacher” or “secretary”. According to the students, the description of the “teacher” role is consistent with the explanatory, exploratory, and clarifying work processes, described in [5]. The “secretary” role may entail acting as a facilitator for the group, or mere dictation, where the student writing is not taking part in the problem solving. However, with reference to [5], none of the students expressed experiences consistent with the work process termed insertion. This is also in accordance with the observations by the supervising teachers.

Furthermore, the students appreciated the role of the teachers as supervisors and the importance of immediate feedback. This depended on “teacher density”, i.e. their presence and availability, and the precision with which they met the students’ needs. From the teachers’ perspective, the fact that they were two meant that they could provide effective supervision. Furthermore, because the students’ work was immediately available on the IWB, they were able to provide concise feedback, addressed to the entire group, as opposed to individual students.

The challenges expressed by the students mainly concerned the actual writing on the IWB. Even though the students expressed awareness of the learning outcome associated with acting as a “teacher” or “facilitator” in front of the others, they often found this position challenging, and even daunting, this was emphasised by the female students. This represents an aspect of the collaborative learning situation which will be subject to careful consideration in the future, given that the aim is to further realise the potential of collaborative learning.

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Wind Energy Master

A fully online part-time programme

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Conference Key Areas: Continuing EE and Lifelong Learning, Open and Online EE, Sustainable Development Goals in EE

Keywords: Online, E-learning, continuing education, Master's programme

INTRODUCTION

The need for continuing education is growing in our society as the work force has become more mobile and learning is a life-long process. Plans for new wind power installations around the world are extremely ambitious for the coming decades [1-2] and this creates an immediate demand for skilled engineers with specialized knowledge [3]. The demand may partly be addressed through an increase of life-long learning opportunities and a greater variety of study modes like part-time, distance, and modular learning [4]. Higher education is entering a new era where practical skills and contact to the rapidly evolving labor market may be valued as much as traditional rankings and accreditation [5]. Online competency-based education has an enormous disruptive potential in this context.

Enrollment fees for traditional university programmes are soaring in countries like the US and UK and a new market for Massive Open Online Courses (MOOC) clearly reflects this. The Technical University of Denmark (DTU) offers a successful MOOC called 'Wind Energy', which has been completed by more than 2.000 learners so far. Analytics from the MOOC show that approximately 50% of the learners are already employed in a full-time job. This is an indicator of the market for online continuing education in the field of wind energy and has been a great motivation for establishing a full online Master's programme about wind energy engineering at DTU.

The purpose of this paper is to outline a concept for an online part-time programme, which is currently used for education in wind energy and holds a potential for application within other engineering disciplines. Similarities and differences are examined between *i)* the online teaching and learning experience as opposed to education in a physical setting, and *ii)* a part-time programme for continuing education

as opposed to full-time university programmes. The question is: *Can an online Master's programme for continuing education be used to build up capacity within engineering disciplines?*

1 ABOUT THE WIND ENERGY MASTER

[Wind Energy Master](#) is a new part-time programme executed fully online. The programme is designed for continuing education. Regulations by the Danish Ministry of Higher Education and Science state the overall framework. Requirements for access include a bachelor's degree or higher and at least two years of relevant working experience. The programme workload is equivalent to 60 ECTS and it can be spread over several years. Completion of the programme leads to a Master's degree, which is not to be confused with a M.Sc. A full M.Sc. degree would require a work load of 120 ECTS and this may be unrealistic in the context of continuing education.

The target group for the Wind Energy Master is truly global as reflected in the first year's intake of 47 participants from the wind energy industry and related fields all over the world (*Fig. 1*). Of these participants, 75% are located outside Denmark. Around half of the participants hold a M.Sc. degree and the other half a B.Sc. as their highest degree. Two participants hold a Ph.D. degree. The programme was launched for the first time on September 4th 2017.

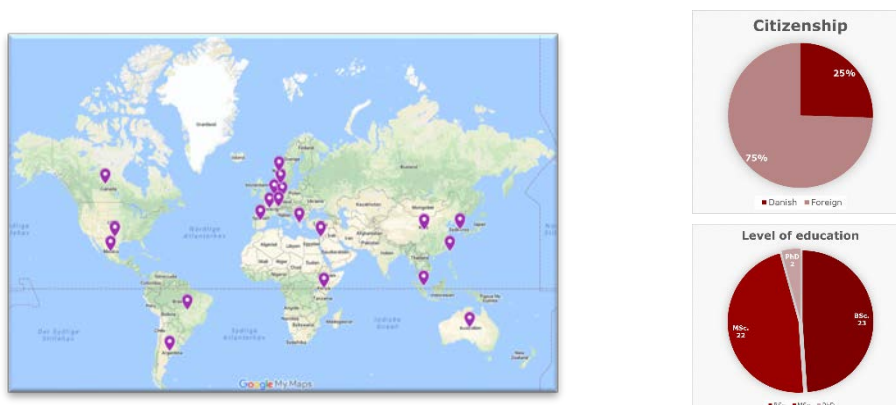


Fig. 1. Left: Current participant's country of residence (map courtesy Google My Maps). Right: Distributions of participant's citizenship and level of education.

The Wind Energy Master aims to give a broad overview of wind power generation from planning and economics to design of wind turbines. Mapping of industry requirements has revealed that some employees in the wind energy industry lack insight in the consequences of decisions they make for other parts of the production chain and ultimately for the company's economy.

The Department of Wind Energy at DTU holds a vast experience in continuing education and E-learning. The Department has offered training courses for the wind energy industry for decades and since 2011, some of these courses are available online [1-3]. The overarching idea is to offer fully flexible supervised courses, which are easily followed by employees in the industry in parallel with a busy working schedule. The expected long-term outcome is a production of up to 100 DTU Master's of Wind Energy per year who will fulfil their current position better or find new employment in the global wind energy industry.

2 TEACHING METHODS

2.1 Overall choice of teaching methods

Flexible learning is the overall teaching method chosen for this Master's programme because it allows participants to study anytime and anywhere. The first intake reveals that participants in the programme come with very different backgrounds and qualifications. The flexible learning method together with the use of the most sophisticated E-learning tools allows us to differentiate the learning process.

The individual courses take advantage of a number of additional teaching methods. Learning by inquiry is used through virtual poster presentations and participant's production of short movies about central course topics. Spiral learning is utilized e.g. for the development of a computer code for turbine blade design where new aspects are introduced gradually throughout the course.

2.2 Pedagogical model

The five-stage scaffolding model for teaching and learning online [9] is the foundation for the design of this Master's programme as well as individual courses. The model states the importance of building a 'safe' and encouraging learning environment online where the teacher takes a facilitating role. As participants advance up the five-stage scaffold, they will gradually become more and more independent and responsible for their own learning process (*Fig. 2*). In the following, we sketch out our implementation of the model in practice.

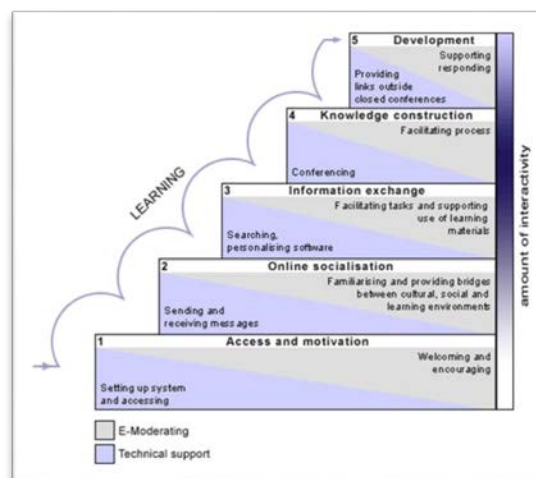


Fig. 2. The five-stage scaffolding model for teaching and learning online. From Salmon, G. (2011): E-moderating. The key to teaching and learning online. 3rd Ed. Routledge: London and New York.

The Wind Energy Master begins with a one-week 'onboarding' module where participants obtain access to the learning management system (LMS) and university resources such as intranet, library resources, and software licenses. They write a biography, upload a photo and share a few words about their background and motivation in the discussion forum of the course. The Head of Studies greets each participant individually and hosts a live welcome webinar. By the end of the onboarding week, everybody has met each other and any technical issues have been resolved. Participants can now shift their focus entirely to the learning content.

The programme consists of nine independent courses and a final project. The courses are structured into weekly modules with a wide range of learning elements such as short and focused video lectures, practise quizzes, calculation exercises, written assignments, and discussion with teachers and peers. Later in the programme, participants work on a small project, which leads up to the final project. The project work requires higher-level skills and ensures progression throughout the programme.

2.3 Assessment methods

Assessment methods vary from course to course in this Master's programme, in accordance with the rules and regulations about university exams in Denmark. For some courses, summative assessment is carried out through submission of one or more written assignments to be evaluated by the teachers. Other courses use quiz exams with automatic correction. The quiz exams must be taken by all participants on the same date within a time window of typically 2 hours. Questions and answer options are shuffled to prevent cheating. Several courses end with an online oral exam through the meeting platform Adobe Connect. During the exam, participants must demonstrate that they are alone in a room and present a proof of identity. They are then questioned in the same manner as during an oral exam on campus. A censor takes part in selected exams and careful testing of the technical setup is performed in advance to prevent any difficulties during the examination. Defence of the final project takes place on campus and this is the only time participants are required to travel to DTU.

2.4 Teaching technology

The online programme is taught through the LMS called Brightspace, which is integrated with student and course administrative systems at DTU. The system is the single point of access for all course content. We put a major effort into alignment between courses when it comes to the LMS setup. This helps participants to navigate in the learning material. Teachers use a range of tools and technologies to produce the learning content. To mention a few, video lectures are produced in a dedicated studio, or on the teacher's own PC using a screencasting tool. Quizzes and assignments are setup in the LMS, which contains functionalities for teachers to give feedback and to monitor the participant's progress. Some teachers use a tablet to draw and explain content.

2.5 Interaction amongst teachers and participants

Teacher-participant and participant-participant interaction is the key to a high completion rate and a deeper learning throughout the Master's courses. Asynchronous communication takes place through topical discussion forums and e-mails. Synchronous communication takes place via the chat function in the LMS and through weekly live sessions where participants get the opportunity to ask questions directly to the teachers, or give their own presentations of key learning points. Since the participants are distributed all around the world, a morning and an afternoon version of each live session is offered and participants have the opportunity to view recordings of the sessions afterwards. Altogether, the team of teachers strive to offer a fully flexible programme where interaction can occur anytime and anywhere.

3 COLLECTION AND ANALYSIS OF EVIDENCE

Surveys are carried out each semester to gather data about the participant's learning experience and outcome. At the programme level, a survey addresses the online

learning experience and the programme as such. At the course level, DTU's procedure for quality assessment is followed where an evaluation form is completed by the end of each course. Once the evaluation forms are gathered and analysed, they are reviewed by the Department Study Board and results are published. All surveys include a space for free-text comments so participants can write specific comments to be considered by the teaching staff. Results presented in the following are based on the evaluation forms gathered from the first cohort of participants during the autumn 2017.

4 RESULTS

4.1 Programme level

Fig. 3 shows examples of participant's feedback at the programme level. The feedback shows very clearly that participants find the onboarding week valuable as 92% agree to this. The result is very motivating for continuing or even expanding the onboarding activities in the future. When it comes to the level of flexibility offered by the Master's programme, 65% are satisfied. Free-text comments reflect that some participants feel restricted from attending the live sessions due to their responsibilities at work. Typically, only a fraction of participants attend these optional sessions.

A vast majority of 86% find that the online learning experience is fruitful as compared to learning in a physical setting. This result is very encouraging, not only for this programme, but for the use of a similar concept for development of other educational programmes in the context of engineering. It is supported by the fact that 96% of all participants would recommend the Master's programme to others.

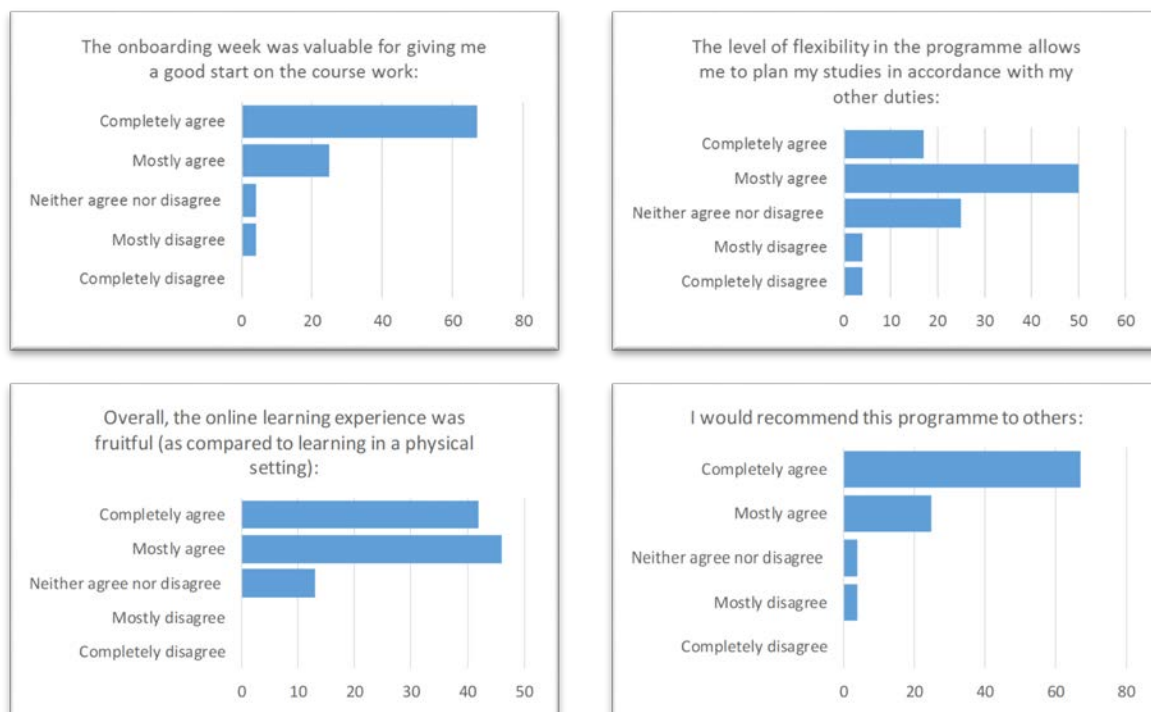


Fig. 3. Examples of participant's feedback at the programme level. The plots are based on survey responses from 23 participants during the autumn 2017.

4.2 Course level

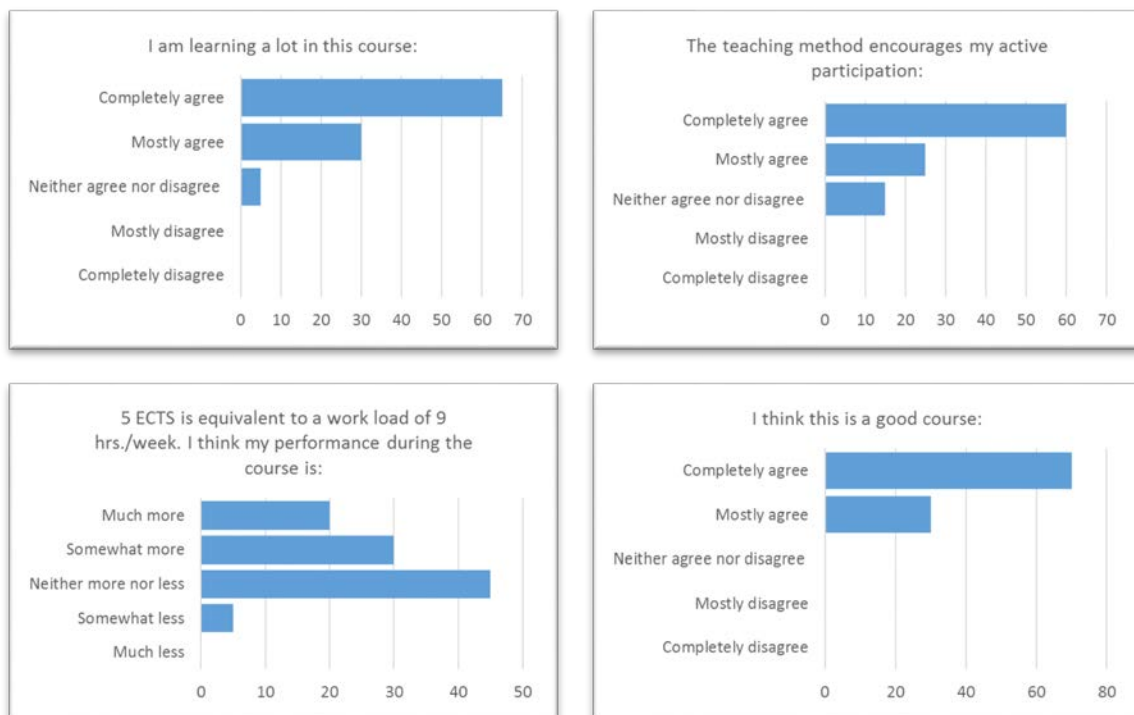


Fig. 4. Examples of participant's feedback for the course 'Materials in Wind Energy'. The plots are based on survey responses from 20 participants who followed the course during the autumn 2017.

Fig. 4 shows examples of participant's feedback at the course level by the end of the course 'Materials in Wind Energy'. Of the 20 course participants, 19 persons or 95%, agree that they are learning a lot in the course and 85% agree that their active participation is encouraged. All 20 participants agree that the course is good.

When it comes to the participant's workload, 50% state they have spent more than the estimated nine hours per week on the course work whereas only one person has spent less. This reflects the challenge of meeting the diverse group of participants at the right level of difficulty. Free-text comments show that programming has been a challenge for some and they may have spent extra time on learning to program in addition to the actual course work.

5 ONLINE EDUCATION VS. A PHYSICAL SETTING

We have presented a few key evaluation results from the online Master's programme in wind energy. The full evaluation surveys hold further details about the participant's perception of the programme and each individual course. We will base our final remarks on all the evidence gathered during the first year.

The concept for an online Master's programme presented here embraces a wide range of learning activities and assessment forms most of which require active participation. For example, participants may be asked to complete a quiz or write reflections in a discussion forum by the end of individual video lectures. The continuous engagement of participants ensures achievement of the learning objectives and contributes to

constructive alignment and a deep approach to learning. All of this is challenging in a traditional physical setting such as a lecture room.

Structuring of the learning content within a LMS makes the online learning process transparent and easy to follow. Participants are always aware of their own progress and teachers are, too. The teacher's supervision can thus be directed towards the participants who need it the most. For instance, participants who are a bit behind with exercises or assignments receive an encouraging message from the teacher. The high level of transparency represents another strength of online education compared to teaching and learning in a physical setting.

Establishment of a personal connection between teachers and participants is essential for the success of this programme in contrast to large-scale unsupervised online courses such as MOOCs. The teacher's online availability on a daily basis and the personal feedback on assignments give a personal touch and feeling, which is almost equivalent to meeting each other in person. The personal connection is of course also dependent on the participant's willingness to reach out for the resources at their disposal. Experiences from the Master's courses show that some participants are eager to contribute to written and oral discussions online whereas others hesitate. Active participants are bound to get the most out of the courses.

6 CONTINUING EDUCATION VS. FULL-TIME UNIVERSITY PROGRAMMES

Flexibility is an important strength of this part-time programme with respect to university programmes on campus with much more rigid time schedules. We can reach participants all over the world; and individual participants can study when and where they want. With the flexible teaching style comes a large degree of responsibility for one's own learning. Most participants live up to this challenge but a few cannot find the time to fit studies into their daily routines and drop out.

The biggest challenge when it comes to this part-time Master's programme is to match the very diverse backgrounds and levels of knowledge of the participants in the programme. A way to address the issue in the future could be to differentiate the learning activities so participants get challenged with different problems depending on their level of background knowledge. The positive side of the participant diversity is that there is a large potential for integrating real-life problems and examples in the teaching based on participant's inputs. This brings the teaching closer to reality and to the immediate needs of the wind energy industry.

7 CONCLUSIONS

Early findings from the first semester of a new online part-time Wind Energy Master show that online teaching can be powerful for engaging participants in courses and for achieving a deep approach to learning. Evaluations by participants at the programme and course level show positive results and indicate that learning objectives can be achieved and new engineering disciplines mastered from a distance. The concept presented here could easily be applied in connection with other engineering disciplines, as it is independent on the field of teaching. Findings and experiences from the first year of teaching the programme are promising for growing continuing education online and for achieving life-long learning objectives all over the world for the benefit of society.

8 ACKNOWLEDGEMENTS

Teachers and participants in the 'Wind Energy Master' are acknowledged for their contributions to establishing the data set analysed here.

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The STEAM Camp

Introducing Sustainable Development Goals in K-12

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Conference Key Areas: Curriculum Development, Sustainable Development Goals in Engineering Education, Innovative Teaching and Learning

Keywords: STEAM, Project-Based Learning, Teacher Professional Development

INTRODUCTION

Although MIT's main focus is college level education, both at the administration and at the faculty level there is a great understanding of the importance, and a growing interest towards transforming and enhancing pK-12 level education, both by developing new resources but

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also by attempting to transmit MIT's core values to the pK-12 level system. As a result, MIT already has a long history of pK-12 summer outreach programs, with particular focus in STEAM education.

For one to better understand what MIT inspired pK-12 education would look like, one should first acquire a better understanding of the values that guide the MIT community. Taking a look at the MIT Seal, as presented in *Fig. 1*, the Latin motto *Mens et Manus*— “mind and hand”—and the volumes, Science and Arts, reflect the ideal of cooperation between knowledge and practice [1], and the whole MIT education is designed with these ideas at heart. Today, 150 years later, “MIT has a long history of pedagogical boldness balanced with deep introspection. The Institute's very existence is based on a grand and daring experiment in teaching. It is a hands-on, science- based, problem-focused engineering education that continues to define MIT's educational model to this day” [2].



Fig. 1. The MIT Seal

In addition to providing student education, one more core mission to MIT is to form collaborations and partnerships dedicated to solving complex, global scale, real-world, sometimes even what appears to be “unsolvable”, problems. Most of the times, solving this type of problems require strong, innovative, interdisciplinary approaches. With this mission in mind, MIT has been working on the UN Sustainable Development Goals through various new campaigns and initiatives, such as the *Campaign for a Better World*; the *MIT Energy Initiative*; the *Jamel Water and Food Security*; and many others.

1 THE STEAM CAMP

1.1 Camp Design and Implementation

In an effort to bring new learning opportunities and motivate students to explore STEAM related areas, MIT proposed a combined 2-week long summer camp for a subset of pK-12 students (ages 8-12 years old) and teachers in the region during the summers of 2017 and 2018. The STEAM Camp sought to bring MIT's curriculum and learning approach to students and teachers from a diverse number of schools in Hong Kong, and the camp was designed with 3 broad goals in mind: a) to advance the scientific understanding of the participants, b) to support teacher professional developments and STEAM curriculum development, and c) to develop digital resources that promote student growth through experiential, project-based education. The whole effort was placed within the Sustainable Development Goals context, as it provides a great pathway towards real life problem solving. “Energy” was selected as the theme for the 2017 STEAM Camp, while the theme for the upcoming 2018 camp will be “Into The Water”. The Camp was offered at the Chinese International School in Hong Kong. The Camp director at the School and her staff handled

registration and logistics for the implementation of the camp and will continue to do so in 2018.

In the summer of 2017, 200 students from schools all over Hong Kong were exposed to a broad range of advanced STEAM content, designed by MIT faculty and staff, and taught the MIT way, with hands-on, immersive learning by doing. As part of the 2-week long summer camp, Hong Kong students engaged in hands-on activities to advance their knowledge, which they could then use in the development of ideas and solutions for a project of their choosing associated with “Energy”. The first week was designed to help students develop their base knowledge through a variety of modules that were not only engaging but, ideally, different from lessons and activities that they had normally experienced in their regular school classrooms. With 200 students attending the program, the campers were split into eight 25-student groups. They were also split up by age, grouping 8-10 years old students separate from the 11-13 years old ones. Throughout the first week, these groups remained together as they attended each module. Progressing into week two, the campers were then tasked with designing and constructing a project that applied (or at least was partially informed and inspired by) the knowledge that they acquired during the first week. Students then formed groups around ideas that they found interesting and used their remaining time to prototype, build, fail, and rebuild their projects. The project-based learning approach is central to the Camp and type of learning we would like to promote among schools in Hong Kong. It has roots in the Constructionism learning theory [3], which states that knowledge is not only built in our brains, but that this learning process happens more effectively in “a context where the learner is consciously engaged in constructing a public entity, whether it's a sand castle on the beach or a theory of the universe”. The Camp ended with an open house event where students shared their work and projects they had developed over the course of the two-weeks with their parents and other members of the Hong Kong community.

The STEAM summer camp was also designed to provide a vehicle for hands-on teacher professional development as Hong Kong teachers worked alongside MIT instructors to facilitate camp activities. Teacher education workshops happened a few days before the camp began, in afternoon sessions. The MIT instructional staff gave abbreviated versions of the 2.5-hour activities to familiarize them with the lessons the teachers would be attending over the first week. The teacher education component of the Camp included elements of successful professional development [4][5]: allowing teachers to provide input regarding topics for professional development, building on teachers' experiences, creating a practical and applicable experience, encouraging teachers to facilitate concrete learning activities, and fostering an environment for practical reflection. The 30 attending teachers were also divided up and distributed amongst the student groups. The schedule was set on a rotation basis to make sure that all who attended were able to experience nearly every module. As the camp started, attending teachers were expected to join groups of students *as students* during the daytime, and to stay for an additional period after students had departed to give feedback. These discussions would inform our staff about modifications that could be made to the materials to allow for the lessons to better fit a variety of Hong Kong curriculum standards. During the second week, teachers had the option to join a team of students, become a roving mentor to assist groups, or build projects themselves. Teachers were also invited to attend a reflective conversation at the camp's end.

1.2 The Hong Kong Educational Framework

In planning for the modules that would be implemented during the STEAM Camp, the developers were guided by requests from the leadership at the Chinese International School for activities that followed MIT's "Mens et Manus" approach to learning with strong focus upon activities that were project- and design-based as opposed to those that might be lecture-heavy. Upon implementing them during the program with both the local Hong Kong youth and educators, our team sought to obtain feedback from and create modifications with the educators during the afternoons after students had gone home. While this process yielded some helpful suggestions, we ultimately decided that the modules would need to be co-developed with local educators prior to the program to reap the most benefits. Additionally, teams from MIT will be encouraged to relate their activities directly to Hong Kong's ecosystems and to follow STEM curriculum guides [6] that were referred to our team by last year's educator cohort.

2 SUSTAINABILITY MODULES DESIGN

2.1 Module Selection Process

Centering on the theme of "Energy" for the 2017 STEAM Camp our group created the MIT pK-12 Learning Grant, a grant opportunity that sought to cull unique activities for the camp from the wealth of knowledgeable individuals and programs at MIT. While there was an initial desire to limit the opportunity to the traditional set of faculty and staff, we decided instead to expand the open call to anyone from the MIT community that was interested in developing programming that would benefit those attending the camp. This meant that MIT students could also develop their own modules and apply for the grant. The Learning Grant opened on February 15th 2017 and ran for four weeks. In that time, we received 7 submissions: three from education-focused groups on campus, one from a laboratory doing work in health technologies, and three from MIT undergraduate students.

2.2 Module Design Principles and Evaluation Criteria

Each module proposal submitted for funding through the STEAM Camp Grant should fulfil a number of requirements. Each team submitting a proposal should address in detail the following items.

- **Module description:** a full description of the module including the topic's lesson and activity, how it will differ for the younger and older age groups, and a write-up of learning goals for the students and ways to assess the success of the module.
- **Teacher professional development:** a layout of the module's related session for participating educators along with the intended learning goals for teachers to bring back to their own classrooms.
- **Why is this relevant?:** an explanation to justify both why the proposal is uniquely appropriate for this program and why it is important to sponsor it.
- **Biographical profiles of team:** a list of the staff that are developing the module along with potential travel availability.
- **Itemized budget and narrative:** a spreadsheet of development costs and the materials and supplies needed for the week along with a justification for all listed.

Furthermore, it was made clear to MIT faculty, students, and staff that the leading team would give greater attention to proposals that make connections MIT research, as well as to proposals that make connections to the latest drafts of the *Hong Kong STEM Curriculum Guides* [7]

To evaluate these, we recruited individuals from the MIT pK-12 community to act as grant reviewers and content evaluators to choose which modules would be funded. In the end, six modules were chosen, after deciding to merge two proposals together into a more complete activity. The committee of faculty and staff affiliated with the MIT pK-12 Action Group evaluated and consider the proposals based on the following criteria:

- Potential to significantly improve students' understanding of STEAM-based education
- Considerations for how lessons can be used in classrooms with limited resources
- Originality of ideas and approaches
- Clarity of module design, learning goals, and proposal
- Feasibility: resources are sufficient to implement module
- Measuring success: expectations for outcomes and long-term impact

2.3 Camp Modules

Six projects were selected by the group to be implemented during the first week of the 2017 STEAM Camp. Table 1 provides the title and a short description of each module. All modules listed in the table were developed in two versions: one for younger students and the other for older students in the range of the program. In addition to these initially modules, two short modules were included in the program with the specific goal of instilling a level of curiosity among the students, a state of mind known to favour people's ability to learn [7]. The first one, had camp's younger students create miniature solar cells using conducting glass coated in titanium oxide and deep-hued dyes, and the second had the students play a new participatory simulation game named "Energeo." In this game, students are tasked with finding ways to meet energy needs for the cities they live in while also being aware of consequences their actions have on neighbouring cities and the world at large.

Table 1. Modules selected to be implemented in 2017 under the "Energy" theme.

Internet of Things for Healthy Plants (MIT App Inventor)	This module introduced students to App Inventor, a block-based programming language, as a means for fostering their digital empowerment while growing their understanding of plant health and different forms of energy.
Creative Learning Skills with Scratch and Makey Makey (MIT Media Lab, Lifelong Kindergarten Group)	This module encouraged students to create and code their own projects using the Scratch [8] and Makey Makey [9] platforms. Both of these platforms support creative learning through projects, passion, peers, and play [10].
Electrical Engineering Basics with an IR Controlled Circuit (Natalie Mionis, Undergrad '18)	This module focused on the basic fundamental concepts of electrical engineering, as well power and energy transfer. Students built a small circuit that drove a motor to spin a propeller, controlled via an infrared light remote.
Building an Ethanol Biochemical Factory using Ampli Construction Sets (MIT Little Devices Lab)	Using a modular system for biochemical reactions called Ampli, students used discrete plug and play elements to experience the design and biochemical programming of reactions that encourage tuning, tweaking, and real-time analysis via on board sensors.

Food as Fuel! (MIT Teaching Systems Lab)	In this module students looked at how food is processed in the body by tracking caloric intake and measuring metabolic rates.
Wind Turbine Design (Emily Tsang and Teresa de Figueiredo, Undergrads '17)	Students designed and constructed wind turbines in teams. Then they had to learn to develop solutions as new problems, associated with their assigned region, were introduced.

3 FEEDBACK AND REDESIGN

We used a design-based research approach to conduct a pilot study and gather information about various aspects of the STEAM Camp, varying from the elements of the Camp itself, to the learning experience of the student and teachers [11]. The data, collected by 10 teachers and 25 students, using pre and post surveys allowed us to conduct a preliminary analysis, reflect and revise the following elements of the Camp:

- Less modules: a smaller number of modules will allow additional time with the content and the MIT instructors and a deeper engagement with content and tools.
- Ownership of materials: the MIT instructors will work closely with the designers and teachers to make the necessary adjustment to the materials.
- Additional opportunities for teachers. As the modules for the camp are chosen and refined, a group of Hong Kong educators will also be paired with the MIT developers to co-develop and ensure strong connections to the local curriculum and context. These teacher fellows will also work together with the MIT educators in the implementation of the modules during the Camp.
- Close alignment to teachers' interests. We are planning to have teachers complete a survey with further inputs regarding their current teacher professional experiences and more concrete expectations for the camp.

4 SAMPLE OF STUDENT PROJECTS

Students worked together to create around 40 different projects using the concepts, materials and tools available. The following projects provide an idea of the kinds of projects developed by participant students during the second week of the STEAM Camp.

4.1 Solar Energy Project

This solar energy project was created by a team of two girls (see Figure 1). They created both a physical model of the solar energy system, but they also worked created a Scratch project that guests could interact with during the Open House. Their goal was to help people understand how much they could save by using solar energy.

In the physical model, they connected 4 solar panels in series to power a small light bulb. They later thought of the need of a battery to store energy from those solar panels to use at night, but they did not incorporate that to the model. In addition to the physical model, they build a project in the computer using Scratch, the programming environment developed at MIT. Their Scratch project calculated the amount of energy consumed by people, when they provided an average amount of money they paid for electricity in a given month, and the amount of money and electricity saved by installing their Solar Energy System. In order to build these two components of their project, they worked closely with the mentors from MIT

to understand the problem, design a solution, build and test until they were ready to share their project.

4.2 Phone Solar Fan Project

This project was developed by two young boys who were inspired by the heat to make something portable that could help them cool down (see Figure 2). Using cardboard, solar panels, a 3V motor, and a 3D printer, the team created an iPhone case that could cool down its user when walking in the sun. After measuring the size of the phone, the boys created a fan using an online modelling tool and printed out a fan blade shape that would fit snugly on the motor's axle.

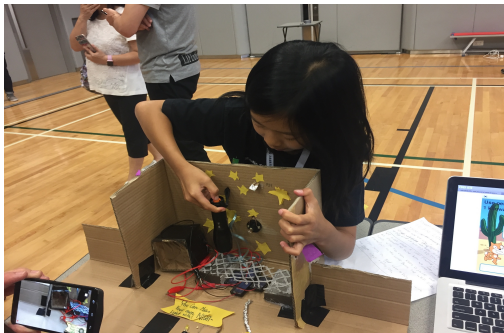


Fig. 1. Solar Energy Project



Fig. 2. Phone Solar Fan Project

5 CONCLUSIONS AND FUTURE WORK

The MIT STEAM Camp in Hong Kong provided a success learning experience for the 200 young students, 30 educators, and 9 MIT facilitators. The Camp ran to conclusion with a large number of personal learning experiences, interesting projects, and along with many lessons learnt for everyone. After evaluating the 2017 STEAM Camp, and as we move into the 2018 summer, we are cognizant of where we can make improvements and taking steps into implementing the feedback we received from all participants in the program. The upcoming theme will be *Into The Water*, again taking direct inspiration both from the educator's suggestions and Hong Kong's plans for STEAM Education but also from the United Nations' Sustainable Development Goals and the MIT research on the topic. A similar process to the 2017 Learning Grant has already been announced for the 2018 pK-12 Learning Grants on January 2018, and accepted proposals include projects for students between 10-12 and 12-14 years old. In addition to the 2018 STEAM Camp preparation, we are also continuing the development of a platform where all modules will be made available to the public for anyone to run.

6 ACKNOWLEDGMENTS

Authors would like to thank the founder of the 2017 and 2018 STEAM Camps in Hong Kong, MIT faculty, students and staff for designing the modules, supporting and implementing the program. We must also recognize the large amount of effort and support exhibited by the Chinese International School in Hong Kong.

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oHMint: Online Higher Mathematics for MINT Students

An Online Mathematics Course and Learning Platform

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Conference Key Areas: Open and Online Engineering Education, Innovative Teaching and Learning Methods, Discipline-specific Teaching & Learning

Keywords: e-learning, mathematics, online course, STEM, MINT

INTRODUCTION

Over the last decades, digitalisation has become an increasingly important aspect of teaching and studying at university level. Online learning tools address this current spirit and offer opportunities that go well beyond the classical textbook: practically unlimited temporal and spatial flexibility while maintaining a high level of interaction with the learners are just two of these.

The project oHMint is an ongoing initiative with the goal of providing an online self-study course and learning platform for higher mathematics, aimed at all students of engineering degree programmes at German universities – an enhanced university course with all the advantages that a digital learning environment offers. Its kickoff is organized and funded through the Hamburg Open Online University, with the technical implementation being handled by integral-learning GmbH. The oHMint project was initiated by the OMB+ consortium, a group of 14 German universities offering an online mathematics bridging course for those interested in a STEM university degree programme. This bridging course is being used extensively at around 50 German institutions, and oHMint benefits significantly from the expertise gained through its development. Currently, one chapter of oHMint is being produced in a pilot project as a prototype for the future development of the entire course spanning four semesters. This serves as an opportunity to test the implementation of new didactical approaches for delivering content as well as innovative types of exercises, taking into account the specific needs of young people today when it comes to learning mathematics. The full oHMint course will provide freshmen and students of higher semesters with a modern way of transitioning smoothly from a high school level of knowledge in mathematics to a bachelor degree level. One of its unique characteristics is the broad support of the universities in the OMB+ consortium and user group, which is a promising base for a wide acceptance of oHMint throughout Germany.

This paper is structured as follows. Chapter 1 covers the background of oHMint, giving an overview of OMB+ and HOOU. Structure and content of the course are explained in chapter 2, while chapter 3 deals with didactical methods and innovative aspects of oHMint. Chapter 4 concludes and presents an outlook for the future.

1 BACKGROUND OF OHMINT

1.1 The Online Mathematics Bridging Course OMB+

The “Online Mathematik Brückenkurs Plus” (“Brückenkurs” translates to “Bridging Course”), short OMB+ is an online learning platform directed towards those interested in STEM degree programmes. It offers participants the means to repeat and complement high school mathematics and more precisely, the subject matters defined in the cosh catalogue [1]. Mathematically based in this catalogue, the OMB+ has been developed by a consortium of 14 German universities and the company integral-learning GmbH under the auspices of TU9, an alliance of nine big technical universities in Germany. It is a successor of the course OMB (see [2]), which had been created by the KTH Royal Institute of Technology in Stockholm and translated into German by a cooperation between several German universities. The OMB+ is text oriented, but includes a big amount of questions, interactive elements, videos and examples with standard solutions which can be uncovered step by step. Until now, around 50 German institutions (universities, the German Physical Society DPG and others) use and recommend the OMB+, which is also available in English. Supplementary chapters covering e.g. stochastics, complex numbers and formal logic have been added, further educational videos are in the making and the translation into Chinese is in progress. For more information see [3] and www.ombplus.de.

1.2 The Hamburg Open Online University (HOOU)

The [HOOU](http://www.hooou.de) is a joint initiative of six institutions of higher education in Hamburg: Universität Hamburg (UHH), Hamburg University of Applied Sciences (HAW), Hamburg University of Technology (TUHH), HafenCity University Hamburg (HCU), Hochschule für bildende Künste (HFBK) and the Hochschule für Musik und Theater (HFMT). It was founded by the Hamburger Senat (Senate of Hamburg) in 2015 as the educational branch of “Strategie Digitale Stadt” (Strategy Digital City), an initiative to bundle processes of digitalization within the city.

The HOOU has four guiding principles. First, a clear *focus on learners and collaboration*: the students are at the centre of all efforts concerning the development of study materials and learning scenarios. Second, *scientificity*: studying at HOOU is oriented towards academic learning and fosters the solving of problems. Third, *engaging new target groups*: the HOOU is open for everybody who is interested in the discussion of academic subject matters and not exclusively for students of the involved institutions. And finally, *openness*: the HOOU is oriented towards open education and facilitates the creation and distribution of open educational resources.

The production of the first chapter of oHMint is funded by the HOOU and running from November 2017 through December 2018.

2 STRUCTURE AND CONTENT OF OHMINT

2.1 Modularisation

The preliminary structure of the curriculum for the full oHMint course was designed by the OMB+ consortium. It spans four semesters and aims to cover all the mathematics typically taught in STEM studies at German universities. The curriculum was carefully structured, keeping in mind that different (types of) universities have different needs for their respective degree programmes. With oHMint, eventually available in German and English, we aim to create a course that consists of units which can be combined in various ways to cover these needs. The fact that a broad spectrum of institutions is represented in the OMB+ consortium justifies our hope that the final course will be widely accepted within the relevant community. This clearly distinguishes oHMint from existing higher mathematics online courses at German institutions.

There are three types of units in oHMint: *base units* cover standard content and are expected to be included in every higher mathematics course, regardless of the institution it is taught at. *Supplementary units* go deeper into the (theoretical) background of a base unit, and include more abstract views on base unit concepts as well as more involved parts. Finally, *optional units* exist for subjects that are not necessarily always part of a higher mathematics course, depending in particular on the study programme and/or institution. The idea is that lecturers will be able to choose and combine the units that are relevant for their classes to provide students with everything they need (but not more).

Parallel to the development of the content of oHMint, a data base is being created that keeps track of all the interconnections between mathematical concepts and results in the units and which will help to ensure the desired modularity of the course.

The units themselves are text-based and consist of lectures, exercises, trainings and final tests. They are supplemented by videos where important concepts or ideas are also shown. Each chapter starts with a motivation for the new mathematical concepts taught such that students develop a sense for the importance of the content they are supposed to learn. Moreover, many interactive elements are being implemented in oHMint, some are discussed in more detail below.

2.2 Scope of oHMint and ECTS

The full first-semester oHMint course consists of the following units:

- Three base units: numbers and functions, differential calculus, integral calculus.
- Four supplementary units: differential calculus, integral calculus, sequences, series.
- Eight optional units: continuity, determination of zeros, L'Hospital's rule, partial fraction decomposition, approximate integration, sequences, series, Fourier analysis.

The European Credit Transfer and Accumulation System is used at European institutions of higher education as well as in some non-European countries. Credit points measure the volume of learning based on workload and desired learning outcome. In Germany, one ECTS point is equivalent to 25-30 hours of studying.

An assignment between the content of the chapters of the oHMint first-semester course and ECTS points has been made by the oHMint working group. This has been done as follows: for five sets of lecture notes from different German universities, the number of pages covering the content of a single unit was set in proportion to the total number of pages. This ratio was then used to calculate the corresponding ECTS credits per unit as part of the ECTS credits for the whole class.

3 DIDACTICS AND INNOVATIVE ASPECTS OF OHMINT

3.1 Didactical Methods

Our guiding principles how higher mathematics should be taught are a spiral curriculum (after J. Bruner, see [4]) where relevant ideas and concepts are presented and evolved in repeated opportunities over the course, the development of intuitive understanding, awareness, and knowledge of mathematical thinking (see e.g. [5], [6]), and in general an application oriented approach within the engineering framework. Further for our project relevant approaches to teaching mathematics are described in [7]. On the other hand we have the constraints of an online platform with limited direct interaction, and students of engineering with an extrinsic motivation to study mathematics, even though with a high level of self-organization and determination that allows them to participate in a self-study course.

On the detailed level we follow the ideas of cognitive load theory [8] which focuses on the limited capacity of working memory of students. New ideas and concepts are introduced incrementally starting from the central issue and adding mathematical constraints as the subject evolves, always keeping the cognitive load small and focused. The formally exact representation is the result of this process and not as often a starting point of teaching, making the constructive process of mathematical knowledge visible to the students.

Our database of mathematical interconnections (see 2.1) supports the development of the spiral curriculum as examples and exercises are shared between the units and viewed from different perspectives, making the interconnections visible for students.

The distinction between intuitive thinking and correct formulation of mathematics as well as fostering the awareness of it is one of our main goals. New ideas are always associated with a purpose and followed by an interactive exercise allowing the students to evolve in a self-acting way and assess their progress continuously. Different types of exercises support the comprehension of ideas, the stabilization of acquired knowledge or the development of routine skills. Application-oriented exercises from science and engineering impart an understanding of the importance of the methods to the relevant application domains. Problem sets on different levels

of content that are automatically corrected allow the students to assess their growth of knowledge and prepare them for the exams.

3.2 Gamification

Gamification can be defined as the use of game design elements in non-game contexts, see [9]. This may take various forms, from gameful (rather than playful) interactions between different persons to the introduction of single player components aimed at increasing motivation and engagement in the individual. Since most engineering students are predominantly extrinsically motivated when it comes to learning mathematics, we develop a variety of such components for oHMint which create a new incentive for active participation in the course. It is the aim of the current pilot project to test several approaches and choose the most successful ones for implementation in the entire course which will subsequently be developed. A selection of these is described more detailed in the following.

- **Badges:** We are developing a system of badges that participants receive for completing certain tasks, such as finishing a chapter or unit, successfully solving problems or working on oHMint for x consecutive days. The positive effect of badges has been documented, see [10]. This will however be an optional element since not everyone likes to be “distracted” by such matters.
- **Exercises in game form:** For skills that require routine we are developing a gaming approach. The player is given a task such as “what is the derivative of the function $f(x)=...?$ ” and has a certain amount of time to answer it. If answered correctly, the player receives points and proceeds. There are different levels with harder exercises worth more points. After finishing the game, players have the option to enter their score into a high score list. We are also investigating the option of enabling players to compete against each other in a duel or small groups. However, the technical development of such a component lies beyond the scope of the current pilot project.
- We are also discussing the option of developing a game in the style of the well-known game show “Who wants to be a millionaire?”.

Developing and realizing these ideas we benefit from close interaction with the e-learning group at Universität Hamburg. Furthermore, we work with student helpers to get feedback from the target group of oHMint and include it directly into the development of the course. This enables us to create and design content in a way that is suitable for the needs of the next student generation.

3.3 What makes oHMint special?

Lecturers can design their own course by selecting content units depending on the degree programme or background (polytechnic/university). See 2.1, Modularisation.

We implement innovative types of exercises: audio files provide the opportunity to practice the transition between written and spoken mathematics – something that online courses often lack; in “reversed” exercises the students shall find flaws in a given line of arguments; in “drawing” exercises they are asked to sketch the graph of

a function with certain properties. Moreover, there is a large amount of quick checks, i.e. short questions or problems interspersed in the course where students can immediately check after the introduction of a new content if they understood it or not.

A group instructing mode will be available. In this way, professors can not only compile a course suitable for their needs but also follow the learning progress of their students in a gradebook overview. A flipped classroom version is also being created. And finally, a call centre run by integral-learning GmbH will be integrated into oHMint as it already is in the OMB+. This means that participants of oHMint can get help for mathematical questions from 10 am till 8 pm via internal chat, telephone, skype (telephone and chat) or internal forum as a free service.

4 RÉSUMÉ

4.1 Summary and a Look into the Future

As mentioned in 1.2, the production of the first oHMint base unit is funded by the HOOU. It is intended to serve as a sample for the production of the remaining units of the first semester course as well as for the second to fourth semester courses. The oHMint working group, currently a subgroup of the OMB+ consortium, plans to use this sample unit to create attention for the project and raise funding, as well as to convince other working groups to join the oHMint working group and/or produce a unit for oHMint themselves. After completion, each unit will be translated into English. A preliminary version of the base unit differential calculus will be put to the test in the winter term 2018/19 at HCU Hamburg as a flipped classroom version. This will provide valuable feedback from students of STEM degree programmes as well as from lecturers for the future development of oHMint.

Overall, we believe that oHMint poses an important step in the digitalisation of STEM education in Germany. The broad supporting base guiding its development ensures that it is tailor-made for the needs of lecturers and students alike, and its modular structure makes it suitable for all institutions.

4.2 Acknowledgments

We gratefully acknowledge the financial support of the HOOU for the current project, the guidance and input of the OMB+ consortium (especially Volker Bach) in the development of oHMint and support beyond the technical lead by integral-learning GmbH.

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Nurturing Creative Engineering Graduates By Embedding Creativity Heuristics Into Existing Subjects

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Conference Key Areas: Teaching Creativity & Innovation, Innovative Teaching and Learning Methods, Innovation as the context for EE

Keywords: creativity, engineering education, thinking heuristics

INTRODUCTION. CREATIVITY: THE ENGINEERING EDUCATORS CHALLENGE

Over 50 years ago Olken [1] reflected on the importance of creativity training for engineers and inability of engineering education to nurture creative graduates:

“If our inventors of the future are to have the higher analytical abilities needed to cope with our increasingly technical inventions, the present overemphasis or unbalance of analytical training relative to training in creativity will increase even more rapidly than our present creativity training courses will be able to correct it. We will therefore need much greater development and expansion of creativity training in engineering schools than are now planned, merely to keep the imbalance at its present level. In short, as far as the future is concerned in creativity training of engineers, we will have to run much faster just to stand still.” [1].

It seems that development of creative graduates still represents a significant challenge for engineering education in many countries. The following are some recent examples from Europe, Australia and North America that evidence the need for engineering educators to improve creativity training.

Gaudron and Kövesi [2] recently analysed opinions of French engineering students on the skills they would need to possess to innovate as well as students' perceptions on gaining these skills while studying engineering. The biggest disagreement between the importance of the skill and the successful acquisition of that skill at university was discovered for the creativity skills (4.2 versus 1.7; on the Likert scale of 5, with 1 corresponding to complete disagreement and 5 – to complete agreement) [2]. Valentine, Belski, and Hamilton [3] discovered that Australian engineering curricula devote very little space to nurturing creative problem solving skills. Only 20 subject outlines of 919 core subjects that were taught by 34

electrical/electronics programs explicitly stated that some concepts of creativity and/or innovation are mentioned or taught to students. Marquis, Radan, and Liu [4], who evaluated the degree of teaching creativity by analysing outlines of 1184 subjects taught by five faculties at a Canadian university, found that only 1 of the 149 subject outlines from engineering faculty mentioned creativity. Daly, Mosyjowski, & Seifert [5] scrutinised syllabuses of seven engineering subjects from a public university in the United States of America and found that all the seven subjects were focused on skills of reorganising, analysing and evaluation and had significant gaps in instruction on creative skills.

It would be incorrect to generalise the findings of scholars from France, Australia, Canada and USA and to conclude that the situation with nurturing creativity in future engineers is poor at all educational institutions. There are some reports of successes in creativity training [6-9], but these successes seem to represent exceptions in development of creativity by engineering educators, rather than the rule.

In essence, the findings of Valentine et al [3], Gaudron and Kövesi [2], Marquis et al. [4] and Daly et al. [5] demonstrate that the abovementioned Olken's reflection is as relevant today as it was 54 years ago. The challenges of educating creative engineers have not been yet resolved and are still on the agenda of engineering educators.

1 ENGINEERING CREATIVITY

In order to improve creativity skills it is necessary to define creativity and to establish the criteria to measure the improvement in creativity skills. Scholars have been interested in sources of creativity and the ways to enhance it for centuries. The domain of human creativity has been extensively researched for over 100 years. Nonetheless, the researchers have neither agreed on the definition of creativity nor on the proper methodologies to measure it [10, 11]. Some scholars suggested that creativity means different things in different domains [12, 13] and argued that the definitions and the means to measure creativity need to be domain specific [14].

Taking into account recent findings on domain specificity of creativity skills, this paper will use the definition of creativity developed specifically for engineering, the definition that took into account legal aspects of patentability and patent authorship:

“Engineering creativity is the ability to generate novel solution ideas for open-ended problems, ideas that are not obvious to experts in a particular engineering discipline and that are considered by them as potentially useful”. [15]

This definition of creativity suggests that in order to enhance students' creativity it is required to boost their *ability to generate novel ideas* to open-ended problems. One of the ways to develop this ability is to introduce students to effective thinking heuristics. Actually, the successes in creativity training of engineering students mentioned in the previous section of this paper were achieved as a result of teaching students various creativity heuristics. Also, the importance of heuristics for generating novel ideas has been considered as essential by creativity scholars for over three decades [16]. Let us establish thinking heuristics that can facilitate generation of novel design ideas.

2 HEURISTICS FOR CREATIVE ENGINEERING DESIGN

2.1 'Creative' Stages of Engineering Design

Engineers need creativity skills to design novel artefacts and to improve existing systems. Consequently, to establish how to enhance students' abilities to generate novel ideas and what thinking heuristics to teach, it is necessary to determine which stages of engineering design are the most critical in formation of novel ideas.

Howard, Culley, & Dekoninck [17] considered over 20 models of engineering design process and nearly 20 models of creative process and mapped the creative process onto design process. They concluded that in practice creative output occurs mainly during stages of task analysis and idea generation.

Although the importance of the design stage of idea generation for attaining creative ideas is self-evident, it appears that the stage of task analysis, which is also known as problem finding, problem framing, situation/problem analysis, etc., is equally important for attaining creative solutions. The essential role of the problem finding stage for developing creative artefacts had been recognised by many researchers that explored the winning approaches of famous design innovators and engineering experts [18-21]. Therefore, in order to select the heuristics that can aid in creativity training of engineers, it is necessary to establish thinking heuristics that can help engineers in accomplishing the design stages of task analysis and idea generation.

2.2 Thinking Heuristics for Task Analysis

Numerous scholars discovered that both students and professionals effectively generate innovative ideas during the stage of problem finding with help of simple thinking heuristics. Famous design innovators, for example, framed their problems by means of the following activities: (a) by altering the initial constraint set [20]; (b) by reassessing the problem from first principles [18]; (c) by re-evaluating the product's application; (d) by identifying the key question to be addressed [22]; (e) by immersing in the problem situation, studying it in depth and reflecting [19, 23]; and (f) by changing the focus of task analysis from the systems level to the level of individual elements and then back [19]. A recent case study reported that a simple TRIZ (Theory of Inventive Problem Solving) heuristic of Situation Analysis that was used by engineers to frame a problem was imperative for development of an innovative crash barrier that was patented and also won a government tender [24].

As expert engineers, students can also boost their creativity using thinking heuristics during problem framing. For example, a simple heuristic known as TERISSA (Task Evaluation and Reflection Instrument for Student Self-Assessment) that engaged students in evaluating a complexity of a problem before and after solving it helped students in problem analysis and engaged them in meaningful self-reflection [25].

Recent Australian study revealed that creativity skills can be taught effectively by embedding learning of simple thinking heuristic into existing discipline subjects.

One hundred and ten students who were enrolled in the first year subject of Engineering Materials at Swinburne University of Technology participated in the study of Blicblau and Ang [26]. During one of the subject laboratories that was conducted in a blended learning mode (no face-to-face contact with laboratory tutors), students were asked to select materials to build various engineering structures, like bridges, homes or hand tools. After students made their decisions on the materials for manufacturing the structures, they were asked to learn the heuristic

of Size-Time-Cost (STC) Operator and to repeat the exercise of material selection. The Size-Time-Cost Operator heuristic suggests to ponder on the changes to the problematic situation under six (unreachable) conditions: when the *Size* of the problematic issue is either infinite (1) or zero (2); when the *Time* to improve the situation is either infinite (3) or zero (4); when the *Cost* of the improvement is either infinite (5) or zero (6).

Blicblau and Ang reported significant differences in choices of materials made by the students which could only be explained by the use of the Size-Time-Cost Operator heuristic:

When students responded to the first engineering activity for realistic solutions to the materials selection problems, they all selected either one of two classes of materials for the engineering components, i.e. metals (e.g. varieties of steel, aluminium, or composites)... When students were asked to... [use] the TRIZ (STC) approach... a variety of traditional (steel, aluminium and wood) and non-traditional materials (titanium, carbon nanotubes, graphene, diamond, ceramics, and gold) were selected for the various constraints. [26]

Blicblau and Ang concluded that the STC Operator heuristic helped students to remove the constraints related to traditional engineering techniques and to consider novel materials and novel manufacturing techniques. In essence, a simple heuristic of Size-Time-Cost Operator that was 'embedded' into an existing laboratory exercise, helped students to expand their view on the materials available to manufacture various structures.

It is important to note that, although the application of the STC Operator heuristic was not compulsory and did not influence the laboratory mark, the majority of students enrolled in the materials course used the heuristic and were enthusiastic about the outcomes it helped them to produce.

2.3 Thinking Heuristics for Idea Generation

The ability of thinking heuristics to aid in idea generation has been evidenced by numerous findings from industry and academia. Scholars of engineering creativity that studied the methods used by famous designers discovered that some great designers even developed their own heuristics to attained winning ideas. The following are some examples of these practical methods: (a) engage in mental transfer of technology from one application to another [23], (b) identify analogies between the problem and various other products with similar functionality [23], (iii) formulate the Ideal Ultimate Result and reflect on the reasons that obstruct its achievement [24].

The ability of the TRIZ heuristic of the Eight Fields of MATCEMIB to trigger novel ideas has been supported by numerous experiments that involved over 1,500 engineering students from six countries. It was found that this simple heuristic statistically significantly increased the number of diverse ideas proposed by subjects for an open-ended problem [27-29]. Daly, Yilmaz, Christian, Seifert and Gonzalez [30] reported that a number of design (thinking) heuristics helped engineering students to propose more ideas for their projects.

Another recent study used the educational materials of the TRIZ Repository [31] that was developed with the support of the Australian Government Department of Education and Training. This Repository offers its users four kinds of resources: educational materials for self-learning, educational materials for academic use,

research papers and case studies on the application of TRIZ heuristics. TRIZ Repository was developed in order to allow subject coordinators to embed one or two heuristics into existing courses with minimal effort on their part. Educational materials on all heuristics contain short introductory videos, simple solution templates and cheat sheets that can be used by individual students in and out of class.

Sixty students enrolled in various diploma programs at the Toi-Ohomai Institute of Technology (TOIT) in New Zealand were introduced to three TRIZ heuristics in semester 1 of 2017 [32]. Students were a mix of school leavers and mature age students and represented both first-year and second-year (graduating) student cohorts. Three class sessions to introduce TRIZ heuristics of the Eight Fields of MATCEMIB, the Ideal Ultimate Result (IUR) and the Size-Time-Cost Operator were conducted. This was done in accordance with the recommendations provided by the TRIZ Repository [31].

The Eight Fields of MATCEMIB heuristic is a subset of the TRIZ tool of Substance-Field Analysis [33]. It recommends for a user to consider solutions that are based on eight different principles of operation: Mechanical, Acoustic, Thermal, Chemical, Electric, Magnetic, Intermolecular and Biological (MATCEMIB). A number of experiments conducted internationally showed that this heuristic can help students to statistically significantly increase the number and the breadth of ideas generated for solving an open-ended problem [e.g.29]. The IUR heuristic suggests for a practitioner to formulate the Ideal Ultimate Result for the problematic situation (the problem has to resolve itself) and to reflect on the reasons why the IUR is not achievable [34].

Twenty-one TOIT students participated in a web-based survey that was conducted a few months after they had been introduced to the TRIZ heuristics in class. Most of the survey participants confirmed that they had devoted their own time and studied more TRIZ heuristics from the TRIZ Repository on their own and agreed that TRIZ heuristics helped them to generate more novel ideas. *Table 1* depicts student opinions on the influence of heuristics presented in [32].

Table 1. Student opinions on the influence of TRIZ heuristics. All questions used the Likert scale of 5 (1 – strongly disagree; 5 – strongly agree) [32]

	I believe the heuristic(s) I have learnt helped me to understand my problem much more clearly	I believe the heuristic(s) I have learnt helped me to generate more ideas for my project	Learning the heuristics changed a way I resolve problems
Mean	4.00	4.06	3.87
SD	0.365	0.443	0.500

Students also assessed the usefulness of the educational materials provided by the Repository as fully suitable for self-learning and useful in their future career [32]. Furthermore, four graduating students had actually incorporated the outcomes of their application of the TRIZ heuristics into their final project reports.

3 DISCUSSION

It is hard to disagree with creativity scholars and engineering experts on the value of thinking heuristics for problem analysis and idea generation. Years of research and hundreds of novel designs have verified that application of thinking heuristics can positively influence the outcome of engineering work.

Accepting the importance of thinking heuristics and taking into account successes of educators from Swinburne University of Technology and Toi-Ohomai Institute of Technology in embedding them into existing subject, a conclusion can be reached that embedding effective creativity heuristics into existing engineering subjects may help educators to improve the situation with development of students' creativity. It can be argued, though, that engaging engineering students for just one hour to learn a heuristic may not result in a long-term improvement of creativity skills. It is possible that the improvement in problem framing and idea generation that students experienced directly after they were introduced to thinking heuristics in class may not last and may not transfer to long-term improvement of creativity skills. This scenario is certainly viable, however, the outcomes of the experiment conducted by Valentine, Belski, & Hamilton [35] suggest that long-term retention of the heuristic approach by students who were engaged in one-hour 'training' session is likely. Eleven weeks after being exposed to the Eight Fields of MATCEMIB heuristic for 30 minutes during tutorial, students were able to generate statistically significantly more ideas for an open-ended problem compared to students who have not been introduced to the Eight Fields of MATCEMIB heuristic [35].

At the same time, the successes in embedding simple TRIZ heuristics of Size-Time Cost Operator, the Eight Fields of MATCEMIB and the Ideal Ultimate Result presented in [26, 32] cannot be considered as the final confirmation that any simple thinking heuristic can be embedded in any existing subject and will enhance students' creativity skills. Educators need to choose subjects that suit creativity development and also select heuristics to teach that are the most adequate for a specific subject.

This paper has devoted most of its space to thinking heuristics of TRIZ. This does not mean that other thinking heuristics cannot enhance problem framing and idea generation. Heuristics of TRIZ were considered because they specifically were developed for engineering and therefore suit engineering well.

4 CONCLUSION

The challenges faced by engineering educators are growing. Discipline knowledge expands exponentially; engineering companies request graduates with well-developed 'soft' skills (team work, presentation, cognitive, etc.). It is practically impossible to devote a separate subject specifically to development of creativity skills with already extremely busy engineering curriculum. Some novel approaches to instil creativity into engineering students are required. The successes of simple heuristics in enabling both experts and novices to propose more novel ideas suggest that it would be advantageous to teach thinking heuristics at engineering schools. Moreover, the existing evidence of successes in teaching simple thinking heuristics to engineering students as well as availability of educational resources may enable many engineering educators to embed simple thinking heuristics for problem analysis and idea generation into existing discipline subjects.

5 ACKNOWLEDGMENTS

This study was supported by the Australian Department of Education and Training.

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Criteria for Entrepreneurial projects

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Conference Key Areas: Fostering Entrepreneurship, Engineering Skills, Curriculum Development

Keywords: Entrepreneurship, projects

INTRODUCTION

In 2015, the Faculty of Engineering Science at KU Leuven chose to put more emphasis on Entrepreneurship in the curriculum [1,2]. A broad definition was used to describe Entrepreneurship: "Sense of initiative and entrepreneurship refers to an individual's ability to turn ideas into action. It includes creativity, innovation, and risk-taking, as well as the ability to plan and manage projects in order to achieve objectives." [3].

Amongst several initiatives to promote entrepreneurship, this paper highlights a new course created to enable students to engage in an entrepreneurial project (i.e., *Entrepreneurship in Practice*).

For the Faculty, this course emphasized the need for well-defined criteria to determine whether a project classifies as “entrepreneurial”. To make a clear difference with other projects offered throughout the curriculum, criteria were defined together with the other Faculties of the Science and Technology Group.

Course evaluation is based upon many factors, with (self-)reflection at its centre. This reflection is thus an important aspect throughout the projects.

This paper first introduces the need for entrepreneurial projects (section 1), then discusses the criteria that define a project as ‘entrepreneurial’ (section 2), as well as the course evaluation (section 3). Finally, some examples of projects are described (section 4) and findings are given (section 5).

1 NEED FOR ENTREPRENEURIAL PROJECTS

During their curriculum, students of engineering take part in many projects. The Faculty of Engineering Science at KU Leuven has more than 10 years of experience in preparing their students for professional practice through a learning pathway called “Problem Solving and Design”. This pathway consists of four courses, spread over the three years of the Bachelor program, in which students collaborate on small project teams on real-life engineering problems.

Major elements of the learning pathway are (1) the different steps of the design process (information gathering, problem definition, generation of ideas, modelling, schematically representing diagrams, calculating and experimenting, evaluation and decision making, and practical realization), (2) reporting, both oral and written communication, and cooperation in a team, and (3) planning and project management [4, 5, 6].

Next to this learning pathway “Problem Solving and Design”, quite a few courses offer projects targeted at applying the theoretical concepts of the course on a practical problem. Some of these projects are made by students individually, some are made in group.

The projects described above focus on many major skills necessary for engineers, but the typical entrepreneurial aspects are not part of their objectives.

In 2014, the Faculty of Engineering felt the need for a more specific focus on Entrepreneurship in the curriculum. Several actions were under taken. (1) The existing Bachelor course *Industrial Management* was reformed, with a focus on Entrepreneurship. The course is now called *Industrial management & Entrepreneurship*. (2) A new elective course in the Master was introduced, focusing on business simulations, strategic management, and creativity and decision making for product development. This is complemented with elective courses offered by the Faculty of Economics & Business.

To turn theory into hands-on experience, the Faculty of Engineering Science created then a new course *Entrepreneurship in Practice* where students can do an entrepreneurial project. The course exists in two variants: a 3 and a 6 credit variant. It

is an elective course which the students can take up from their second bachelor year until their master years. It is the student who has to propose a project. Luckily there are many organizations that offer and coach projects. However, not every project is entrepreneurial. So there was a need for clear criteria to define if a project would fall under the flag of “Entrepreneurial Project”. The next section elaborates on these criteria.

2 CRITERIA FOR ENTREPRENEURIAL PROJECTS

The criteria were split in three groups, each again subdivided in subcriteria. The groups are (1) Putting ideas into action, (2) Acquiring resources, and (3) Interdisciplinary work. The following subsections will develop on each of these criteria.

2.1 Putting ideas into action

The first category 'putting ideas into action' (Figure 1) starts directly from the broad definition of entrepreneurship. The project should result in something useful for a target group.

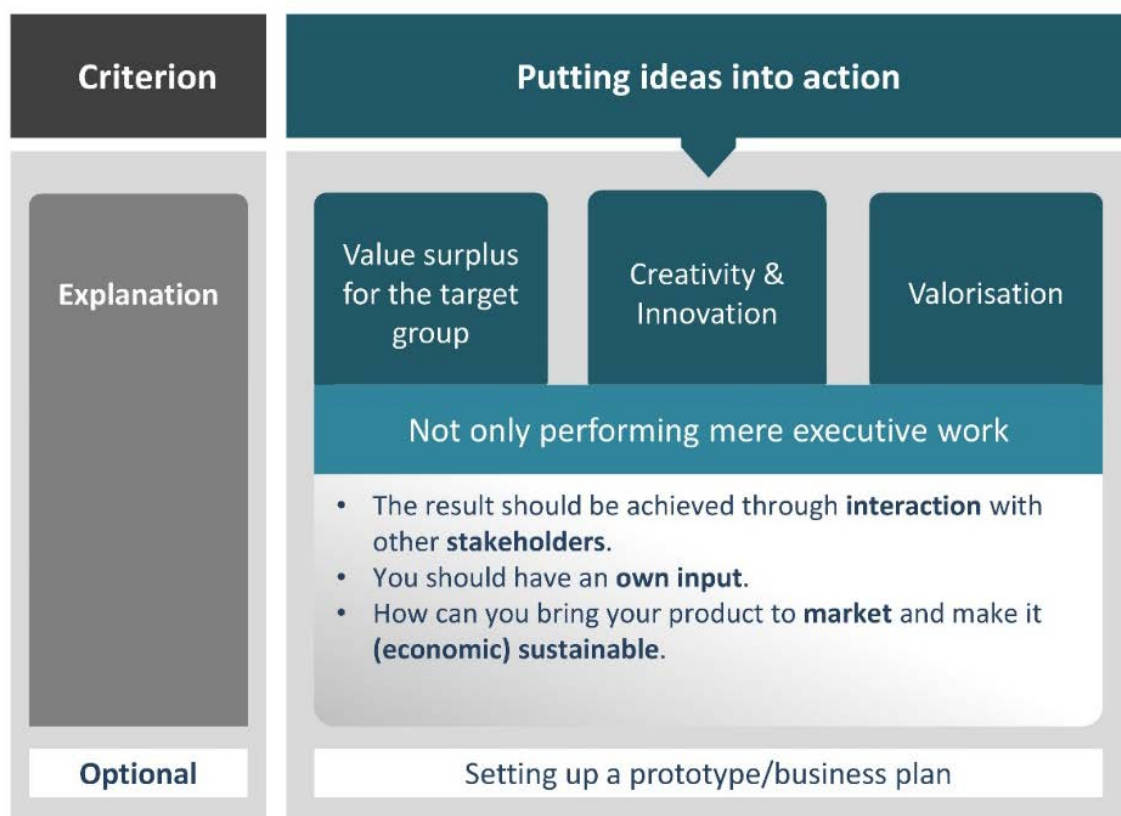


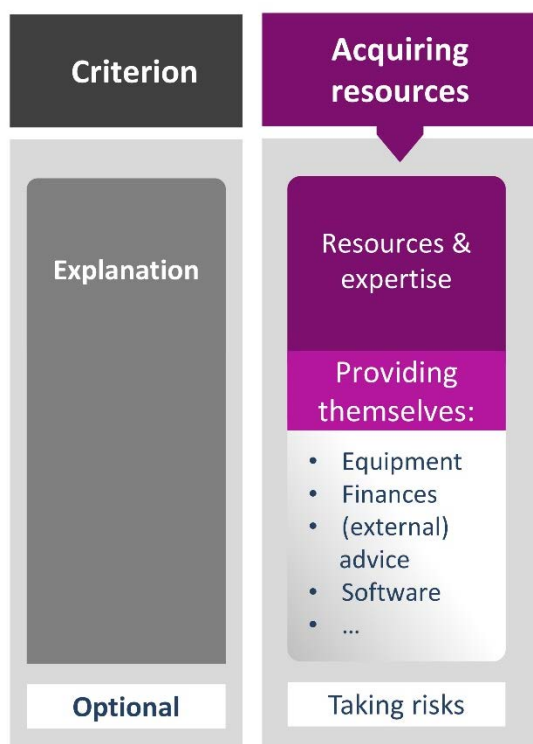
Figure 1

Important is that students talk to real stakeholders. This can be end users, but also local organisations, financial institutions, etc. In regular projects, the role of the stakeholders is often taken by the professor and the assistants. In an entrepreneurial project, however, the student has to go outside the university to find relevant stakeholders. Sometimes surveys are made, or in depth interviews are taken.

In devising what the project could have as output, what “product” (in the broad sense) could be conceived, creativity and innovation are important.

Furthermore, the student has to think about how the product will reach the end users. This can be very elaborate and contain a business plan, but thinking about valorisation in general terms is a minimum. Finally, the sustainability, in the broad sense of the term, is important. Not only the materials used, but the economic sustainability must be discussed. A prototype or mock-up can be made, but is not necessary for all projects.

2.2 Acquiring resources



The second category of criteria (Figure 2) is about acquiring resources. In regular projects, students receive the necessary equipment and software, but are often required to find extra information through literature. In an entrepreneurial project, external advice, coming from outside the university, is often a must. In some projects, financing has to be found, and students write proposals for subsidies from the city or the government. Occasionally, students set up crowd funding.

Important in this category is that students have to take a lot of initiative. Coaches can give leads, but it is the students who have to go outside the university to find the necessary resources for their project.

Figure 2

2.3 Interdisciplinary work

The third criterion (Figure 3) is about interdisciplinary work. All entrepreneurial projects take part in the real world. And the real world is interdisciplinary! Of course the students are educated in one discipline, even if the engineering studies are quite broad. But in an entrepreneurial project, students have to work beyond their own discipline to find out what the consequences are of their choices. We refer here to so called T-shaped professionals.

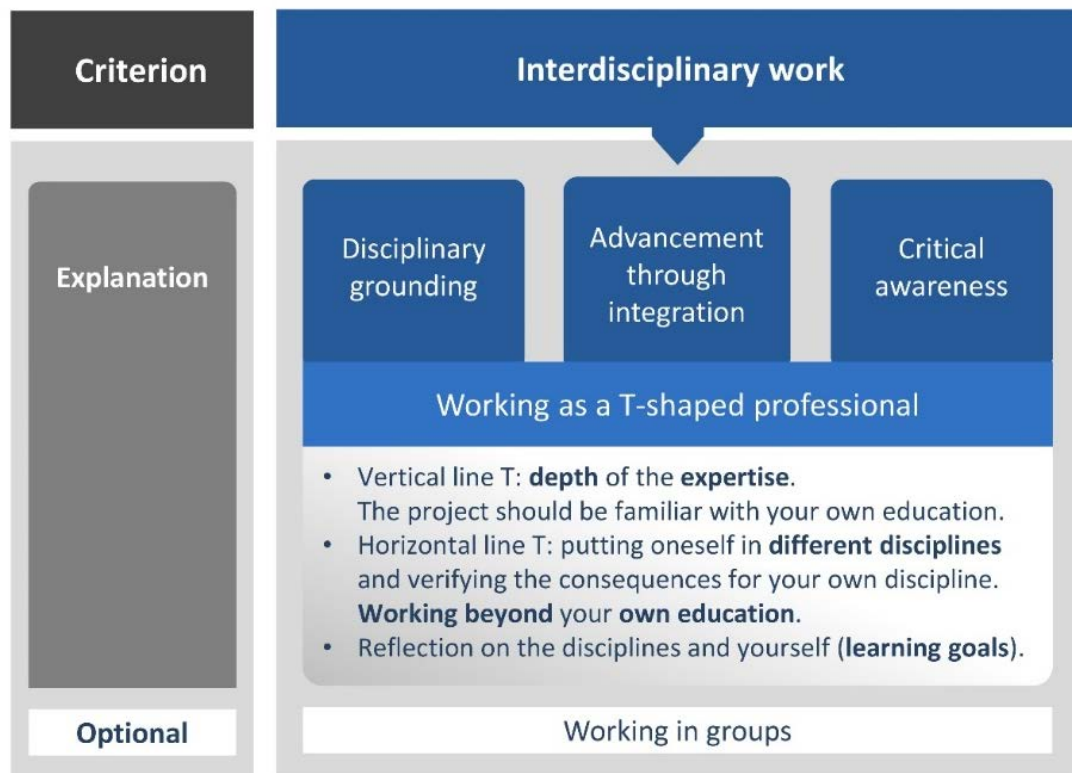


Figure 3

More specifically, students have to possess deep disciplinary knowledge and be able to function as 'adaptive innovators', crossing the boundaries between different disciplines. In this metaphor, the vertical line of the T represents the depth of the students' disciplinary knowledge and the horizontal line of the T stands for the students' ability to collaborate across a variety of disciplines. To contribute to a creative and innovative process, students have to fully engage in a wide range of activities within a community that acknowledges their expertise in a particular discipline and be able to share information competently with those who are not experts [7].

Ideally, an entrepreneurial project is performed in group, where the different members of the group have a different expertise and background. As our university is a comprehensive university, some projects are carried out by a diverse group of students from engineering, economics, medical doctors, sociologists, ... Such diversity enlarges the added value for all students involved: they learn from each other how students from other disciplines think, and how they tackle problems.

Finally, reflection is crucial. This will be elaborated in the next section, as it is a major part of the evaluation.

3 EVALUATION OF ENTREPRENEURIAL PROJECTS

3.1 Reflection

The following quote underlines the importance of reflection. “We do not learn from experience, we learn from reflecting on experience” [8].

To encourage reflection, students are asked before the beginning of the project to give a list of competences and engineering skills they want to improve during the project. This makes the student reflect on his current capabilities, and on the possible gap between the current situation and his ideal “future self”.

In their report at the end of the project, students make a critical reflection on the competences they wanted to improve. Ideally, students learn things they had not expected to learn. They are asked to reflect on their curriculum, and to show the relation between the project and their study program. Which content of which courses was relevant for the project? Was the course content adjusted to the project needs?

Finally, they have to reflect on the way they have executed the project. Did they make the right choices? Where did they fall short and why?

3.2 Evaluation

The evaluation is based on a written report and an oral presentation. Of course the results of the project, what has been achieved, is assessed. But more importantly, the way the project was executed and the choices were made together with the innovation shown are evaluated. Last but not least, the way the student reflects on his own achievements, on the skills and competences he improved, and on his curriculum, have a large impact on their final grade.

4 EXAMPLES OF ENTREPRENEURIAL PROJETS

This section gives several examples of projects that have been done in the past two years.

4.1 PiP

PiP (Product innovation Project) is an education format where an interdisciplinary team of students works together during a full academic year to come up with a solution for a task given by the project sponsor. This sponsor can be a company, a social organization, a governmental body, ... A PiP-team consists of a mix of students with various backgrounds (engineering, economics, ...). Together they must deliver a working prototype and a business case.

Two concrete examples: (1) The city of Leuven asked a PiP-team to propose a way to enhance the experience of people while shopping. (2) BASF (a large chemical production site) and Microsoft asked a PiP-team how the Microsoft HoloLens technology could improve various trainings or processes at the BASF company. In both cases, the students extensively talked to stakeholders, came up with several ideas, and discussed these with their sponsor. One idea was then chosen, a prototype was developed, and a business plan was drawn.

4.2 Academics for Development

The goal of Academics for Development is to offer students the possibility to contribute to real life issues in developing and developed countries. AFD organizes projects in which a multidisciplinary team of students work together throughout an academic year with a partner organization on an issue that the partner has put forward. During the first phase of the project, the students prepare, analyse, and elaborate with their partner(s) on possible solutions and ideas in Leuven. During the second phase the team is given the chance to implement their ideas and/or solutions on site. The ultimate goal of each project is to realize durable and meaningful social impact.

Two concrete examples: (1) The Poopó lake in Bolivia is suffering through the negative effects of climate change, and the lake is drying up. Catapa, a Belgian NGO, aims at alleviating these negative effects through the collection of rainwater through tanks on local buildings. The AFD-team supports the implementation, monitoring and evaluation mechanisms, as well as financing schemes for the overall project. (2) BeeTogether is a project in Tanzania where the AFD-team supports the local bee-keeping sector.

4.3 Academics for Companies

Academics for Companies (AFC) is a student-run organization that does consultancy for companies. Two examples: (1) A market research for the state television into technologies such as Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR). (2) The company Millibeter produces insects to process waste. The company is expanding and needs therefore to relocate. The AFC-team made a full analysis of the problem and drafted a complete logistics plan.

4.4 Self-proposed entrepreneurial projects

Students can also come up with their own ideas. Here is an example.

In the Filia project seniors and students are brought into contact with each other. The students carry out various tasks for seniors ranging from companionship to computer lessons or gardening. The Filia project is a platform that acts as an intermediary in a local community. The project aims at making a prototype platform, marketing plan, and a business plan.

5 FINDING

We found the definition of the criteria very useful, in three different ways. First it helps the students to understand what is meant with an entrepreneurial project, which otherwise would be too vague for them. This clarity encourages students to engage in these projects. Second, quite a few professors of the Faculty of Engineering have doubts about the usefulness of these projects. They believe more in teaching deep technical knowledge. The criteria show them that these projects do not just involve fooling around, but that the learning covers many different important aspects. Lastly, the criteria help the students to reflect, and can be used as a guideline during the oral evaluation.

6 SUMMARY AND ACKNOWLEDGMENTS

The authors want to thank the lecturers and students involved in entrepreneurial projects!

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Engineering students' shared experiences and joint problem solving in collaborative learning

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Conference Key Areas: Engineering Skills, Teaching Creativity and Innovation, Discipline-specific Teaching and Learning

Keywords: Collaborative learning, video ethnography, interaction analysis

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INTRODUCTION

In engineering education students' are commonly expected to think and learn collaboratively [1, 2] in, for example, problem-based-learning (PBL), design projects, and lab-work. Thinking collaboratively is seen as a critical and creative process that leads to deep and meaningful learning experiences and outcomes. Collaboration implies a shared activity and should thus not be conflated with co-operation there the latter also represents individual contributions to a common task, but without the shared influence from the members of a group. Spoken language is commonly seen as the primary resource for engaging in collaborative learning [3], while other resources are seen as secondary. These often overlooked resources are ephemeral (gestures, body-movements, etc.) or present in tangible media (models, foam, etc. showing ideas of individual and collaborative thinking.

Despite the importance given to collaborative learning in engineering education, students' collaborative learning *processes* in naturalistic educational settings have been given little attention in previous research. The aim of this study has been to explore what interactional work student teams do in collaborative learning settings such as PBL and lab-work? What kind of resources do student teams use to collaborate and complete tasks? What is the role of the resources used?

1 BACKGROUND AND THEORETICAL FRAMEWORK

Studies have shown that representations and drawings are crucial in mediating different understandings among group members in engineering education [4]. According to Juhl and Lindegaard [4] talk, observations and ideas are often inscribed into two-dimensional representations capturing ideas or design proposals. Whereas Juhl and Lindegaard study representations as static products of individual and collective work, we focus on the process of making use of various representations/knowledge objects in students' collaborative thinking. This theoretical perspective is informed by embodied interaction analysis [5] and socio cultural theories highlighting the importance of mediating artefacts in thinking and collective reasoning [6]. As discussed by, for example, Davidsen and Ryberg [3] collaboration is more than language and should integrate a view on the bodily-material resources, also in studies of engineering education. This stance emphasise that collaborative thinking, also in engineering education, is haptic, kinaesthetic, visual, and spatial, not only verbal and linguistic, or logical and mathematical [7].

2 METHODOLOGY AND SETTING

To investigate the aim of this study students' courses of action have been recorded using video in a PBL-project at Aalborg University (AAU), Denmark, and in lab-work in a high-frequency electronics course at Linköping University (LiU), Sweden.

2.1 Aalborg University

At AAU collaborative problem-based projects performed by groups of students (typically 5 – 6 in a group) in the PBL-based Architecture and Design programme have been studied. In this paper we present a study of a group of six students (4

female, 2 male) in their sixth semester. They have the task of designing a real office building for an external partner in a large city in Denmark and in the session analysed they are preparing for a status seminar the next day. The interaction within this and other groups has been recorded using multiple video cameras during complete sessions – in this case the session lasted almost 6 hours. To facilitate analysis, recordings have been synchronized – the still photo in Fig. 1 shows an example of how the interactions within the group have been recorded by five cameras (including one body-mounted GoPro camera).



Fig. 1. Excerpt from synchronized video recordings that shows one group of students seen from multiple cameras. All pictures display the groups' activities at the *same* time, but from different viewpoints. In the lower middle picture, one student points to a detail in a drawing while the group discusses a design decision.

2.2 Linköping University

At LiU, students' courses of action in labwork (typically 2 – 3 students in a group) in one course in high-frequency electronics has been studied [8]. The interaction within a group during has been recorded using a single video camera.

2.3 Interaction analysis

As described above students' activities were recorded using digital camcorders. These data were subsequently used to detect typical interaction patterns and find evidence supporting, or refuting, hypotheses regarding the generality of these patterns [9]. We have in particular been looking for how the students were actually working together, what they did, what resources they used, what they made relevant, and how they oriented themselves towards the object of learning. This means that our primary unit of analysis was the activities of the groups. After repeated viewings, some episodes were found to contain more interesting and comparable activities in relation to our aim. Particularly interesting parts of these episodes were transcribed to allow for detailed examination of interactional patterns. In the transcriptions, standard conventions used in conversation analysis have been used [10] and transcripts included in this paper were ultimately translated into English. Pseudonyms have been used for students' names.

3 FINDINGS

As the space is limited it is only possible for us to present two short excerpts from our analysis of video data in this paper: One from the PBL group at AAU and one from the high frequency electronics lab at LiU. We have made a much more extensive analysis of the videos and have selected the episodes described below as they were representative and illustrative for what we found during our analysis. I.e., similar episodes to these we are describing here exist throughout the analysed interactions. In total we have recorded students' activities using digital camcorders, resulting in 1,000 hours of video from PBL-projects at AAU and 400 hours of video observation at LiU from lab-work in electronics and electric circuit theory. In addition to these recordings students' learning in mechanics labs have also been studied at LiU using video [11].

3.1 PBL at Aalborg University

The groups in this PBL design project have their own designated working space – resembling what architects traditionally refer to as a studio. As can be seen in Fig. 1 the boards surrounding the working space (and serving as dividers to other groups working spaces) are cluttered with drawings, sketches, photographs, and sticky notes. These serve as a historical trajectory of materials and design ideas and are constantly present to the student group.

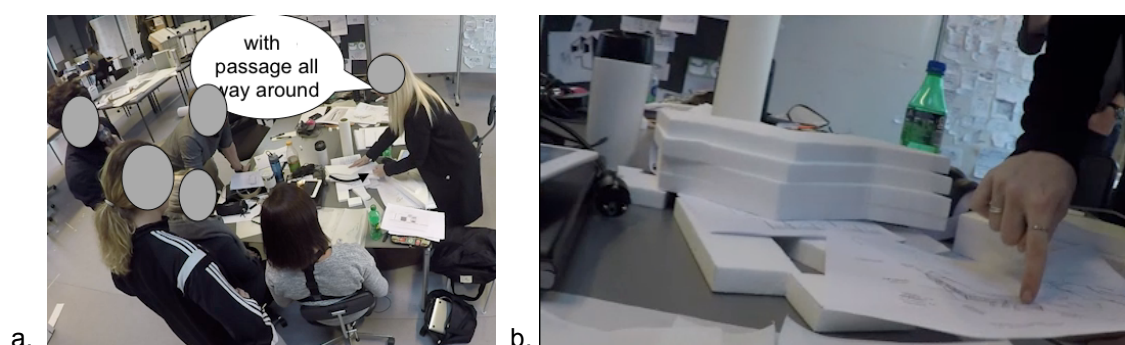


Fig. 2. a) Mette demonstrates (see turn 1 in excerpt 1) the passage. b) Mette points to a detail in a drawing (turn 12). The 3D foam model is also visible in this picture.

Immediately before excerpt 1 starts the students are discussing how to address design problems. A 3D model consisting of different separate layers made by foam is fetched by Mette. Heidi with support of Sine proposes that the top floor of the buildings should be slightly dislocated to complete the shape of the building. Mette takes up Heidi's suggestion and in turn 1 and Fig. 2a it is shown how she demonstrates how this solution might work.

Excerpt 1 (See also Fig. 2a – 2b):

- | | | |
|-----------|--|--|
| 1. Mette: | with a passage all way around and then | Mette dislocates the top floor in the 3D foam model and indicates with a hand movement the location of a passage. See Fig. 2a. |
| 2. Heidi: | but I also think (.) what you now (.) if you imagine this are you dragging- then you could also imagine the you drag the window tiers in well so there still is a roof sticking out over so you created an possibility for staying | First points on a drawing on the iPad and thereafter on the 3D foam model. |
| 3. Ina: | yeah | At the same time Mette |

- | | | | |
|-----|--------|--|--|
| 4. | Sine: | yeah precisely | fetches a drawing on paper. |
| 5. | Heidi: | for example (if one had it here) | |
| 6. | Ina: | that could also work | |
| 7. | (1.9) | | |
| 8. | Heidi: | yeah but | Points on the 3D-foam model. |
| 9. | Ina: | is it | |
| 10. | Heidi: | here here is the window (.) but there is still a roof here for example and then you actually have a room up here | Points on the 3D-foam model. |
| 11. | Ina: | yes (.) and it was actually therefore | Moves closer and points on the 3D-foam model |
| 12. | Mette: | I was in doubt that you meant (.) so with window bands on | Points in drawing. See Fig. 2b. |
| 13. | Heidi: | eh:: yes if one imagine something there also | Also points in the drawing. |
| 14. | Sven: | (it makes) you to pull it back | |
| 15. | Ina: | but you keep the shape | |
| 16. | Heidi: | the window is maybe actually (0.6) here | Points on the 3D-foam model. |

The students' discussion of the advantages and disadvantages of the solution with a dislocated top floor continues for some while after turn 16. In this discussion ample use of the 3D foam model is made and its 3D features is supporting their collaborative thinking. In the excerpt it can be seen that gestures [12] are used indexically by a speaker to indicate what she is referring to or to demonstrate a feature of the imagined and concrete building. Although not visible in this excerpt, the students also used gestures to make "gestured drawings" [13] in the air to substitute for making a quick sketch or for enhancing an argument. Furthermore, the students made extensive use of drawings made by hand on paper or made on an iPad or computer as well as quick sketches on paper in parallel with the ongoing discussions. Moreover, from the excerpt one can get the impression that only the female students are active (e.g. talking and gesturing a lot). However, investigating the whole session this is not true and in Fig. 1 one can actually see the male students active in the background.

3.2 Electronics labwork at Linköping University

In the lab sequence analysed the task students are facing is to make measurements on several circuits consisting of unknown elements and to model this circuit. For measurements a digital oscilloscope is used. The oscilloscope is connected to a computer enabling the results to also be displayed on the computer screen. A complication for the students in solving this task is that in RF-electronics many of the idealization assumptions on which basic electric circuit theory and electronics are not valid.

Excerpt 2 (See also Fig. 3a – 3d):

- | | | | |
|-----|-------|--|--|
| 17. | Leif: | it is (.) it ends like it is short circuited | Points to the oscilloscope with his left hand index finger. See Fig. 3a. |
| 18. | Rune: | m:: | |
| 19. | Leif: | is blocked | |
| 20. | Rune: | m:: | |
| 21. | (1.6) | | |
| 22. | Leif: | this would mean that we have (.) a coil | |

- (.) a capacitor
23. (10.5) Leif makes a sketch in his scribbling pad
24. Leif: right
25. (6.7) Rune points to something in the sketch
26. Leif: it should be something like that
27. (3.7)
28. Leif: high (.) low frequencies
- (.) high
- (.) in between some (.) some rattle
29. (2.4)
30. Leif: here we have (.) the positive flank
31. (4.2)
32. Rune: (yes that we know)
33. Leif: up to here
34. Rune: Yes
35. (2.2)
36. Rune: we get up (.) well then we had a coil and a capacitor
- Points with the left hand index finger in the oscilloscope picture. See Fig. 3b
- Moves the index finger towards the flank. Fig 3b.
- Moves the index finger back and forth between the two previous indications.
- Points with a pen in his right hand to the flank and moves the pen up and down. See Fig. 3c.
- Distinctly point with the pen to the end of the flank. Fig. 3c.
- Make a sweeping hand movement along the measured graph. See Fig. 3d

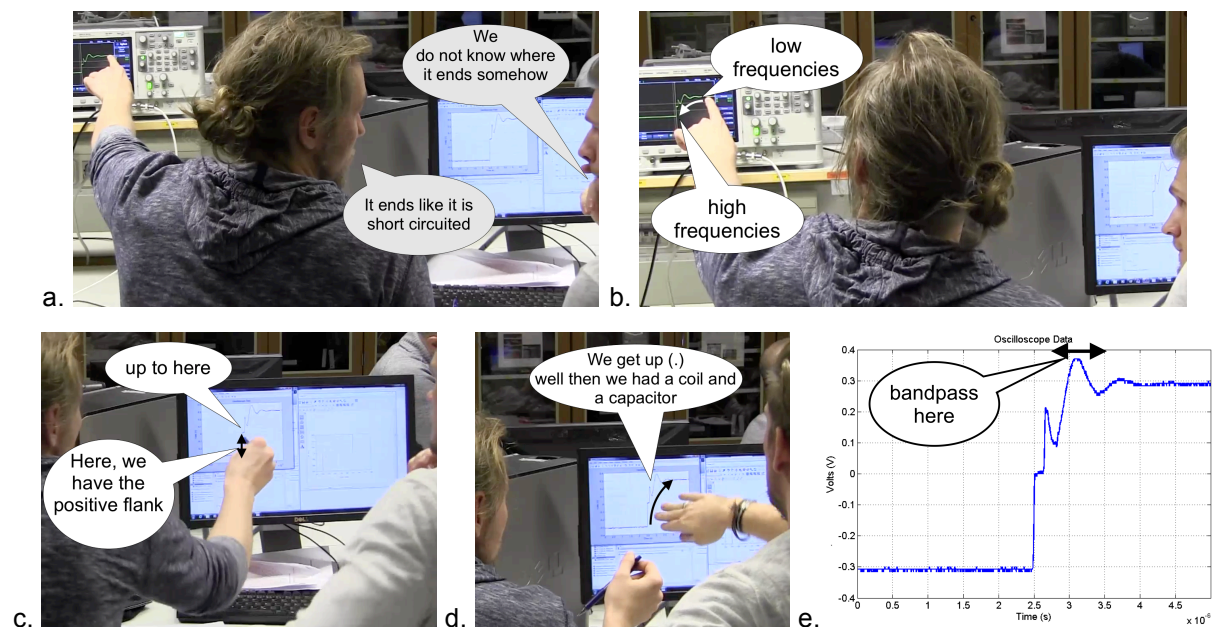


Fig. 3. The oscilloscope is seen in the upper left corner and the measurements are also displayed on the computer screen. *a)* Leif is responding to Rune in turn 17. *b)* Leif indicate the high and low frequency characteristics in turn 28. *c)* Leif indicates the flank in turns 30 – 33. *d)* Rune suggests in turn 36 that the circuit consists of a coil and a capacitance. *e)* Shows how the oscilloscope graph looks on the computer and in Figure 3e it is also shown how Leif points to the peak as a confirmation of the idea of a coil and a capacitance.

For about a minute the students are continuing discussing the circuit, go back to a previous measurement on another circuit to compare, and make some sketches. Finally they feel confident that the circuit consists of a coil and a capacitor and as a confirmation Leif points to the peak as displayed in Figure 3e and moves the pen as is indicated by the arrow.

Similar to the PBL-students gestures are important in Leif's and Rune's interactions. Both for pointing and for making "gestured drawings". An additional resource used by Leif and Rune were to use a computer to make simulations.

4 DISCUSSION, CONCLUSIONS, AND IMPLICATIONS

The use of video ethnographic and embodied interaction analysis methods in this study have made it possible for us to do a fine-grained investigation of the interactional work students do and the resources they use to collaborate and to complete tasks as teams. This has enabled the study *in situ* of how students' daily activities are materially, bodily, and interactionally organized, as well as of details of individuals' actions and the conceptual and material resources used. As there is a lack of studies in engineering education research attempting to do this our study demonstrates the feasibility of the method.

The two educational settings briefly described in this paper could, on a first impression, seem to be rather different. However, the communalities found in our analysis are striking. In both cases the use of a wealth of bodily-material resources are an integral and seamless part of students' interactions and they are used by students in their joint production of understanding and imagining. Bodily resources (e.g. gestures, utterances, bodily orientations), concrete materials (e.g. 3D-foam models, paper models, real circuits), "low-tech" inscriptions (e.g. sketches, drawings on paper, sticky notes) and "high-tech" inscription devices (e.g. CAD-drawings, digital oscilloscopes, computer simulations). The use of these resources is heavily interwoven and difficult to separate. Our findings stand in contrast to the cognitivist "presumption that all psychological explanation must be framed in terms of internal mental representation, and processes" [14]. A consequence of this presumption is that material resources have no or low "cognitive value" [15, 16] or are something that is just "manipulated" [17]. Our study disproves this assumption. Furthermore, if tools and resources are taken into account it is common to see these as synonymous with "digital technologies". However, our study show that a focus only on "high-tech" resources would be problematic and that we in engineering education research should rather attempt to understand how students use many and varied bodily-material resources and in engineering education encourage their use [cf. 18, 19].

Moreover, we can in both cases see that the use of bodily-material resources transcended the boundaries of the individuals and became tools for the group's collaborative thinking, thereby fostering connection between individual cognition and collective re-cognition [cf. 20, 21, 22]. Thus, "distributed cognition" [23, 24] is clearly visible in our findings; achievements do not only arise from individuals thinking, but also through collaborative thinking distributed among the members in the teams *and* from the use of bodily-material resources.

It has not been possible for us in this short paper to give full justice the richness of our data and to explore all implications in depth. Given the apparent differences in the learning environments our results demonstrate that the role of bodily-material resources as cognitive tools in collaborative learning activities should be further investigated.

5 ACKNOWLEDGMENTS

Partial funding from the Swedish Research Council (Vetenskapsrådet) through grant VR 721-2011-5570, and the participation of the students at Aalborg and Linköping Universities are gratefully acknowledged.

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Video Tutorial Designs for Learning: Facilitating Engagement and Entrepreneurship in Welfare, Learning and Experience Technology Engineering Students

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Conference Key Areas: Curriculum development, Fostering entrepreneurship, Innovative teaching and learning methods

Keywords: video tutorial design, PBL, engagement, entrepreneurship

INTRODUCTION

This paper presents initial findings and first experiences with a problem-based learning approach to developing video tutorials with the aim of facilitating engagement and entrepreneurship in a course in Learning & Technology for 9th sem. students from Welfare Technology and Learning & Experience Technology, respectively.

Previously the course was offered only to students in Learning & Experience Technology (LET), however from 2017 going forward the course is offered to students from Welfare Technology as well. This proposes challenges related to increased diversity in theoretical knowledge, skills and competences related to learning theory and its application domains, differences in methodological approaches and practice as well as different expectations with regard to relevance to future careers. Furthermore, prior experiences with the course suggested a need to encourage a deeper understanding of the theories introduced on the course and a greater transferability of tools, methods and skills to other relevant contexts.

In an attempt to meet these challenges, the curriculum of the course in Learning and Technology was redesigned and a problem-based learning (PBL) approach [1] was implemented to facilitate engagement through active learning as well as the development of entrepreneurial engineering skills and competences through contextual application of theories and tools introduced in the course.

Central to the course was the students designing and developing a 5 min. instructional video related to a health/welfare technology or educational technology of their own choice. Since the students were all in their final year, many had developed prototypical technologies in prior projects applicable as cases in the course, whereas some chose technologies they would later be working on as part of their coming Master's thesis. Others are already employed part time either in their own company or one related to their profession, and chose a case relevant to said company.

The students worked in groups of three to four, and the mini-project consisted of three phases: (1) A design phase which included a problem analysis and 'user needs in context' studies. (2) A development phase in which the students were required to test their tutorials through two iterations and present their initial findings to each other at a status seminar. (3) An analytical and reporting phase in which the students reflected upon their tutorials, methods and results in relation to relevant learning theories and research methodologies. Throughout the course, sessions were offered on learning theories, user-centred design and evaluation methodologies as well as instructional sessions on tools for video tutorial design and development.

In the following, we will discuss the concept of designing video tutorials as a learning design, and relate it to relevant PBL principles. This is followed by a section describing our methodological approach and the type of data we collected as part of this case study. Finally, we will present our findings and reflections with the regard to learning outcomes and particularly in relation to facilitating student engagement and entrepreneurial engineering skills through video tutorial designs for learning.

1 THEORETICAL FRAMEWORK

In this section, we will introduce and discuss research on video tutorials and their use in both formal and informal learning settings from both a consumer and producer perspective. Furthermore, we will elaborate on the PBL elements implemented in the curriculum design both generally and in relation to our particular focus on facilitating engagement and entrepreneurship in engineering students from Welfare Technology and Learning and Experience Technology.

1.1 Video Tutorials as Learning Designs

Video tutorials have long been replacing the paper tutorial [2], and an increasing use of educational video tutorials is seen in both formal and informal learning settings, ranging from video tutorials located by students themselves for study or leisure

purposes, to professional tutorial programs introduced by teachers as supplementary material or part of flipped curriculum initiatives [3]. When students use video tutorials on their own initiative, it is often a supplementary tool for understanding new and hard or particular hands-on topics like programming for which video tutorials are generally considered simple, rudimentary and authentic [4]. In flipped classroom or flipped curriculum initiatives, the video tutorial will often replace literature readings and general preparation [5].

The increasing availability of video tutorials enabled by open source platforms such as Youtube as well as easy access programs and tools for video production and editing is generally agreed to hold great potential when it comes to self-directed and student-centred learning [5]. However, only little research has been conducted on the learning potential of the design and making of these video tutorials as part of project and/or problem-based learning designs [4].

In [6] we found that the design of video tutorials held particular learning potential in relation to the application of theory in the design phase. This gave the students not only a language for articulated reflections on the user and context as well as aspects of the learning processes they were aiming to facilitate, but also a deeper understanding of the theory itself. Being both designers and consumers of video tutorials encouraged them to reflect upon design steps and decisions as well as the effect it has on the user and potential learning outcomes of watching these videos. Thus, to a certain degree the students evolved from native tutorial consumers to reflective tutorial designers [6].

On the other hand, the curriculum design also posed certain challenges related to the diversity of science cultures in different educational programmes as well as expectations toward applicability in future careers, which we will discuss and elaborate further in this paper.

1.2 Problem-Based Learning and Video Tutorials-based Learning Designs

Although video tutorials could generally be considered problem-oriented by definition, since they address a need for new knowledge and/or skills and often used upon encountering a particularly problem. However, the development of video tutorials is not necessarily problem-based, since the target audience and context is not always known or well described and thus the content is not necessarily situated and may cover more, less or something completely different from what is actually needed.

Thus, to further ensure a problem-oriented approach to the design and development of video tutorials in this course, we aimed to align the curriculum design with the following PBL learning principles (*Table 1*) common across different PBL models [7]:

Table 1. PBL learning principles

Approaches	Principles	Curriculum Design Decisions
Social (collaborative) learning approach	Teams	<i>The students worked in groups of 3-4 and collaborate in all phases of the project.</i>
	Participant-directed	<i>The students chose the case, generally opting for technologies they were already working with or had developed themselves</i>
Cognitive learning approach	Problem-based	<i>The students were required to do initial ‘user needs in context’-studies to get a deeper understanding of the particular problem or need.</i>
	Project-oriented	<i>The task involved different complex problem analyses and implementation of problem-solving strategies within a given timeframe.</i>
	Experience	<i>The students were encouraged to draw from prior experiences with their chosen technologies and required to get new through user studies.</i>
	Context	<i>In addition to the ‘UNICS’ study, context was specifically addressed in lectures on research methodologies and evaluation.</i>
Content approach	Interdisciplinary	<i>The course covered two programmes (Welfare Technology and Learning & Experience Technology), however groups were not mixed</i>
	Exemplary	<i>Focus on translating theories and experience to other relevant contexts</i>
	Theory and practice including methodology	<i>Focus on translating theory to their coming professional practice and on developing a professional identity as a designer for learning</i>

2 METHODS AND DATA

Over the course of 13 weeks, the students were required to:

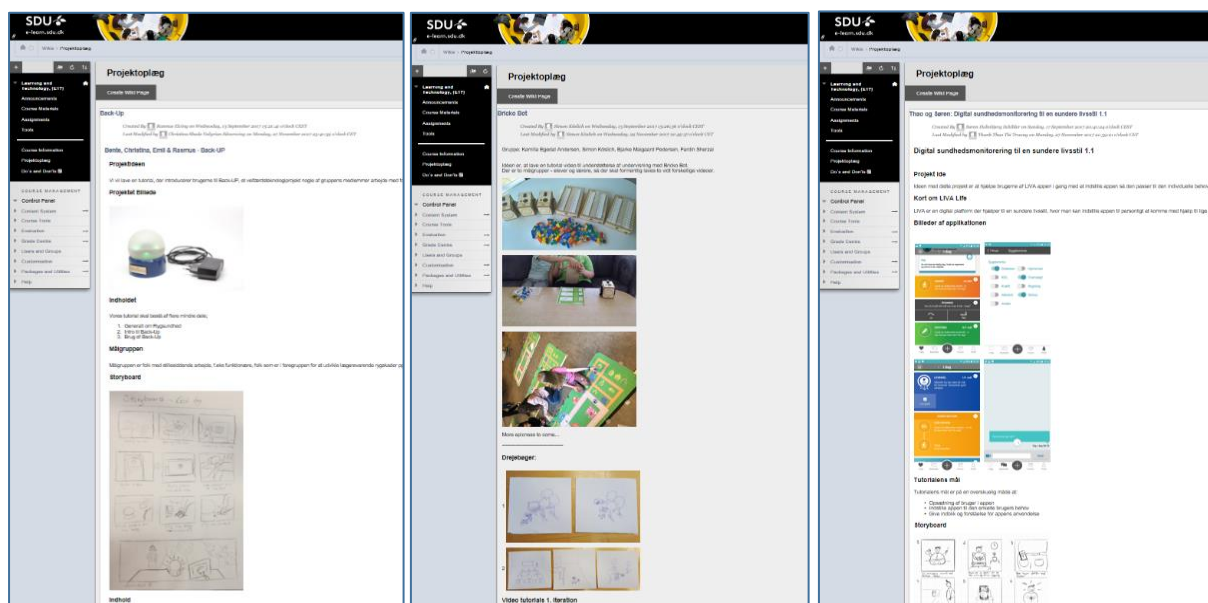
- Develop a 5 minute video tutorial and test with the target group in two iterations
- Develop a storyboard based on a ‘user needs in context’-study
- Formulate learning objectives as part of the design process
- Hand in a 5 page report (with links to storyboards and two versions of the tutorial), discussing the design in relation to learning theory, research approach and methods as well as evaluation and results

The students designed and developed the tutorials using FlashBack Recorder, Camtasia Studio or similar to record screen, sound and webcam and tested these in two iterations with the target group. A status seminar was organized midway allowing the students to present preliminary work and provide each other feedback.

In addition to state of the art research on video tutorials as learning designs and an introduction to relevant tools, the curriculum included sessions on relevant user-centred research methodologies (action research, co-creation and design-based research); a session on interaction design and user behaviour (information architecture and persuasive technology, user needs in context, storyboarding); several sessions on learning theory (cognitivist and constructionist approaches to learning, tacit knowledge and learning processes and evolutionary learning models) as well as a session on evaluation design and strategies for implementation.

An internal wiki page was created on BlackBoard (see *figure 1*) for the students to upload and share problem statements, storyboards and design ideas, findings and reflections from tests as well as examples from their tutorials. The wiki-page allowed the students to get inspiration from and comment on each other's' work.

Figure 1. Examples of BlackBoard wiki pages



Empirical data for the evaluation of the teaching design included the developed tutorials and written assignments, wiki-pages, observations (from teaching and exams) and an open-ended questionnaire.

3 RESULTS AND DISCUSSION

The tutorial designs were very diverse and included both app- and website tutorials, e.g. explaining how to use an Augmented Reality museum app (*figure 2*) or tips and

tricks to ease and enhance the use of the local learning management system (*figure 3*) or explaining C++ programming in Visual Studio relevant to younger students at Welfare Technology (*figure 4*). Other tutorials introduced and explained the use of novel technology, either developed by the students themselves, e.g. a health device to improve back health in sedentary work situations (*figure 5*) or the programming of an educational robot (*figure 6*), or functioned as a prerequisite for using technology (in this case Hololens) for which the students had developed an application (*figure 7*).



Fig. 2. AR museum app tutorial

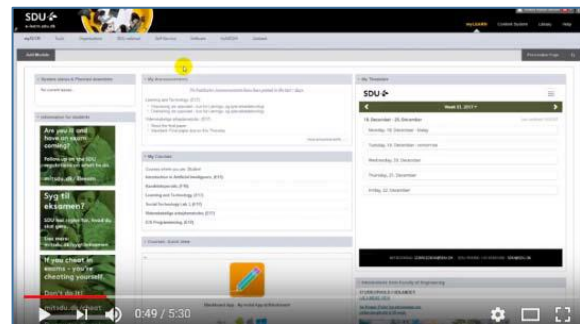


Fig. 3. BlackBoard tips&tricks tutorial

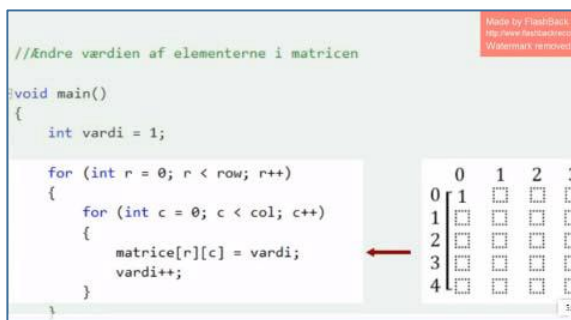


Fig. 4. C++ programming tutorial

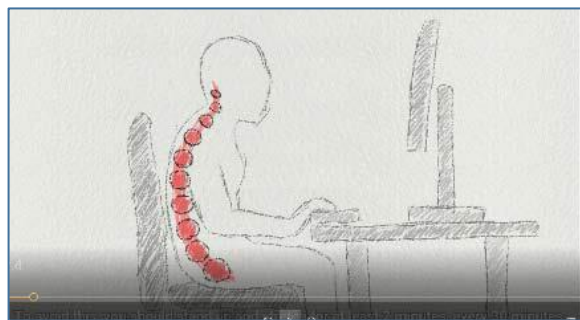


Fig. 5. BackUP health tech tutorial



Fig. 6. Robot programming tutorial



Fig. 7. Hololens gesture tutorial

3.1 Learning Outcomes and Challenges

As argued in [6], the case demonstrated that the students were able to conduct a contextual analysis of user needs and apply these as well as theoretical knowledge to their video tutorial designs. Particularly theory on tacit and explicit knowledge was used to explain and reflect on different aspects of learning processes facilitated through visual aids and video tutorials. The students worked creatively with the design

and development of the tutorials, and feedback from users and co-students was incorporated into and improving the tutorials in the second iteration. However, the student evaluation questionnaire also revealed certain challenges, particularly related to developing a curriculum relevant to two very different study programs as well as to ensure the transferability of knowledge and skills from the course to future careers, which we will elaborate in the following.

3.2 Facilitating Engagement and Entrepreneurial Skills

In addition to the specific learning outcomes addressed in the course, the PBL principles (with regard to social, cognitive and content aspects) in our curriculum design (see *table 1*) were implemented to try to facilitate engagement and the development of entrepreneurial engineering skills.

From a *social learning approach*, the teamwork approach and self-directed learning facilitated engagement, and the students were particularly positive about sharing their work and reflections on the designated wiki-page. However some students found the workload of the project to somewhat withdraw from their general understanding of learning theories, particularly theory they did not directly apply to their project. The fact that they could choose cases related to their own technologies or start-up companies facilitated engagement and reflections with regard to entrepreneurial competences and future career, however students from Welfare Technology had difficulties connecting the development of video tutorials to their particular profession.

From a *cognitive learning approach*, the problem- and project-based learning facilitated engagement, however there was a rather big difference between the level to which students from Welfare Technology and Learning and Experience Technology found the course content and context relevant and to what extent they could draw from past experiences. Thus, the welfare technology context and its relation to learning might need to be explored and exemplified further in future curriculum designs.

From a *content learning approach*, the students were highly capable of applying theoretical knowledge to practice and discuss research methodologies in relation to their own profession, however the learning design could potentially benefit from increased attention to interdisciplinarity. For instance, since the students formed the groups themselves, they ended up dividing into groups according to their study program and thus did not fully utilize the potential for learning and knowledge sharing across disciplines. Group members with different backgrounds and diverse practices could perhaps also support the PBL principle of exemplarity, i.e. the transferability of knowledge, skills and competences to other contexts and domains as well as increase the visibility of knowledge and skills particular to the individual profession.

4 CONCLUSION

In this paper, we discussed the potentials and challenges of problem-based video tutorial design as an approach to facilitate learning, engagement and the development of entrepreneurial skills for engineering students in Welfare Technology and Learning

and Experience Technology. Future work includes further developing the curriculum in accordance with our PBL approach, particularly focusing on increasing interdisciplinarity and transferability of knowledge, skills and competences to related contexts and future careers within the Welfare, Learning and Experience Technology domains.

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Setting up a Community of Practice for a University CubeSat programme

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Conference Key Areas: Innovative Teaching and Learning Methods, Engineering Skills, Discipline-specific Teaching and Learning

Keywords: Community of Practice, CubeSat, NanoSat, Knowledge Management

INTRODUCTION

CubeSats were introduced by Robert Twiggs from Stanford University and Jordi Puig-Suari from California Polytechnic as an educational project for engineering students [1]. Their aim was to give students a practical experience of designing, building, testing and launching a real satellite. The CubeSat standard has since spread around the world and is now used not only by Universities, but also by space agencies and industry.

In previous work, the authors conducted a survey of 45 University teams on how best to set up and manage Cubesat projects [2]. One issue raised by many respondents was the difficulty of passing information and expertise between successive cohorts of students. This makes developing a CubeSat at a University uniquely challenging; for instance, requirements may have been written, or a crucial design decision made, by a student who has since left the University. Another challenge is how to pass information between students and staff in different departments. To overcome these challenges, a “Community of Practice” (CoP) approach is proposed here as a way of connecting a University CubeSat community and of encouraging better knowledge management. This approach has not, to our knowledge, been used with a CubeSat project before.

The goal of this paper is firstly to describe how the University of Bristol CubeSat project was set up as a Community of Practice and secondly to evaluate the value of Community of Practice to the participants in a qualitative way, using the concept of cycles of value [3].

In this paper, the background section provides a review of the different areas relevant to this work: CubeSats, Communities of Practice and their evaluation, and Concurrent Design Facilities. The methodology section describes how the community was established and how the evaluation interviews and survey were carried out. The results section is split into each of the cycles of value and discusses some lessons learned and recommendations for other multi-disciplinary and multi cohort student projects. The conclusions summarise the key points.

1 BACKGROUND

The educational reasons why CubeSats are interesting to Universities include the opportunities for students to innovate, to experiment, to collaborate and to acquire practical experience of building spacecraft [4]. Several Universities using 'Problem-Based Learning' philosophies have adopted CubeSats as a project which equips students with technical skills, develops their ability to collaborate and their programme management skills [5]. Research has established that CubeSat projects provide students with the experience of challenging schedules, managing subcontracts, motivating a team and interacting with a customer which prepares them well for work in industry [6]. The University of Bristol has decided to build its own series of CubeSat satellites to add an exciting challenge to student experience, actively engage student societies, increase employability through cross-disciplinary teamwork and unite different subject disciplines with an interest in space.

University CubeSat programmes can struggle with knowledge management issues, due to their transient and multi-disciplinary workforce [2]. A proposed solution comes in the form of a Community of Practice (CoP). The concept of Communities of Practice was first proposed by Lave and Wenger, who defined them as: *"groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly"* [7]. Key characteristics of CoPs include support for formal and informal interaction between novices and experts in the community, the emphasis on learning and sharing knowledge, and the investment to foster the sense of belonging amongst members [8]. However, when evaluating the CoP, there are exist fewer studies. Value creation, as defined by Wenger [3] provides a simple yet flexible framework, already used in an educational context, upon which to establish the value of the community to its participants. The value creation is divided into 5 cycles of value and these cycles define a spectrum of value creation, from everyday interactions to impacts outside the community. These cycles are described in more detail in section 3. Each of these cycles produces a distinct data stream with specific indicators that can be monitored. Value creation will be used in this work to evaluate the value of the CubeSat Community of Practice to its participants in a qualitative way.

Many activities can be offered as part of establishing a Community of Practice and one of those offered by the University of Bristol to its students was a Concurrent Design Facility (CDF) activity. These are a way of parallelising the design work on

different parts of an engineering system with all participants in one room working intensively. They are used in space mission design to reduce the length of early phase spacecraft design projects. CDFs have been used for many years at the European Space Agency [9] and by the NASA Jet Propulsion Laboratory Project Design Center [10].

2 METHODOLOGY

2.1 Developing the Community

The University of Bristol Satellite programme has been set up as a Community of Practice following the workflow described in Figure 1. The programme evolved from the wish to bring together the community of space researchers within the University together on a joint project. Both students and staff wished for the majority of projects to be established within the curriculum in order for students working on the projects to have credit for the work that they did. This involved the following Electrical, Aerospace, Mechanical, Physics and Earth Sciences disciplines working together with student societies. In order to decide the 'domain of interest', the authors liaised with the Research Directors of all University Faculties in order to call for ideas. The selected mission was proposed by the School of Earth Sciences, and its ambitious scope requires a multidisciplinary team of students. Feasibility studies were carried out by students to find out the key issues and technical drivers for this mission.

The next step after this, was to raise funding for physical infrastructure. Staff and students worked together to request funding. This included building a ground station and a satellite laboratory with test equipment, cleanroom and mission control but also procuring funds for student societies to provide training activities and competitions. This domain and key issues then established, it was then possible to identify the methods, tools and resources necessary to establish the community. In terms of tools, one of these was the online platform used as the main method of communication between the members of the community. Initially, the online platforms selected by the community, for their familiarity and ease of use, were a combination of the University of Bristol Virtual Learning Environment (Blackboard) and Google Drive. The following year, a different platform was provided based on Microsoft Outlook Teamsites/Sharepoint. This provided an internal website for students and staff, with a shared drive and easy way of communicating via the website and email.

Various different activities and tools were used to help build the community. Staff and students jointly organised an extra-curricular 'CanSat' competition to enable teams of students to build a miniature satellite in a soda can and drop it from a drone. This was aimed at encouraging novices or new students to join the community. This was a practical project which developed student skills in soldering, 3D printing, laser cutting, electronics testing and flight testing.

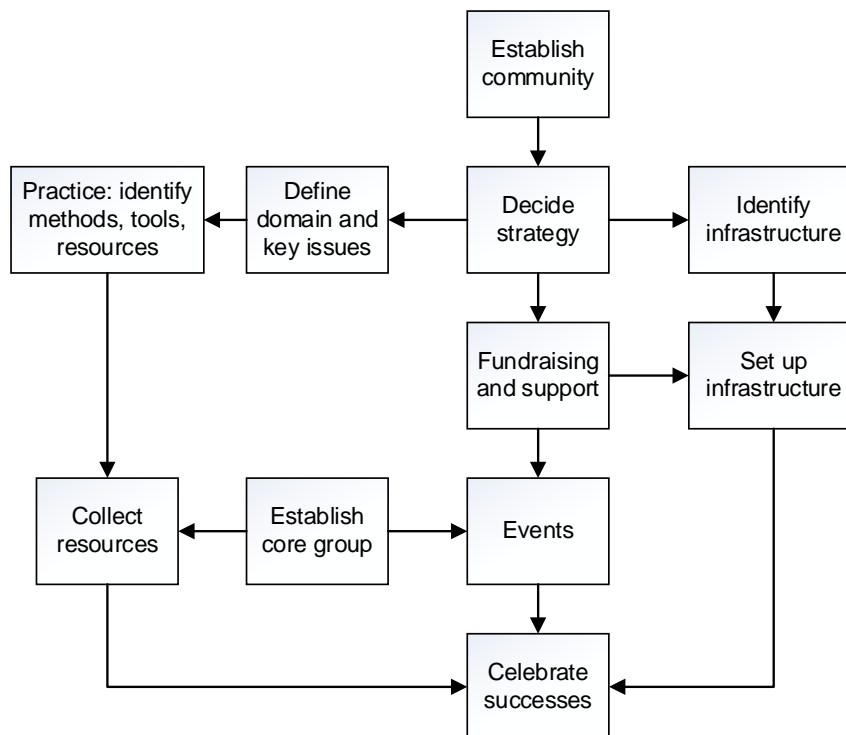


Figure 1: The process used to set up the University of Bristol Satellite programme as a Community of Practice

Social events included pizza evenings for students to get to know each other. Workshops were run to encourage all students working on curriculum-based projects to share their ideas and ask for advice from other students and staff. Three workshops were held for 20-30 students and 5-8 staff. At these, students presented and discussed their work in groups. An accelerated concurrent design facility (CDF) activity was run over 2 days in June 2017 for 4 staff and 13 students participating in projects. This was mentored and run by RALSpace Ltd, a world class Space laboratory.

2.2 Evaluation

The aim was to identify the value gained from activities such as the workshops, CDF and communication tools. So, at the end of the academic year, after all activities had been finished, a series of semi-structured interviews were held with 3 focus groups of students. The students were selected by availability. Nine students from 2nd, 3rd and 4th years were interviewed in 3 separate groups about their views of the Community and what value it might have contributed to their experience of the CubeSat project. The questions were based on the cycles of value concept developed by Wenger, Trayner, de Laat [3]. Ethics committee approval was sought and obtained for these interviews which were carried out according to University data and confidentiality regulations.

3 RESULTS AND DISCUSSION

3.1 Value Creation

The results from the interviews have been analysed through the lens of 'value creation', which is formed of 5 cycles of created value [3]. The interviews have been analysed qualitatively in the following sections, looking for comments which correspond to the different cycles of value.

Cycle 1: Immediate value - activities and interactions

In cycle 1, value is created by any connections made within the community. There was interaction between students from different years in the different activities, notably the workshops, competitions and CDF. Students commented that they gained: "more information about the whole picture that we want to achieve." Conversation during workshops was about solving problems or exchanging information. Students stated that a CDF set up was different to a university learning experience as: "there's no set right answer and it's really nice that ideas come and just get pinged around" where "everybody learns together" creating a "dynamic process for everyone's learning".

Cycle 2: Potential value — knowledge capital

In cycle 2, value created by the learning which has not yet been applied, is also known as 'knowledge capital'. The workshops and CDF allowed the application of lecture material theory to practical or theoretical projects. One student commented: "I can finally connect the lecture material ... with some calculations that I've been doing, which I think is very useful because I knew on paper how it worked but now I think I understand it as well". Also, the Community of Practice way of working gave students an insight into how projects may be completed outside an academic setting; "I've never had the experience of working with ... people who are way more qualified than I am in something, ... yesterday I felt a bit useless". A student commented that the CDF "doesn't give you a sense of completeness or correctness." This lack of 'completeness' is a new feeling for students used to marking schemes and solutions. This may be their first taste of working in industry on a real problem. Another summarised: "It gives a perspective of how engineers in this sector work".

Cycle 3: Applied Value – changes in practice

The third and fourth year students could apply their knowledge in workshops as they already had experience of the project in previous years. Of the CDF, one commented: "Everyone is working in such close proximity, it doesn't really leave too much time for you to be twiddling your thumbs. It's almost like a series of mini deadlines." This meant "productivity is high." The 'mini deadlines' were a different way of working to what these students were used to, but it had the outcome of changing how they worked and producing high productivity.

Cycle 4: Realised Value – Performance improvement

This describes the impact of the CoP on achieving what matters to the stakeholders. Students commented that being able to communicate in a setting like the workshop made the design process more efficient and improved the overall performance. A problem that took months to solve before just took a few days. The students felt “having everyone in the same room at the same time allows you to talk to people, get work done and I think it's quite time efficient in terms of getting things done”.

Cycle 5: Reframing value: changing frameworks

Changing frameworks is the process of re-evaluation of the task and how the direction of the programme might be changed by the community. Examples of this included: “I think most people haven't really considered how much we actually need to do for calibration”. This new understanding and redefinition of the programme is critical to the success of the project. Experts and more experienced students were more likely to gain this level of value.

3.2 Analysis and Themes

It appears from the analysis of the focus groups, that higher levels of value were created for students in higher years. This was perhaps because they had previous experience of the satellite programme to draw upon. This would have meant a more sophisticated understanding of the project and therefore more ways to extract value from the community. Students in lower years were ‘novices’ to the project and therefore had a steeper learning curve when they participated in the community. Novices found that the joint workshops were a good introduction to the project and useful for an overview of the CubeSat project. The CanSat competition was also popular with novice students and was considered a rewarding way of developing practical skills and getting ‘hands on’.

The 2-day CDF was considered by participants as both challenging and rewarding. The novices in earlier years found the learning curve challenging and sometimes felt a bit ‘useless’, but they benefited from the mentoring by the other students and industry experts. The 4th year students shared a frustration in feeling like they were repeating work that they had already done in their projects. However, many positives were noted by them including that design decisions could be made more efficiently as the information was easily accessible. Other value created by the CDF included reframing of the mission and identification of future work.

Tools and communication were one of the most problematic areas of the community. Encouraging the students to communicate with each other sometimes felt like an uphill task for the authors. This may have been because the participants did not wish to rely on others for critical parts of their assessed work. However, during the workshops, students often realised that there were others working on associated areas, or that there was previous work which might be useful. This was vital for the continuity of the programme.

3.3 Celebrating Success

The last stage of the diagram in Figure 1 is 'celebrating success' and there have been many successes in the satellite programme. 70+ students have been involved with the community over the past 2 years. Many of those have gone on to jobs in the space industry with this relevant experience. Several students have won prizes at prestigious international conferences for reporting on their work and many more have gained awareness of workplace techniques and practical skills.

3.4 Lessons learned

The following are a list of lessons learned through the experience of setting up and running this community:

1. **Choose your tools wisely:** it is best to let the community decide the tools together. The authors have found an internal website with document storage very useful, but social media tools, such as Slack, failed due to lack of use.
2. **Attract in novices:** new members are the lifeblood of the community, but they need to be attracted in via competitions, workshops and exercises such as CDFs and then mentored. It is then important that they can access easily the legacy of previous work through summary documents, wikis, reports etc.
3. **Ensure regular access to experts:** access to expertise via supervision, workshops and CDFs is extremely helpful as students may go beyond the knowledge covered in their degree course.
4. **Use workshops:** these bring the community together; they provide a perspective of the direction and current status of the project, as well as motivation for all students.
5. **Communities boost skills:** the community activities helped students gain new skills including technical ones, such as 3D printing, Arduino programming and soldering and non-technical ones, such as programme management, peer to peer mentoring and time management.
6. **Consider whether to run as curricular or extra-curricular:** Embedding projects in a curriculum can be challenging: students can become driven by the format of the deliverable and the type of assessment. The advantages are that the students are rewarded for the time invested and have an incentive to properly document their work. Extra-curricular activities need to have other incentives, such as gaining skills or prizes and deadlines.

4 CONCLUSIONS

In this work, the setting up of a Community of Practice has been used as a tool for the establishment and management of the University of Bristol Satellite Programme. In this work, the process of setting up the Community of Practice for this satellite programme has been described. This has provided a framework upon which to build a community of diverse stakeholders including local industry, students and academic staff. In order to evaluate the value of the community to its participants, semi-structured interviews with students from different years have been conducted. These have been analysed qualitatively using the concept of cycles of value. This identified the different levels of value gained by the students through these events. Overall, there

was a pattern of the students in higher years gaining higher levels of value. Communities of Practice are a useful tool in multi-disciplinary long duration programmes such as CubeSat projects and lessons learned are provided to others contemplating similar projects.

5 ACKNOWLEDGEMENTS

The authors would also like to acknowledge the funding of equipment and student competitions by Boeing UK. The CDF activity was funded by the UK Space Agency as part of an NSTP contract. RALSpace Ltd kindly provided the facilities and mentoring for the Concurrent Design Facility activity. Dr Berthoud was funded by a University of Bristol Teaching Fellowship for this work and would like to thank Professor Sarah Baillie for her ideas and support.

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A students' perspective on entrepreneurship and innovation in European STEM Education

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Conference Key Areas: Curriculum development; Fostering entrepreneurship; Teaching creativity and innovation

Keywords: Entrepreneurship; innovation; engineering education; Board of European Students of Technology

INTRODUCTION

The dynamic and fast-changing nature of our world today places new demands on current and future STEM graduates [1]. Although the new “global engineer” is expected to be mainly a team player rather than an individual one, engineering curricula still largely emphasise technical skills and underemphasize the needs of the modern business world [2]. Relevant skills are not only soft skills like effective communication, good project management, and fast problem-solving, but also entrepreneurial skills. Entrepreneurial competences include, amongst others:

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opportunity recognition, opportunity assessment, risk management, creative problem-solving, value creation, and using networks [3]. Equipping students with these skills, in addition to soft skills, enables students to be more proactive and confident. According to [4-5], entrepreneurship education can be divided into three types according to its objectives: teaching “about”, “for” or “through” entrepreneurship whether it aims to increase awareness, encourage students or graduate entrepreneurs, respectively. These goals should be considered when integrating entrepreneurship into students’ curricula. Furthermore, it has been agreed that individuals, as entrepreneurs, can not only act alone but as well as part of a corporate system, instigating change/innovation within an existing business, generating economic, social and/or cultural value without necessarily creating a new organization [6].

Moreover, in the literature [7], the term “entrepreneurship” can frequently be found along with the terms “innovation” and “creativity”. Research work within the literature argues that creativity and innovation competences are inherent to entrepreneurial competences and can be learned and taught as a transferable “meta-competence” as part of the process of personal development within an educational environment [7]. The development of CIE (creativity, innovation, and entrepreneurship) competences in a holistic approach can contribute to improve an individual’s ability to face the current and evolving challenges of today, and become a “global engineer”.

One fundamental question is how universities will keep pace with the abovementioned trends in order to provide students with the most suitable curricula, skills, and facilities. Whether soft skills, entrepreneurship education, and related CIE competences are being incorporated effectively is still a question. But more importantly, there is an urgent need to take this analysis from the viewpoint of the most important stakeholder in education: the student.

Board of European Students of Technology (BEST) is a non-political, non-governmental and non-profit student association, counting more than 3300 members and reaching with its activities more than 1.3 million technology students of 95 Universities, each one represented by a Local BEST Group (LBG), through 33 European countries [8]. One of the main goals of BEST is to increase technology students’ awareness of educational matters, in order to help students with their self-development and to transmit input on educational matters to European higher education stakeholders by collecting individual opinions from students, the academic world and companies.

In this work we report the development of the students’ view on teaching entrepreneurship and innovation throughout the past thirteen years as well as the impact on current and future university curricula. Furthermore, the improvement of learning facilities was studied.

1 MATERIALS AND METHODS

Events on Education (EoEs) were created by BEST in order to raise awareness and involve students in the process of education improvement. EoEs aim to bring together European students with different cultural and educational background, professors and company representatives. Insights can be produced in an area where students are often seen as passive recipients and a broader understanding of the topic can be generated. Within the scope of emerging academic publications, the

students' voice can be amplified to be heard by professors, teachers and engineering educators all around Europe.

The following paper relates to four EoEs, whose topics were either directly or indirectly related to students' perspective on entrepreneurship and innovation. An EoE organised in Porto in 2017, gathering 22 STEM students had sessions where the next generation challenges and their solutions were discussed [9]. During an EoE in Ankara in 2015, the quality of their current education was assessed by 22 European students of technology in the sessions: "European Tertiary Education; Needs, Problems, Solutions" [10]. In EoE Ljubljana 2010, "Creativity and Innovation in University Settings" was discussed, among other topics [11]. Finally, at an EoE in Zagreb, organised in 2009, 25 European STEM students tackled the needs of developing entrepreneurship, innovation and creativity in the European Union [12].

A session of an EoE is a beforehand prepared time slot during which members of the BEST Educational Involvement Department act as facilitators. The role of a facilitator is to guide the session in an efficient and outcome-oriented way, encouraging everyone to participate without giving personal opinions. During the above-mentioned sessions, different kinds of facilitation methods were used, such as Brainstorming, Discussion Group, Sharing Session, World Cafe, or SWOT analysis. All these techniques were used to answer questions connected to entrepreneurship and innovation in European STEM Education. All the data collected during the sessions was processed in order to create the final extensive report of the event.

In addition to using the report texts individually, we performed a meta analysis by computing TF-IDF [13] scores for 34 reports of educational events organised by BEST. TF-IDF is a ranking method that is commonly used in information retrieval: it generates a document score based on the frequency of a term within a document and the number of documents in which this term occurs. A document obtains a high score for a term if the latter frequently occurs in the given document but is rare in other documents. Using TF-IDF rankings, we were able to identify the main topics covered by the events over time and vice-versa also find the most relevant events for a given topic.

2 THE STUDENTS' VIEW ON TEACHING ENTREPRENEURSHIP AT UNIVERSITY: PAST, PRESENT AND FUTURE RECOMMENDATIONS

2.1 Occurrence of "entrepreneurship" and "innovation"-related terms over the last 13 years

To get a first overview of how the focus on the topics entrepreneurship and creativity has changed over the past years, the relevance of BSE reports since 2005 was analysed using a search query based on the keywords "entrepreneurship", "innovation", "creativity", and "start-up". Figure 1 shows an overview of the document scores over time. It quickly becomes apparent that before 2005, there was no mention of any of these terms, whereas starting from 2005, the occurrence of the four terms is a lot more frequent. There is a large peak with the report of the EoE Zagreb 2009 – which explicitly covered the development of entrepreneurship, innovation and creativity.

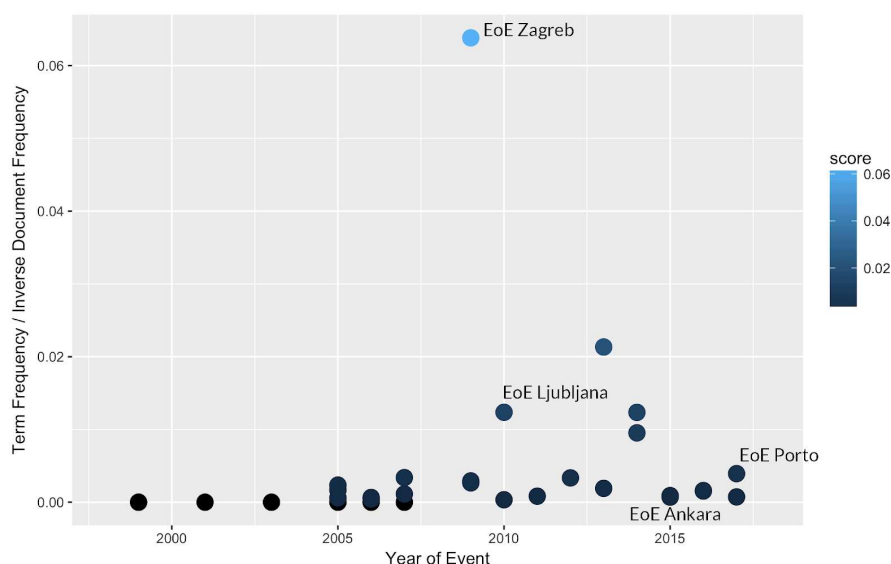


Fig. 1. Sum of TF-IDF scores BSE reports obtained for the search terms “entrepreneurship”, “innovation”, “creativity”, and “start-up”.

Related literature also shows an increase of importance over time. From conventional business education, entrepreneurship classes started to also be integrated into other study programmes and are now part of many curricula. Entrepreneurship continues to evolve and grow, as described in [7].

2.2 Entrepreneurship classes between 2009 and 2015

The next step was to compare this development to what students stated about entrepreneurship and innovation classes at their universities with respect to importance and quality. In the EoE Zagreb 2009 report, it was noted that “courses do not offer practical knowledge and that ideas and hands-on-work are what actually makes good entrepreneurs”. At EoE Ljubljana in 2010, students stated they wished for “better support of entrepreneurship at universities” and suggested that universities could “organise more practical projects, where students [do not only have to build] a prototype, but also make an evaluation if such a product could be commercialised”. Finally, at EoE Ankara 2015, students stated they would prefer to have “more creative and entrepreneurship courses”. None of the reports suggested that there were already enough entrepreneurial classes.

These results indicate that entrepreneurship does indeed not seem to have found its way into the average curriculum just yet or that it is still underrepresented. In addition, students seem to prefer a “for” or “through” rather than an “about” approach to entrepreneurship.

Similar trends were also identified in literature. [14] argues that there is a recognisable shift from teacher-centred to learner-centred methods: it is likely that in the future, there will be more practical and “active” courses available to students. In addition, Vincett and Farlow describe how experiential entrepreneurship courses can help improve business ideas [5].

2.3 Current university curricula and perspectives for the future

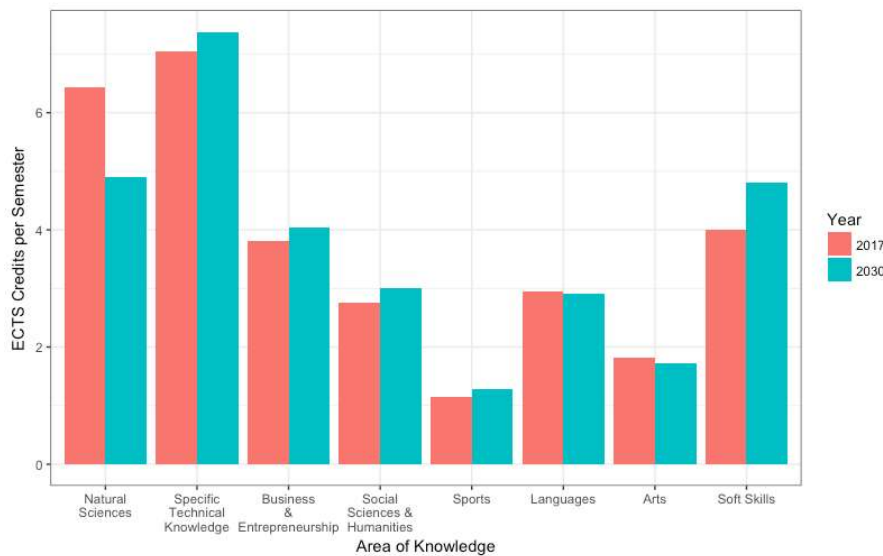


Fig. 2. Distribution of ECTS credits in the ideal curriculum for 2017 and 2030 from a students' point of view. The ECTS credits values represent the mean for each subject area, calculated from the curricula individually proposed by the students.

In Figure 2, the ideal present (2017) and future (2030) curricula that engineering students created at EoE Porto are summarised. Students had to allocate a specific amount of ECTS to the provided subject groups to make their ideal present and future curriculum. First, each student designed his or her own ideal curriculum. In the end, an overall mean for each individual subject group was calculated from all the curricula proposed by the students. The individual and group curricula can be seen in the EoE Porto report [9]. Less than half of the credits were awarded to *Natural Sciences* and *Specific Technical Knowledge*: this means that students attributed more than half of the credits to subjects not necessarily related to their field of study. The most prominent non-technical area, *Soft Skills*, obtained 13.2% of the ECTS for 2017 and 15.6% for 2030. It was closely followed by the area *Business & Entrepreneurship* with around 13%.

These numbers show that students do not only study in order to learn as much as possible about their subject; rather, they also want to develop other skills and thus be better prepared for their future lives.

Similarly, Edwards-Schachter et al. found that while “students seem to agree in the relevance of creativity in entrepreneurial contexts, educational institutions do not seem to promote it within their training plans” [7].

3 HOW SHOULD PROFESSORS PROMOTE ENTREPRENEURSHIP AND INNOVATION

Professors take a major role in shaping students to become a reliable workforce during their studies. In Figure 3, the position of the participants of EoE Porto regarding their professors is summarised. Around 75% of students agree that teachers do not help them being innovative or entrepreneurial and the majority of them think that teachers do not consistently teach them how to learn.

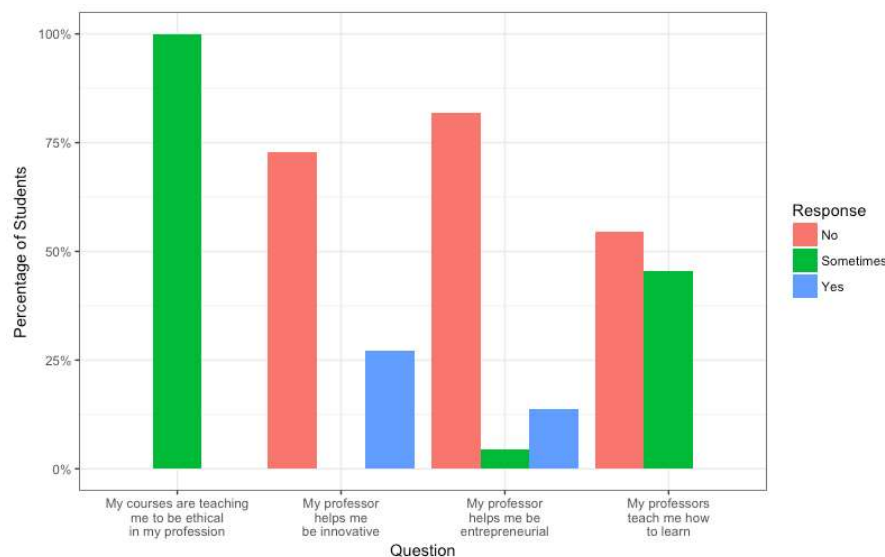


Fig. 3. Students' answers to specific statements on the promotion of entrepreneurship and innovation by professors.

Also in EoE Porto, students discussed how teachers may stimulate entrepreneurship and which teaching approaches to use while promoting the next generation challenges. A shortened version of the results can be seen in Table 1. For stimulating entrepreneurship, students tend to believe that connecting technical studies with business-related topics could be beneficial since several mentions to the business world are made (Table 1, left). As for teaching approaches, the trend maintains with company visits being mentioned (Table 1, right) besides the modern teaching approaches that are already incorporated in some university curricula (project-based learning, flipped teaching, skill-based teaching, seminars, case studies, etc.).

Table 1. Summarized results for the proposed solutions on stimulating entrepreneurship and teaching approaches to promote next generation challenges.

Stimulating Entrepreneurship	Teaching approaches to promote next generation challenges
Integrate business aspect in technical subjects	Company visits
Innovation incubators	Flipped teaching
Start-up mentoring by professors	Project-based learning
Pitching competitions with a professor as a mentor	Online platforms (e.g. Moodle) and MOOCs
Management classes	Research internships during studies
Management, law and design classes	Case studies
Internship in startups	Seminars / conferences
Promote exchange programs	

4 UNIVERSITY FACILITIES

Every year, more and more companies are giving attention to the architecture of the workplace. At EoE Zagreb, while on a session about Innovation and Creativity, students noted that if the worker feels more comfortable and happy at the workplace, he can be more innovative and creative with his work [12]. In an attempt to apply this concept to universities, the session “Next Generation University Facilities” took place at EoE Porto. All participants agreed that the facilities where they studied were important for their education and social life. In Figure 4, the most relevant ideas gathered while discussing university facilities taking into account students’ life and academics are clustered.



Fig. 4. Word clouds representing elements students would like to see present at their university both on the perspective of academics and students’ life.

It was understood that students desire to have startup incubators and open laboratories at their university. This indicates that some students would like to be more entrepreneurial, but the university does not provide the needed facilities.

CONCLUSIONS AND OUTLOOK

This research highlights that although entrepreneurship and innovation have become a more prevalent topic among students since 2005, the trend is not sufficiently reflected in present students’ curricula. Besides having more entrepreneurship and innovation courses, students also want to have more opportunities to acquire practical knowledge and experience on entrepreneurship throughout these courses. In order to foster entrepreneurship and getting ready for next generation challenges, students would like to see, from the university side, a better integration of business-related topics in technical studies, more company visits, incorporation of modern teaching methods, the inclusion of soft-skills in their curriculum and a bigger flexibility in the program of studies. To further improve the education in general and also to the development of creativity and innovation among students, university facilities are another important topic to be considered. Some specific elements to be included in university facilities were pointed out by the students but, in general, they have shown a desire for facilities that are designed to support them to be entrepreneurial.

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Use of agile methods in the education of engineering students

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Conference Key Areas: Innovative Teaching and Learning Methods, Teaching Creativity and Innovation, Engineering Skills

Keywords: soft skills, communication teaching, project management, SCRUM

INTRODUCTION

In this paper, first we present the project management methodology SCRUM as it is generally used in enterprise projects. Then we propose an adaptation of this technique to the context of education: we will call it SCRUM educational management.

Such an approach was applied during a series of classes in an engineering school. Its results - in terms of behavioural skills acquisition (soft skills) - are then presented together with some hindsight based on the feedback collected from this pedagogical experiment.

At the origin of the experiment, two premises: future engineers must acquire the necessary soft skills during their education and students are in need of a constant and enjoyable renewal of learning rhythms; with such context and its widespread use in the corporate world, SCRUM seemed like a good fit for its application in engineers' education.

In France, the accreditation agency for engineering education (Commission des titres d'Ingénieurs) insists on the fact that humanities and technical education must be integrated. The fact that a method used in software companies can be used for education of engineers is one example of this integration.

1 SCRUM PROJECT MANAGEMENT

1.1 Agility

SCRUM processes are currently widely adopted in private companies interested in so-called *agile* management. Agility advocates deploying a project management process based on the reactivity (capacity of adaptation in situations of change) of the actors of the project in favour of the final user (the client) of the envisioned product or service. It contrasts with a more classical approach to project management (relying on specification gathered up front and frozen at project start) in that it allows for a more flexible list of requirements that evolves and matures as the project progresses and new input from the client appears (his feedback, in an agile project, is very often required).

This methodology aims both at taking into account complex situations and at better satisfying final consumer. More information can be found in [1] and for a benchmark of agility among managerial trends see [2].

Agility is particularly interesting in the education of engineers because it forces to build bridges between hard and soft skills: when dealing with a complex project, it is necessary to adapt and student's skills will have to switch back and forth from technical ones to those more linked with personal development such team spirit, organizational capacity, empathy, good relations with the group.

1.2 SCRUM

SCRUM [3] is one specific method of agile management centred on the satisfaction of the end-user. It therefore relies heavily on constant collaboration with the customer as well as adaptation to evolving reorientations that this collaboration implies, this is realised through iterative steps that mark out the project management:

- a collaborative estimation (*Planning Poker*) in which self-organizing teams estimate the effort needed to complete tasks and subtasks

- sprints*: time-boxed work periods during which committed tasks are completed

- sprint reviews* and retrospectives during which the team can reflect upon the previous iteration in order to improve its process and obtain customer feedback about the features

- iterations allow a series of advances thanks to series of tests, till the complete satisfaction of end user

In SCRUM teams, some members play a specific role, such as the *Scrum Master* who is the facilitator of the group or of the project team, or the *Product Owner* who is in charge of the more precise definition of the needs of the final customer.

The word "scrum" comes from rugby, where many other metaphors come from in the methodology. For instance, during a scrum (at the end of a sprint), the ball is put back at the centre of the field and can, because of the scrum (interactions between the team and the client), start moving again in a completely different direction that was not initially planned and so reorient the remaining game [4].

The idea of precise timing (time-boxing) of the different phases of the project is closely related to SCRUM, so not only is there a start time and an end time - as in a classically-managed project with the traditional deadline – but also a series of intermediate milestones that split the

project in sprints whose end is a deadline with a debriefing necessary for going to the next step.

The final deadline can or cannot stay the same, but it is preceded of several intermediate deadlines that are decisive for the orientation of the project.

2 A PEDAGOGIC SCRUM

To benefit from the advantages of SCRUM method (group cohesion, adaptation to changes, customer orientation) while responding to educational aims, a pedagogic adaptation of SCRUM method was proposed to students.

2.1 Pedagogic objectives

The aim of the module concerning communication practical works (for first year undergraduate students) was to review several methods used for professional and scientific communication as well in oral form as in written ones:

realize a pitch for interpersonal presentation (to present a friend so as to value him),

realize a Curriculum Vitae,

analyse and reproduce specialised stylistic elements (such as an industrial patent or medicine instructions).

The duration of the module was of 7 sessions each of one being one hour and a quarter duration.

These very practical objectives had the aim to introduce some elementary soft skills for these new engineering students.

2.2 Pedagogic sprints

The usual duration of a sprint of SCRUM is between one and four weeks. Because of the specific format of the pedagogic sequence, it was necessary to reduce sprint duration, thanks to a specific time management called the Pomodoro technique [5]. It lays on a time splitting allowing maximal concentration on a short duration (25 minutes).

So, the duration of a pedagogic sprint was fixed to 25 minutes, during this time, students have to realise a predefined task of the project. A stopwatch was displayed on the screen for each sprint so that the student knows the time registration and can check time remaining for the task. During a practical work in Polytech, which is 75 minutes, it was possible to obtain 2 or 3 sprints leading to practical realisation of 2 or 3 activities linked to the project. On the global pedagogic module, it was then possible to realise between 14 to 21 sprints.

2.3 Team Building

The composition of project teams, depending on work atmosphere of practical works, was either free or defined by the teacher, we must precise that in a real SCRUM, this composition is realised after team building operations that aim to identify specific skills of team members to employ them at their best.

The teams of students were of 4 to 5 members and if the teacher had defined the groups he had used the knowledge of the skills he had detected previously.

For the realisation of the task assigned, students can use Internet and could access a specific digital work environment dedicated to this activity which had been filled previously by the teacher with useful documents in link with the sprint to be fulfilled.

2.4 Frame of the module

The module was composed in the following way:

- first session: presentation of the SCRUM method and of the expected results of the module
- second session: sprint 1 professional presentation of a group fellow with a deliverable which is a pitch of 3-minute duration
- third session: sprint 2 realisation of a Curriculum Vitae allowing to get a seasonal employment with a deliverable which is a one-page CV
- fourth session: sprint 3 description of the stylistic device of a scientific text (medicine instructions) with a deliverable which is a list of stylistic remarks
- fifth session: an examination in the pursuit of sprint 3 takes place, here the deliverable is the supervised limited time exam
- sixth session: sprint 4 understanding of an industrial patent text with a deliverable which is the description of the concepts underlying the frame of this text
- seventh session: debriefing of the whole module

For each of the sessions, the teacher is the customer (product owner); he has his own requirements and he asks to each project team to answer them in a definite time and to produce a precise deliverable. Teams of students self-organize during a quick brief, a supervisor for the group can emerge then he is the SCRUM master, if not the teacher acting as supervisor facilitates from time to time the group, he can also reorient it if it stagnates.

At the end of each sprint a debriefing of the sprint is organised with several different conclusions according to what happened previously:

- one of the project team (3 or 4 teams work in parallel) realises a deliverable corresponding to the expectations of the product owner (the teacher), then, all the teams can go to the next sprint after analysis of this deliverable.
- no project team realize a deliverable corresponding to the expectations of the teacher (this case is the more frequently met), then students together with teacher analyse the lacks, and the project is reoriented within a shorter sprint (15 minutes) so as to rectify the deliverable and then conclude the activity step to go to the following one
- all the project teams have realised, sooner than expected, the deliverable wished by the teacher: the product owner gives then a complementary instruction that extends the initial deliverable (for example if the deliverable is a CV, a more specific CV is asked, dedicated for the research of a job in a laboratory in a very precise structure with specific characteristics, this obliges the students to modify the CV to be more fitted to the new strict scenario)

Before going to next sprint, the teacher makes a synthesis of the new skills developed by the students; these new skills are the functionalities implemented in the classical SCRUM method: they are indicators of the project progresses and enlighten its degree of achievement.

At the end of the module, the teacher can also organise a SCRUM of SCRUM: in a meta sprint dedicated to the synthesis of all the newly acquired skills for the session, a deliverable which is a list explicating all these new skills.

3 ANALYSIS OF THE ACTIVITY

3.1 Skills acquired during the process

The students gain the classical hard part of soft skills usually afforded by this module that are: realise a pitch, build a CV, analyse a scientific text, but the use of SCRUM gives them more skills, we have identified them because we were able to observe students; these are:

- ability to solve complex problems
- creativity
- group work: sense of community
- empathy, sense of relational and group communication, team negotiation, team spirit
- ability to manage its own time and organisational skills

These soft skills have been acquired in situation, in link with the expectation of an external customer of which student did not have the time to study the profile and in the frame of an active learning in a very limited time. The pressure generated by a strict timing gives a fun aspect to this activity, as well as the freedom let to the team to organise itself, allows a large exploration of heuristics. Many different solutions are proposed at the end of a sprint and as several groups work in parallel, the debriefing allows a debate on those different solutions, allowing a choice between the different approaches. This final debriefing also allows acquisition on new skills laying on the ability to find the good choice of heuristics.

3.2 Assessments

The fact that the complete module is decomposed into several sprints allows to organise regularly assessment phases, those assessments can be realised on the deliverables because each sprint correspond to a deliverable, so it is possible to evaluate the project team on this deliverable.

For our experience, as many teams did not reach in time the deliverable, other ways of evaluation were chosen: one for the oral part of the initial pitch, the other one is a written evaluation on scientific stylistic. But in each of those cases, assessment criteria have been defined and negotiated with project teams during the sprint before the assessment as in the dialogue between engineers and product owner. This is a realistic way of assessment witch both respects the constraints of our HEI and the real life situation.

3.3 Gamification

The fun aspect of the exercise has really stimulated the students and this nearly “caricatured” way of splitting activities that is also encountered in Marshmallow Challenge [6]

or serious games seems really fitted to engineers education. It is an educational act which is not harmless because it is based on a permanent change ideology which is the one of real life: "Change remains the driving force of agility" [7]. Gamification is very used in active pedagogies and reveals to be a good strategy especially for undergraduate students. However, there could be, as for each pedagogy, students that are reluctant, but as pedagogies are different during the 5 years engineering studies the skills could be obtained latter by another method.

3.4 Improvement suggestions

Several improvements could be brought to this pedagogic SCRUM sequence.

As this method is very much used by computer science engineers, using an electronic planning is something that has much sense, furthermore electronic planning is very convenient to present the splitting of SCRUM activities, the objectives, milestones, realized items or elements to be acquired for each project team. This electronic planning could also be a good backlog for each team

Before the real beginning of the module, it could be interesting to have a more important phase for team building with skill assessments between students. This could give more efficient teams.

Merging the team backlog and the sprint memo: the entirety could "a posteriori" become a lesson that the student can keep.

There is a real need to make a link between pedagogic SCRUM and corporate SCRUM. This could easily be done because this method is really very much used in companies; in France people from companies must intervene at least for 25% in the education of engineers, so it would be easy to find an engineer able to speak about its job. Concerning the education of the teachers realising the course it could also be a real mutual enrichment.

Can a sprint of 2 weeks be compared to a concentrated effort of 25 minutes? We think so thanks to the micro sprints concerning the subjects treated in this module, this could be more difficult on more technical subjects.

CONCLUSION

This paper presents an experimentation realised with engineering students, it is not very frequent that a method currently used in companies be applied for pedagogic aims.

Even if the pedagogic SCRUM is not exactly the same a SCRUM used in companies because of constraints of time or of the necessity of assessments, the major elements of an agile method have been kept.

Specific soft skills can be developed thanks to SCRUM such as the ability to adapt to changing constraint, the respect of time that are those of real life in companies. Soft skills usually developed through classical pedagogy by project can also be the result of this experimentation.

It is important to notice that this experimentation, led with a professional tool, has been conducted by a non-technical teacher on subjects considered by technical teachers as collaterals. This show the necessary transdisciplinary skills of teachers to educate students on transdisciplinary fields.

The adaptation of SCRUM for pedagogy on a small size model with different purposes than those of companies has needed crutches such as the mix of SCRUM and Pomodoro (also used in companies) for the timekeeping of activities: activities become micro-sprints that can be organised during practical works and are more fitted with temporality of young people [8].

This sequence could take advantage of the presentation of real SCRUM by an engineers giving to students another ability which is to project themselves in real life after having played.

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Introduction course considerations for supporting graduate students in PBL practices

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Conference Key Areas: Curriculum development

Keywords: BL, Course Development, Graduate Students, Introductory Course

INTRODUCTION

Universities working with problem-based and project organized learning (PBL) are likely to face a challenge when introducing students to its methods, practices and potentials, not least for graduate students coming from non-PBL undergraduate education programs. Each summer, 83% of the graduate student intake at Aalborg University Copenhagen (AAU) stem from undergraduate diplomas from other universities. Most new graduate students therefore lack experience with the PBL-based, project-organized 'AAU model'. To prepare these students, since 2014, AAU study regulations dictate an introductory PBL course for all non-AAU-bred graduate students, running 3 lectures over 2 months, as mandatory across all graduate programs. Despite huge differences in educational direction between programs, as well as previous experience with PBL practices between students, the study regulations have locked the course on a standardized model across all programs, from a one-size-fits-all perspective. The goal of the course is mainly to prepare new students for their practical application of the AAU Model, e.g. in collaborative project work in groups, but struggle with a handful of issues. For example, the course has favored an abstract and theory-driven approach, rather than skills and understanding which would allow students to apply the AAU Model principles in practice, and work with other students who are already familiar with the model. Another issue is a general disregard for the possibility that new students have previous PBL experience, even if not with the AAU model. These issues have formed a disconnect between the course and students, and resulted in low student engagement and interest in the course, as well as a lack of trust in the AAU PBL approach with many new students. Meanwhile, in the latest iteration of the course development, PBL Intro teachers across 9 different study programs, have worked to revise the course ideology and content. This saw its pilot application implemented with 4 study programs, with the aim to make the course practically useful, establish a connection between students with and without previous PBL experience, bring an understanding of the advantages of the AAU model of PBL, and to introduce the necessary skills and considerations for practical application in students' project-based group work. In this paper, we describe the transition to new PBL introduction course approaches, and discuss the effects, based on teacher and student evaluations.

1 BACKGROUND

AAU has developed principles and models for Problem Based Learning and project work (PBL) since 1974. Graduates have been educated to solve problems, engage in cooperative relationships and communicate with different actors in a globalized labor market [1]. The commitment to PBL is highlighted in Aalborg University's strategy [2] as a fundamental

principle for all study programmes. On a practical level, this entails that PBL is embedded in the organization through (among other things) a systematic introduction to PBL at undergraduate - and now also on graduate programmes - to ensure that the AAU PBL model is an explicit learning outcome with all study programmes.

1.1 AAU Model for PBL competences

Many AAU students (especially graduate students) come from an international background, which supports AAU students experience not only nationally-based, but also internationally oriented problem-solving, collaboration and communication, which has been highlighted as competences for a future workforce. Holgaard, et al. [1] also distinguish between two sets of competences; *profession-specific competences* related to the theoretical and methodological mastery of a profession, and *PBL-related competencies*, such as the ability to analyze a problem, the acquisition of flexible knowledge, effective problem-solving skills, self-directed learning skills, and effective collaboration skills, which all are aligned with 21st century skills [3] [4] [5]. The AAU model reflects this in how students have a) courses specifically aimed for field-specific competences, and (b) a semester project where students are required to practice the aforementioned PBL-related competences such as include abilities to identify problems, work interdisciplinary and apply project management skills [2]. The focus on group-based project work in the AAU model is based on constructivist and social learning theories, and rely on scholars who have variations between the understandings of learning, but where all emphasize that learning is based on real life problems. [6]. These considerations are at the core of the group-based, project-oriented focus in the AAU model. While used in course teaching, the semester projects are where they get students develop their primary PBL competences, with years of applied experience with PBL praxis.

1.2 PBL skill development for AAU undergraduate students

One of the challenges for the PBL intro course, has been to align new graduate students with graduate students already having an undergraduate background with AAU. Undergraduate AAU students start their PBL journey on the 1st semester. A 5 ECTS introduction course spans the 1st semester, with lectures on PBL theory and practice, project planning and management, groupwork-oriented communication methods, conflict management methods, academic project dissemination, reflection paper dissemination, etc. In addition, each student receives 6+ hours of consultation work from a select group of teachers, to further improve their understanding of- and relationship to PBL practices and project work, over the 1st year of studying. Undergraduate student practice these skills, primarily through project work throughout the bachelor program, but new graduate students need to acquire and represent similar skills very quickly, to work with previously embedded AAU students. The project work which is the central hub for PBL practice, are set to a 15 ECTS workload each semester, per student. The problem- and project processes (-focus, analysis, -definition, -solution design and development, and -evaluation) are key to working with the curriculum under the AAU Model, as the semester courses' curricula are expected to be included in the project's academic focus and practice. While project groups have an academic supervisor, the success of the project depends on the choices students make (self-directed learning skills, and responsibility which students take for that learning process). It is on this foundation, that student improve their ability, and acquire their educational background; being able to put course curricula into practice, by using knowledge, competences and skills to define and solve a problem. At the same time, students will need to understand the relationship between performing study activities as a group, while being evaluated individually at exams. Compromises between personal preferences and interests are inevitable, and students need to weigh the pros and cons, as well as take personal aim at which parts of a collective work-effort, they will want (or need) to represent at individual exams. Through their undergraduate program, AAU students experience at least two things a) that the PBL-approach to studying becomes completely integrated with the experience of being a university student, and b) the level of their PBL skills become instrumental to develop the level of their academic skills.

1.3 History of the AAU PBL graduate student introduction course

For graduate students coming from outside AAU, the just described PBL study environment of AAU has been complicated to fully utilize, unless they a) have prior experience with similar working conditions, or b) are able to adapt very quickly. Prior to 2014, there was no help for new students, other than what they might get from fellow group members or (in some cases) the supervisor. The 'PBL introduction course' was launched in 2014 to bridge the PBL gap. From 2015 onwards, the course was gradually formalized, standardized and implemented within all master programmes under the Faculty of Technology and Science. In 2016, a 3-lecture (1 ECTS) course was fully established in its formalization and standardisation, with centrally specified content sequencing for each individual lecture, and including pre-produced slides offered across all programs. Meanwhile, for some teachers, the course format left a lot to be desired, as explained in the Introduction to this paper, and which led to the current revision, from 2016 to 2017.

<p>Learning outcomes intro-day:</p> <ul style="list-style-type: none"> • To be able to describe what PBL is as a learning approach at AAU • To be able to describe collaborative and planning perspectives of PBL • To be able to describe and understand plagiarism • To be able to declare and justify an initial individual challenge when using a PBL approach <p>Learning outcomes challenge-day:</p> <ul style="list-style-type: none"> • To practice PBL in a reflective team • To declare and justify an individual challenge and work out a plan how to deal with it • To develop and practice peer feedback skills <p>Learning outcomes evaluation-day:</p> <ul style="list-style-type: none"> • To reflect on PBL practice • To practice presentation skills • To practice critical skills when giving feedback to peers
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Figure 1 Overall themes for the course

2 CASES

In this part of the paper, we will look at the PBL Introduction course as it was structured and run in respectively 2016 and 2017, specifically focusing on the course run for graduate students from the four programs. Initially, each case will be addressed on a descriptive level, from both a topic-quantity and a content perspective. From there, a summary of the course evaluation of the 2016 course will be presented, to roughly inform the changes made for the course in 2017. This will feed into an analysis on the changes between the cases, explaining the reasoning for the transition between 2016 to 2017. Following the analysis, the paper will continue by addressing and discussing the results of the 2017 course.

2.1 PBL Introduction course 2016

The pre-designed slides of the 2016 *lecture 1* had students go through an extensive collection on everything in the AAU PBL model (content themes can be seen in Figure 1). Examples include bullets, terms, models, theories, frameworks, figures, images, approaches, exercises, examples, assignments, discussion topics, practical information, etc. Main topics included 'what is PBL', the AAU Model, AAU PBL principles, unique AAU features, group-based project exams, former student experiences, current graduate student experiences, problem orientation, project planning, project management, scientific writing, referencing, plagiarism, cooperation in groups, thinking models, personality types, learning styles, learning test, team roles, supervision, facilitator (supervision) styles, group work, and PBL challenges. In-class exercises were one 2-minute pair-discussion (on individual group roles), a 3-minute active listening trial, and quiz on plagiarism. For homework, students were asked to prepare a 1st draft of a '*personal PBL challenge*' written reflection assignment, based on their individual thoughts on the lecture content, and send it to the course teacher for comments. As a response to this 1st lecture format, a body of students in 2016 filed an official complaint, asking to be removed from the course. It was described it as a waste of time, based partly on the fashion of marathon format, and what was perceived as simply a repetition of PBL content, which many students claimed to already know from previous education. In this case, course merit was not an option. In response, teachers sent out a survey to map students' needs, so the last two lectures might also address or focus more on those.

Lecture 2 only 2 new topics were (briefly) introduced; reflective peer-feedback, active listening. Continuing the format of the standard slideshow, the dominant part of the lecture was a single, in-class exercise, focusing on 'peer-discussion' (conversation between students),

meant to be a reflection space for the development of their individual 'personal PBL challenge' from lecture 1. For homework, students were asked to simply correct their 'personal PBL challenge', based on the peer-discussions, and send the new version to the course teacher.

Lecture 3 had no new theoretical content (all repetition from lecture 1 and 2). Most of the lecture was once more based on group peer discussions on the 'personal PBL challenge', though it addressed the points from the survey which were not addressed in the 2nd lecture.

An extra addition to the two last lectures, was a list of a topics based from the survey related to their official complaint. The topics were split in two, and addressed in the end of the two last lectures, focusing on what students found to be relevant to develop their AAU Model skills.

2.2 2016 PBL Introduction course evaluation

Students were very negative about 1st lecture, the written homework assignment and stale nature of the much too lengthy 'peer-discussion' process. However, most students had positive comments to the list of topics made from post-complaint survey. Especially an approach to handling conflicts, was deemed interesting and useful, as many students reported to have issues with other group members (ironically, often students with AAU-based undergraduate PBL backgrounds). In this relation, students reported enjoyment with the discussions orchestrated the teacher a lot more, than discussing their 'personal PBL challenge' with each other. For exactly the reasons that students liked the list-based discussion, students disliked the course on an overall level. The rest of the course had a contrasting poor connection (if at all) between the course contents and what students felt they could utilize in practise. The 1st lecture had too many topics, which were either abstract/philosophical or shallow, and never touching on practical issues or application methods for life as a student, and 2nd + 3rd lecture were simply students talking to each other, instead of learning from the teacher. Due to how students' expectations to the course were not met, students felt that it even increased the sensation of disconnect between AAU and non-AAU bachelor students. Many students considered it a waste of time and only attended because they had to pass to graduate.

2.3 PBL Introduction course 2017

Based on the experiences with the 2016 course, and similar complaints from evaluations across similar course runs, teachers across 9 programs redesigned the approach, eventually becoming a pilot-study on the four programs that had previously received the official complaint. The redesign included all themes from 2016 but had them spread out on all 3 lectures. The course also focused on less breadth, more time for depth and placed heavy focus on the topics requested by the 2016 student survey.

The 1st lecture, besides a small introduction to the course, only had 4 main agenda parts. Main topics included a) results and analysis of a PBL-based survey given to the students prior to the lecture on their previous PBL experience, b) the AAU model, c) PBL in projects, and d) a few project planning/management tools. Moreover, study groups were formed for in-class (between students across programs, not familiar with each other) and homework exercises on the PBL course. For homework, students were assigned to an individual Myers Briggs personality test and asked to write a 1-page reflection on how their results could potentially influence their project work at AAU.

The 2nd lecture had 8 agenda points where 3 were larger exercises in the study groups (not a repetition from previous lectures). Main topics included an in-depth look at the Myers Briggs test purpose and value, group-oriented communication, and group-oriented conflict management (each a theoretical and an applied part). The three in-class exercises included: to map the study group's strengths and weaknesses based on Myers Briggs results and Belbin team roles, to practice active listening in 3x10-minute sessions + 10 minutes reflection, and to write a 'code of conduct' collaboration document.

The 3rd lecture had 8 agenda points (where 3 were in-class group exercises), of which some were repetition for reflection on gained experiences over the past 2 months. Main topics included a revisit to the PBL statements included in their 1st lecture survey for new reflections, the AAU model revisited, project examination at AAU, and a course discussion/reflection. For exercises, groups were given 2 preparation sessions to perform a 3-minute presentation on their

opinion on a list of topics, already introduced once in the course (prep session 1: group profile for Myers Briggs/Belbin, collaboration agreements, central PBL experiences from their individual program/project until now; prep-session 2: central PBL experiences from the course, central topics they would have wished more focus on from the course). For a final homework, students were asked to make a 10-point list of a collaboration agreement for group work, a 500-word reflection on its usefulness, and another 500-word reflection on communication and conflict management challenges found interesting or personally constructive, from the lecture discussions.

3 COURSE REDESIGN - MAIN CONTRIBUTING POINTS

In the following, we will list and discuss the main considerations on the revised 2017 course, and elaborate on their effects.

Sending out an initiating survey about students' experiences with PBL and project work and using survey results to introduce the 1st lecture.

In the 2016 course, students reacted to content related to feedback on their own experiences and needs. A survey, sent out prior to the 1st lecture contained items related to their previous experience with PBL, including (but not limited to) past projects' lengths and group sizes, examples of group work experiences, their opinions on the most important, valuable, most challenging, and most overlooked aspects to project and group work. The survey results showed that many students in fact had experience with PBL, project- and group work, but qualitative responses showed that many lacked experience with the scope of AAU semester projects. Qualitative responses also showed that many students had frustration on how past projects or PBL-work had been managed, and that students lacked depth in their understanding of communication and conflict management. The discussions afforded by the survey results, gave the lecture a lot of focus on the task at hand (for the course lectures), and had students talk a lot about risks, dangers, positives, advices, central considerations, etc. It constructively set the stage to introduce how AAU worked in regards to the survey responses, what they would most likely experience as AAU students and what the course would address. Another thing which the survey afforded, was to stimulate students to discuss openly, by bringing themselves and their own experiences into play. From the discussions on pros and cons to various situations, students also appeared to become fairly comfortable acknowledging experience lacks in certain areas. It created an open attitude for both students with- and without PBL experience to share thoughts and ask questions, as neither found themselves having perfect knowledge. The initiating survey was a huge success. It turned the differences in students' PBL experience into an asset for discussion, instead of an issue of being different.

Delimiting the course content based on what is applicable for students in their program practices, and with a synergetic, shared focus between topics.

Due to the quantity and spread of topics addressed in 2016's 1st lecture, the quality (depth) of topics was not possible to realize. No time was available to properly address and explore e.g. the typical contexts or applicability of central aspects to the AAU Model, and students rarely showed understanding or acknowledgement of these aspects if asked. Based on the 2017 lectures, it was apparent that including fewer topics, with more time to explore them, allowed the necessary exploration and in-depth discussions, for students to realize the importance. It enabled more time for examples on situations and application areas for e.g. a conflict management method, gave time for more in-class exercises, and time for sharing of experiences from both teachers and students. All aspects which appeared to evolve students' understanding.

Project writing and report structure

To give an example of a central topic to introducing the AAU Model, the 2016 lectures lacked any focus on how to understand and undertake an AAU PBL project, despite being a quintessential part of AAU education. No attention was placed on how to practically approach the structure of it, and how to understand the use of the PBL principles, to form and guide the underlying logic of the project. For that reason, with the desire to focus on practical application of all course content, the 1st 2017 lecture used the project report structure as practical base, to explain the fundamental principles of AAU PBL.

Frequent, including 'long', in-class exercises

To strengthen the practical application potential, any central themes should receive practical, in-class exercise time. In 2017, students were often asked to talk for 2 minutes on certain topics or smaller questions (to induce curiosity). Spending more time with certain themes, however, was deemed necessary to understand their nature. One example is the 'active listening' exercise, where students spent 40 minutes practicing how to communicate constructively with each other. The point of the exercise was to illustrate the difficulties of performing active listening without deviation, but also how far into conversation topic it is possible to explore, if performed without interruption or premature presumptions from the receiver. This exercise received a lot of attention and reflection from students afterwards. Most students had never been allowed to talk about own opinions (or vice versa withhold opinions) for this length of time, which was an eye-opener for many. The challenge, and the necessary time available, seemed to make many appreciate the complexity behind the exercise.

Homework based on the progression of course content, and have it form a development for students' understanding, to also support the importance of the upcoming course content.

One of the issues related to the 2016 model, was how the written homework assignment 'personal PBL challenge' only changed minimally between lectures, and never evolved. No new perspectives were given between the 1st and 3rd lecture from the course itself. However, students were still asked to improve the document as homework between lectures. Student engagement went stale as a result. As a response, homework assignments in 2017 followed a progression, starting with students building a profile for themselves (Myers Briggs), from which they should work to understand both their own and profiles of other students. This progressed into applied practice, making e.g. collaboration rules and agreements, as well as analyzing potential strengths and weaknesses of different project group constellations.

For PBL-based, project-oriented homework and exercises, base students' time working on understanding tools which can be used by students individually and be aimed to improve their collaboration with others.

As an example of this, it became apparent to the *students* (which is an extremely important realization) during the 2017 course, that they lacked a fundamental understanding and tools to approach aspects of project work, such as communication and conflict management, through use of personality profiles and team roles. Group-based communication and group-based conflict management skills are essential for AAU students, and topics the 2016 course only briefly addressed. From working with the personality profiles and exercising the active listener, students seemed to be well inclined to acknowledge why certain situations could reach a high complexity level, from the appreciation of the complexity of a group's collective profile. And why methods used to address e.g. conflicts, needed to be simple in their approach to be useful for unfolding the complexity of e.g. a consensus-making conversation. (e.g. on how to approach a part of the project) between several (individual) profiles. Or even more complex, the handling of a conflict-oriented situation between contextually opposing personalities.

Spend time making good, simple and interesting slides.

A thing not addressed by any evaluation, but something that became very apparent to teachers, was the effect of slide design. The 2016 slides were approaching what Garr Reynolds would classify as "death by PowerPoint" [7]. Too much text and no visual/auditory dynamics, were likely contributors to the disconnect from students in 2016. Slides for 2017 were redesigned from a 'less (per slide) is more' priority, along with a "high-quality, image-based" visual slide design approach. Small thing, but useful.

4 2017 COURSE EVALUATION

To finally evaluate the 2017 course, a course evaluation was made for each individual student to respond, focusing on the three basic measures on the course experience; most important experiences, impact from the course, and possible improvements. This evaluation method was open-ended and explorative, to avoid leading onto any specific topics or perspectives.

The most important experiences from the PBL course this semester:

The most frequently mentioned topics addressed group dynamics related issues. Especially highlighted was the identification of skills and abilities, using the insights from personality traits and identification of team role profiles to inform group forming. For adjusting expectations, the collaboration agreement was mentioned as useful. The communication approach of active listening was mentioned several times as a tool which was found impactful on discussions. The necessity for compromise in group work was also acknowledged as valuable, also in relation to the having to work with people from many different backgrounds, and having a grounded approach to debating group work was highlighted as useful. In relation to practicing a PBL approach, students had found using PBL methods to solve a real-world problem very interesting. Also mentioned was the realization of how to actually implementing the PBL principles in the semester project and work with problem-based questions. On a note, structuring time was mentioned as important.

Experiences where the PBL course had an impact for you and your group members:

Group dynamics was quite in focus here, e.g. in relation of developing group rules, group contracts and bringing structure to the group. Also mentioned several times was the reflection on group members' strengths and weaknesses, and analyzing skills 'professionally' (as it was discussed how industry uses profiling to set project teams). Communication methods such as expectations management and tools for group discussions made an impact with several students. Also making an impression was using the course methods to observe other graduate students (not course participants), and how they were having noticeable problems with miscommunication and conflict-inducing misunderstandings during group work. Allegedly, this had led to critical situations and highlighted the necessity (for these PBL course attending students) of conflict management skills. Some students mentioned how they had felt a larger sense of responsibility for their project and group work. Project management was mentioned in terms of how to formalize group meetings, and use what they called 'retrospective meetings'. These were explained as 'going back' and reflecting on the what had been happening since last meeting, and why. Task management was also mentioned briefly. The PBL project structure and structure the report was noted as useful, and made an impact for some students. One group noted, a bit surprised, that they had witnessed 'none!' of the course teachings in their fellow 'AAU-native' group members. The presentation of this experience was clearly accompanied by a certain disbelief.

Experiences that you would have liked the PBL course to give you more info

Most responses related to more real-world cases and examples of the topics addressed during the course, such as more anecdotes to explain and unfold group dynamics, case studies from literature and more real-world examples of problems, which would allow some more concrete discussions and analyses of real project problems of the past. Similarly, students mentioned that they had enjoyed the explanation of the project report writing and would like a workshop on writing reports. In addition, they requested more possibility to use their semester project report, as base practice material for the content of the course. More tools for group work was mentioned, without real specification. Others mentioned more specifically, a need for more time with conflict management, with one example being how to manage so-called 'free-riding' group members. More discussion management tools were also requested. For the PBL Introduction course specifically, students would like even more time for exercises, and many mentioned that that lectures should come earlier, so the content would be useful earlier - especially before their semester project group forming, in order to use the tools, they had received.

As for miscellaneous remarks, feedback pointed towards the course having been interesting and useful in many ways, and indeed relevant as a preparational class towards project and group work. Some even thought it was too bad the course was not graded.

5 CONCLUSIONS AND PERSPECTIVES

Comparing the changes described to the 2017 course, to the student evaluations, it seems that many of the topics prioritized in 2017 made positive impressions among the course attendees. This is a big difference from the problems faced in 2016, and the 2017 course has seemed to solve some of the issues that was dominating the previous year. A focal point of the change, was to see if student engagement, could be obtained within a model that needed to be useful across several and very different programs. The method for ensuring this was to redesign the course, to focus on fewer things, with a more in-depth treatment of them, and with everything angled for practical understanding and application, as well as time for reflection with both teachers and fellow students. These aspects seemed to strengthen the teaching, and take to course impact in a positive direction. Some structural changes were made as well, which streamlined the content division between lectures, and provided a more progression-based logic to lecture and homework sequencing. In relation to students learning outcome and rating of the course, the learning outcome seemed to reflect the course content, show curiosity to many different parts of the course content, and generally suggest improvements to students' interest and engagement in the course. It also seems that the course was considered quite useful with many of the participating students. Some even wanted the course graded.

While challenging, it seems that it is indeed possible to design a PBL introductory course for graduate students, which is able to catch their interest and reflect their experiences of studying at a PBL based program. We believe the structure successfully remains a “one size fits all”, but also one that allows for individuality, meanwhile based on the students themselves, more than the field-specific program which they study. During student activities (discussions, exercises, homework, etc.) they become co-designers of the details of the course, while remaining within the learning goals of the course. The fact that some students became able to observe and surpass 'AAU native' graduate students, in their ability to observe and analyze behavior during group work shows promise for future iterations of the course.

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Outcomes of an online practice exam utilising Confidence Based Marking

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Conference Key Areas: Curriculum development, innovative teaching and learning methods

Keywords: Assessment, multiple choice, confidence

INTRODUCTION

Since their inception over 100 years ago (Goodenough, 1950), tests and exams constructed using Multiple Choice Questions (MCQs) have been widely used as a form of assessment in higher education due to their high level of reliability, versatility, efficiency and ease of marking (Roediger III & Marsh, 2005). Despite the wide usage of MCQs and detailed published guidelines for their construction (Haladyna, Downing, & Rodriguez, 2002), there remain inherent limitations such as the difficulty of detecting the guessing of answers (Burton, 2001), the inability to test higher-level cognitive functions and the lack of opportunity for a student to show the working used to obtain the selected answer in order to obtain partial credit (McAllister & Guidice, 2012).

The basic, most common form of MCQ, the “one correct option” style, has been adapted over the years to spawn a range of types that attempt to address the inherent limitations in such a scheme (Rowley & Traub, 1977; Albanese & Sabers, 1988). Alternative grading schemes have been utilised such as allowing more than one correct answer, weighting answers according to their quality and negative marking for incorrect answers (Siddiqui, Bhavsar, Bhavsar, & Bose, 2016). Despite these measures there is still a perceived unfairness in MCQs (McCoubrie, 2004), where students can still obtain a correct answer through an amount of guessing and process of elimination, rather than through the intended cognitive process being tested.

An alternative method to combat some of the aforementioned shortcomings in the use of MCQs is to require an extra metric to be provided with the response to each question indicating the confidence that the student has in their selected answer. Confidence-

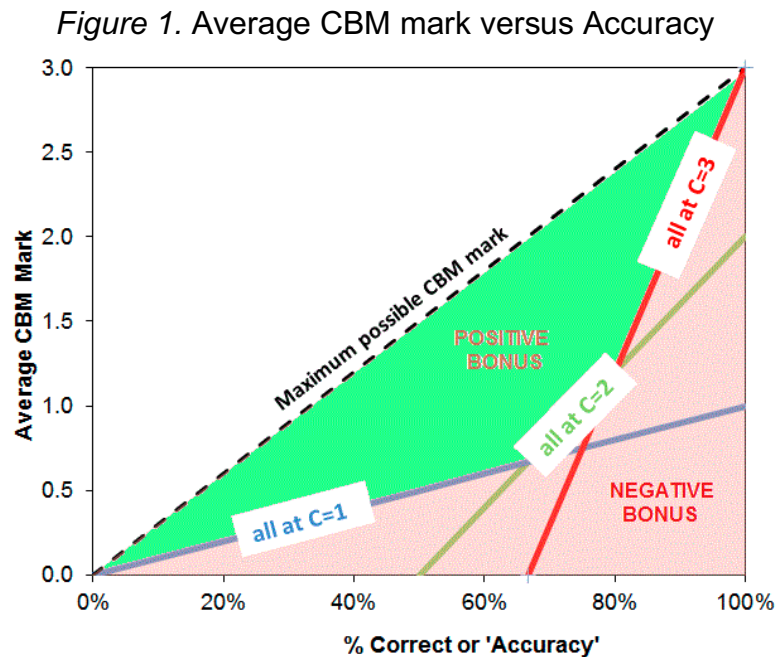
Based Marking (CBM), in which a student must indicate their confidence level in each answer and be graded according to a suitably designed marking scheme, helps to encourage reflection, justification and rigour (Gardner-Medwin, 1995). It rewards both justification to the point of high confidence and the ability to identify reasons for reservation about an answer, and therefore encourages a more rigorous approach both to learning and assessment (Bryan & Clegg, 2006). Students' misconceptions are highlighted when they receive the feedback and the system is perceived as more realistic and fair in that it eliminates a large amount of guessing.

This paper describes the implementation of a CBM MCQ test in a first-year engineering subject through an online practice exam, held in the final week of semester. Feedback was provided to students on their accuracy, measured as the number of correctly answered questions, and the reliability of their assessment of their knowledge, through a CBM-weighted mark and calculated bonus. The goal of the practice exam was to identify individuals' strengths and weaknesses in the subject material in order to guide their study in the Study Without Teaching Vacation (SWOT Vac) period and during the exam period. Data was collected on the performance and confidence levels for each student for each question and analysed to identify relationships and differences across sub groups of students.

1 CONFIDENCE BASED MARKING

To alleviate some of the inherent shortcomings of MCQs and increase the quality of the feedback provided to the students heading into the exam study period, the online practice exam implemented CBM. When using CBM with MCQs, students are asked to state with each answer their level of confidence, C , in the correctness of their decision – $C = 1$ (Low), 2 (Medium), or 3 (High). If the answer is correct, then this is the score awarded. An incorrect answer leads to a score of zero for level 1, and -2 or -6 for levels 2 and 3 respectively. Level 2 gives equally weighted negative marking for wrong answers. Students are told to choose level 2 unless they are very confident (>80% chance of being right), when they should choose level 3, or rather hesitant (<67% chance of being correct), when level 1 is appropriate. This strategy is optimal to maximise their expected scores. The expected average CBM mark for a given percentage correct, or accuracy level, for the three confidence levels is given in *Figure 1*. A student can never expect to gain systematically by either overestimating or underestimating confidence. High marks are obtained firstly, of course, by getting the answer correct.

A bonus is added to the simple accuracy as a measure of how well the student categorises responses as uncertain or reliable (Bryan & Clegg, 2006). The bonus is positive or negative, proportional to the amount the average CBM mark is above (or below) the average that would be obtained if the student had used the same optimal C level for all of their answers as shown in *Figure 1*. Negative bonuses are common in self-tests when students often have misconceptions (confident errors), but students should aspire to gaining positive bonuses of 2-5%.



2 IMPLEMENTATION OF THE PRACTICE EXAM

In order to take a snapshot of the students' knowledge and provide them with this feedback, they were required to complete an online practice exam worth 5% of the total subject assessment in the final week of semester. The format of the practice exam closely resembled the actual end of semester exam, which is comprised of 40 one correct answer MCQs (40%) and several short answer questions (60%). Completing past exam papers is a relatively common observed method of study for students, however most tend not to complete them under strict exam conditions, for example in study groups. Furthermore, as a matter of policy the School of Engineering does not provide solutions to past exam papers which may shape students' study habits with past exams. Students were encouraged to complete the practice exam under realistic exam-like conditions and would receive direct feedback, obviating the need to provide solutions to past exams. In addition, becoming accustomed to the format, length and difficulty of past exam papers acts as a means for students preparing themselves for the final exam. The added benefit is that taking a test generally improves students' performance on a later test; this is referred to as the "testing effect" (Kuo & Hirshman, 1996).

The online practice exam comprised of 40 multiple choice questions utilising CBM, worth 5% of the final subject assessment. The format of the practice exam was chosen to closely resemble the format of the multiple-choice section of the final exam, in terms of both content and number of questions. This similarity would ensure that students were provided with an accurate instrument to assess their knowledge and indicate their potential final exam performance. Some questions were parameterised to dissuade students from sharing answers. Students could review their answers before submitting their exam to be electronically graded.

The practice exam was administered in the final week of semester. In 2015 and 2016, students were to complete the exam within the week with no time limit, whereas in 2017 students were limited to a total time of 90 minutes. This decision was made in order to ensure that the students were completing the practice exam under exam-like

conditions and not treating it as further continuous assessment such as an assignment, where the goal is to try to maximise one's mark rather than assess one's knowledge. Feedback was provided to the students immediately upon the exam closing at the end of the week and was provided for each question in the form of their selected confidence level, their selected answer and the correct answer. Summary feedback was provided in the form of their accuracy score (raw percentage of questions correct), CBM average score and a bonus-adjusted accuracy score.

3 RESULTS

Students who did not complete all 40 questions on the online practice exam were excluded from the following analyses. Repeating students only had their first attempt counted when comparing across years.

3.1 Overall practice exam performance

Figure 2 shows the performance of the 2304 students that fully completed the online practice exam over the three semesters it has been running. The dashed line indicates the maximum possible CBM score for a given accuracy level (percentage correct), which would be obtained if students (unrealistically) selected high confidence for every correct question and low confidence for every incorrect question. The solid line indicates the average CBM score that would be obtained if the student had used the same optimal confidence level for all of their answers. Accuracy scores would receive a bonus proportional to the amount the average CBM mark is above (or below) this line. It is clear that most of the CBM scores are above this line, although there are several extreme outliers.

Figure 2. Online practice exam results 2015-2017 (N=2304)

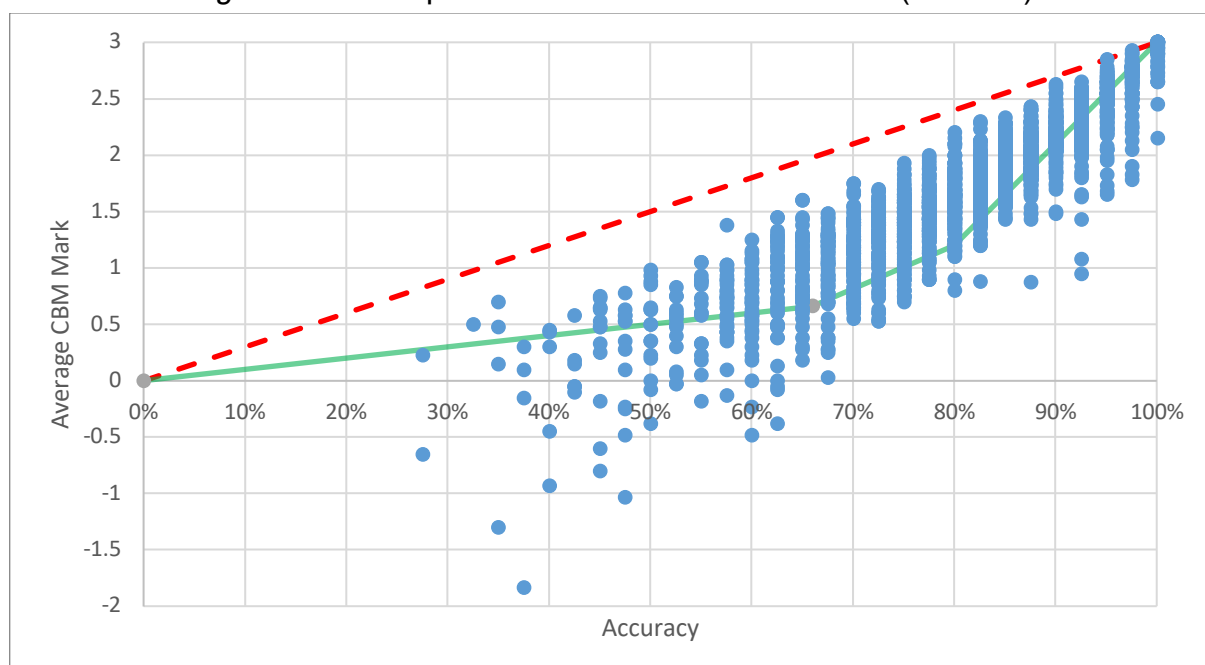


Figure 3 shows the CBM adjusted accuracy score, where most students received a positive bonus (point lies above the dashed line), indicating that to a large degree their confidence levels reflected their accuracy.

Figure 3. Online practice exam CBM adjusted accuracy (N=2304)

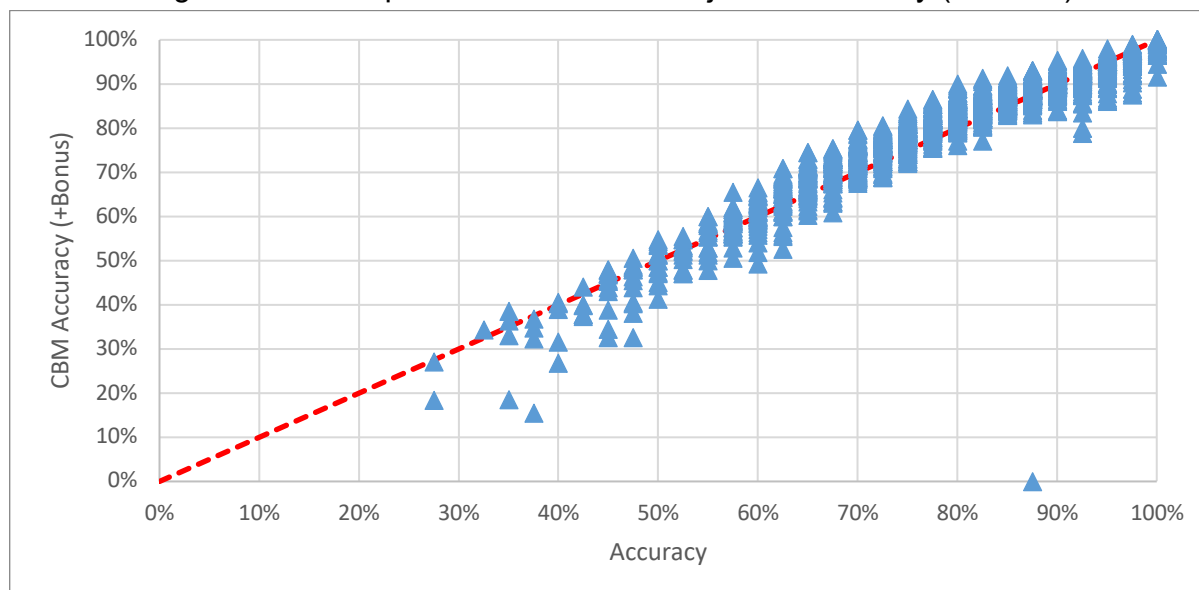


Table 1 shows the mean and variance values for the accuracy (percentage correct reported as a decimal number) and CBM average scores across the three semesters. It appears as though there is a significant decrease in both of these quantities from 2016 to 2017. In particular, performing Levene's test for equality of variances indicates a statistically significant difference in variances for both the accuracy ($F = 11.521$, $p < 0.001$) and the CBM average ($F = 6.254$, $p < 0.012$) from 2016 to 2017. Moreover, conducting a series of independent samples t-tests on the different years' results (accuracy and CBM average) reveals no statistically significant difference between 2015 and 2016, but a statistically significant difference in both the accuracy ($t = -7.456$, $p < 0.0001$) and the CBM average ($t = -6.830$, $p < 0.0001$) from 2016 to 2017. It could therefore be reasonably surmised that the imposition of a time limit on the practice exam in 2017 has caused both of these values to decrease.

Table 1. Results for students across the three semesters

	Year					
	2015 (N=751)		2016 (N=851)		2017 (N=702)	
	Mean	Var	Mean	Var	Mean	Var
Accuracy	0.8162	0.0136	0.8277	0.0140	0.7802*	0.0169
CBM Average	1.7407	0.4125	1.7993	0.3904	1.5707*	0.4644

* indicates a statistically significant difference to 2015 and 2016

3.2 Practice exam performance for subgroups

The results for the average CBM score and accuracy were split according to the gender of the students and are given in Table 2. Female students performed slightly better than males in terms of the mean of both the average CBM score and the accuracy score. Levene's test for the equality of variances for the accuracy score ($F = 1.955$, $p = 0.162$) and for the CBM score ($F = 1.381$, $p = 0.240$), showed no meaningful difference in variances across the two groups. A subsequent t-test for the equality of both means assuming equal variances indicated that the observed difference in means was not statistically significant, to a standard significance level of 0.05.

Table 2. Results for male (N=1759) and female (N=545) students

	Accuracy		Average CBM score	
	Male	Female	Male	Female
Mean	0.8074	0.8162	1.6990	1.7481
Variance	0.0147*	0.0166*	0.4181*	0.4627*

* indicates a statistically significant difference across groups

Table 3 looks at the breakdown of results according to gender over the three years in detail to see if there was any difference in the effect of imposing a time limit in 2017. Indeed, there was a statistically significant difference in the means of both the accuracy ($t=2.307$, $p < 0.021$) and CBM average ($t=2.380$, $p < 0.018$) between male and female students, but only for the 2017 iteration of the practice exam which was lower than both 2015 and 2016. The imposition of the time limit may have accounted for these decreases.

Table 3. Results for students across the three semesters according to gender

		Year					
		2015		2016		2017	
		F (N=157)	M (N=594)	F (N=206)	M (N=645)	F (N=182)	M (N=520)
Accuracy	Mean	0.8025	0.8198	0.8416	0.8232	0.7993*	0.7736*
	Var	0.0180	0.0124	0.0131	0.0142	0.0182	0.0163
CBM Average	Mean	1.6654	1.7605	1.8767	1.7746	1.6738*	1.5346*
	Var	0.5357	0.3791	0.3804	0.3916	0.4678	0.4590

* indicates statistical significance between groups within that year

Table 4 presents the selected confidence levels and percent correct at each confidence level according to gender (male / female). The high confidence level was selected by the majority of students in both subgroups, with slightly more male students choosing it than females. However, female students got slightly more questions correct at this level, which could perhaps explain the overall differences in accuracy and CBM average noted in Table 3. Interestingly, the percentages correct at each confidence level are all within a few percent for the both subgroups, indicating relatively similar judgement skills in terms of assessing confidence levels and within the suggested percentage bounds explained in Section 1.

Table 4. Confidence levels for male (N=1759) and female (N=545) students

Confidence Level	Gender		Percent Correct	Gender	
	Male	Female		Male	Female
Low	16%	15%	Low	46%	47%
Medium	15%	18%	Medium	71%	74%
High	69%	67%	High	91%	92%

3.3 Final exam performance

The final exam performance of students was correlated with various other assessment tasks including assignments, in-class activities and both the practice exam accuracy and practice exam average CBM score as shown in Table 5. It is apparent that the

average CBM score is the strongest predictor of final exam performance, more so than the practice exam accuracy score.

Table 5. Correlation (Pearson) of subject assessments with final exam performance (N = 2289)

Assessment Item	Correlation with final exam score
In-class activities	0.430*
Assignments	0.443*
Practice exam accuracy	0.464*
Practice exam average CBM score	0.490*

* indicates correlation is significant at the $p = 0.01$ level

4 DISCUSSION

The online practice exam, utilising CBM, has shown to be an effective assessment and feedback mechanism for students and educators alike. From the overall bonuses calculated and the distribution of percent correct at each confidence level in *Table 4*, most students took judging their confidence seriously, although some appeared to either not understand the importance of the confidence measure or tried to “game” the system as seen in some of the outliers in *Figure 2*.

While female students have outperformed male students over the three years as a whole, the effect is not statistically significant. As would reasonably be expected, the imposition of a time limit for completing the practice exam, in order to more closely resemble the final exam, negatively affected overall results. This is likely due to students not having enough time to revise and check their answers. Under the conditions of the time limit it was observed that there was a statistically significant difference in the performance between males and females; whether this is an ongoing characteristic of the assessment or simply a one-semester result will have to be seen in subsequent years.

Further study is required to determine how the practice exam feedback, in particular the confidence levels, is utilised by the students for study purposes.

5 CONCLUSION

This paper presented the implementation of an online practice exam, utilising CBM, in a large first-year engineering subject and a dissemination of student results over its three years of operation. The CBM approach adds little complexity but offers students and educators much more meaningful feedback than a simple multiple-choice quiz. Students can use their results and confidence indicators to identify potential misconceptions and inform their study leading up to the final exam. Educators can use aggregated data in order to identify misconceptions common across the cohort. In particular, the CBM average score is the strongest predictor of final exam performance, with a stronger correlation than the simple accuracy score alone. Further investigation of the results for different subgroups and surveying of students may lead to more insights into the effects of its implementation.

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FermProc: A Pedagogical Simulation Tool for Fermentations

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Keywords: e-Learning, Fermentation, Gamification.

INTRODUCTION

Simulators are valuable educational tools enabling students to gain more theoretical knowledge and conceptual understanding [1], [2] due to the manipulation of the models allowing an intuitive learning based on action and offering the student a feeling of control and enhancing explorations. However, it is common that the simulators used in engineering education are conceived for simulating rigorous designs lacking of a thoughtful learning design. Therefore, they are not primarily designed for education and are not well-equipped with tools and frameworks that can enhance the learning process. More specifically, commercial virtual laboratories and/or simulators work as black boxes so their mathematical models are not displayed and it is not possible to recognize the assumptions made [3], [4].

Furthermore, another significant issue faced by the traditional lecture and textbooks system is to find a way of making complex theoretical knowledge more approachable and to create a long-lasting learning experience that can develop into more in-depth learning. Moreover,

learning has to be enjoyable. One way to tackle these objectives is to incorporate game-based elements into learning design [5]. Individual student engagement is one of the challenges of the current education system since, in a majority of cases, the learning was designed without considering the new habits and interests of the students [6]. In this context, the use of games or the introduction of game elements inside a computer-aided pedagogical platform may create a new learning process that corresponds better with the new needs [7].

In this work, an educational computer-aided tool for teaching a specific case study based on a target group of students is developed. This simulator is the result from the application a previously developed methodology in which it integrates the description process as well as the learning design and the introduction of game elements [8]. Therefore, the simulator, *FermProc*, can be further expanded to other processes and learning designs. Finally, it is a brief overview of the current state of *FermProc* and its learning design is presented.

1 REVIEW OF EXISTING SIMULATORS IN FERMENTATION

One of the disciplines that benefit from virtual laboratories is biochemical engineering. In the case of fermentation processes, they may have volumes up to 2500 m³ in a real-world production facility [9]. Therefore, a physical student laboratory of this production volume is not feasible. Some of the available platforms to simulate fermentation processes are summarized in Table 1.

Table 1. Brief overview of some simulators used in the teaching of fermentation.

Software	Description	Disadvantages	Literature
Labster	Fully interactive advanced lab simulations	The implemented models cannot be visualized and it has a limited pedagogical range	[10]
SmiSci Pro//II	Software for the optimization of the plant performance implemented based on the calculation of rigorous heat and material balances. It is a development simulator.	The software works, as a black box with a predefined set of kinetic expressions and its educational value is limited to the overall process developed.	[11]
Aspen Hysys v 7.3	Dynamic process (of development) simulation software.	The software doesn't have implemented any bioconversion but only 5 possible kinetic expressions, limiting the accuracy of the model, as well as its educational value.	[12]
SuperPro Designer	Software for the modeling, evaluation, and optimization of integrated processes. It is a development simulator.	The fermentation unit has predefined models and cannot be modified and therefore, it has limitations for the simulation of a fermentation process.	[13]
PLVPQ	A web- server simulator for chemical and biological processes.	Although it can have different possible configurations for the fermenter, it doesn't allow the display of its model or its modification.	[14]

AQUASIM	Software for simulation and data analysis of aquatic systems	It is the most flexible software concerning model definition, as it has to be specified by the users, and therefore the user requires previous knowledge of kinetic models.	[15]
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However, as listed in Table 1, the most common educational tools for teaching fermentation lack learning design and require a previous knowledge of the systems; which result in a loss in the pedagogical value of the simulator. Moreover, the literature search shows a lack of fermentation simulators that allow the visualization and modification of kinetic models combined with a thoughtful learning design.

2 USER NEED IDENTIFICATION

The first case study, demonstrated through implementing a previously developed computer-aided modeling framework [8], was chosen based on the requirements for the 3rd Semester subject of Kinetics and Modeling of Bioprocess in the bachelor of Sustainable Biotechnology in Aalborg University in Copenhagen, Denmark [16]. Therefore, the learning goal involves the acquisition of knowledge about all the steps for the description of the aerobic cultivation of *Saccharomyces cerevisiae* in glucose and its by-product ethanol in a stirred batch tank reactor. Furthermore, in order to establish the need related to this process, a survey was done with 10 students participating in the mentioned subject.

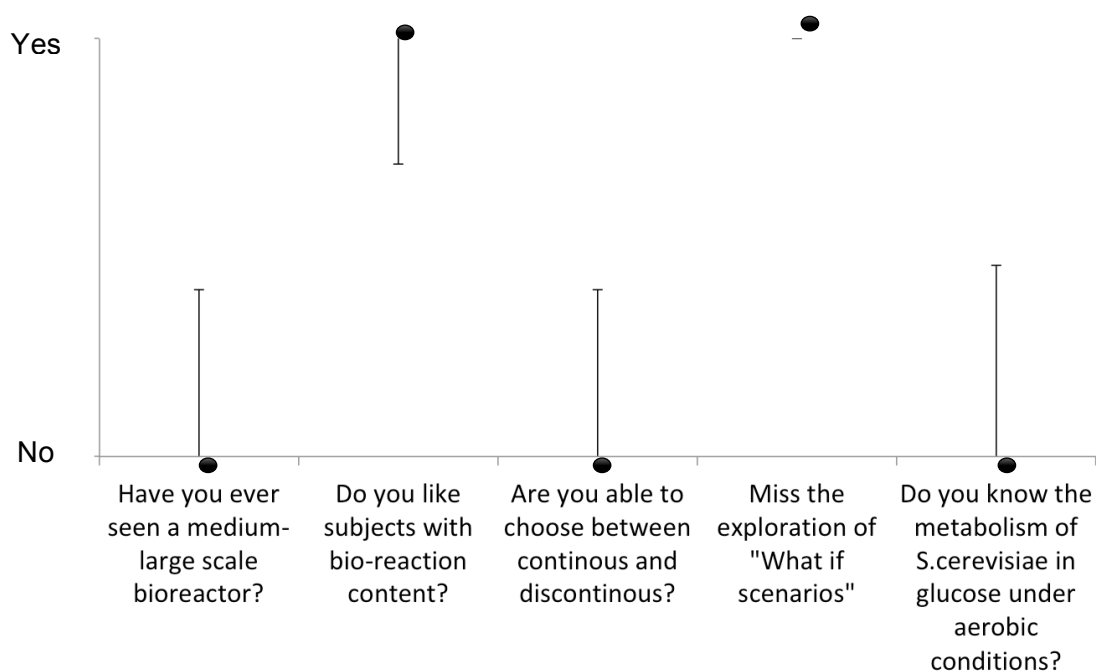


Fig 1. Survey for the need identification for the used of a simulator for the learning of the aerobic cultivation of *Saccharomyces cerevisiae* in glucose and its by-product ethanol in a stirred batch tank reactor.

As seen in *Fig. 1*, it was found that 80% of students have never seen a medium-large bioreactor, whereas the same percentage of participants were interested in the bioconversion process. On the other hand, 80% of the participants were lacking confidence in the choice of important process configurations, such as continuous versus batch operation. Finally, the need was identified as 100% of participants missed the possibility of exploring fictional and non-fictional scenarios, while 80% recognized that they did not have any previous knowledge of the kinetic model for *Saccharomyces cerevisiae*.

3 FermProc

FermProc is the resulting computational tool from the implementation of an existing computer-aided modeling framework integrating game-based learning with a specific learning design.

3.1.1 FermProc challenges

Due to its pedagogical aim and its conceptual design, *FermProc* must be trusted by the student, user-friendly, able to provide the user with an enjoyable learning experience, and with an easy architecture for the addition of new models or modifications of the existing ones. The main challenges for this platform are:

- To provide an organized and free-flowing learning experience. To solve this problem, clear directions are supplied in the platform.
- It must allow and encourage the modification of the model. To do so, the parameters that can be modified are displayed and the kinetic tendency and learning hints are also included to facilitate the experiential learning.
- Feedback must be intrinsic and variable. This is an important element for the implementation of the learning design and gamification. Using one question as an example:

When you choose a production organism, the best choice is:

1. An organism, which can only function under aerobic conditions.
2. An organism, which can only function under anaerobic conditions.
3. An organism, which can only function under aerobic conditions and anaerobic conditions.

Although this question is not a challenge for the target group users, it promotes reflections about the different considerations that need to be taken into account and intrinsic feedback is provided to take the knowledge a step ahead.

Feedback: Aerobic growth can be convenient for biomass production (previous to product formation), because the growth rate is generally much higher. Meanwhile anaerobic growth can give higher yields and lower process costs due to the absence of oxygen required in the process. Therefore it can be useful to have an organism that can grow both aerobically and anaerobically. For example, in case you want to perform fermentation in which you separate a growth phase (batch, aerobic) and a production phase (feed phase, anaerobically). Can you think of an example? Do you know how beer is produced? Maybe ask the person next to you...

This learning follows a constructive learning design. Also, the last sentence invites to a collaborative learning. However, it has not been integrated into the platform as a chat box or other communication system at the current stage of the platform. On the contrary, some of the questions are still using an instructions approach. The corresponding extrinsic feedback can be seen in *Fig 2*:

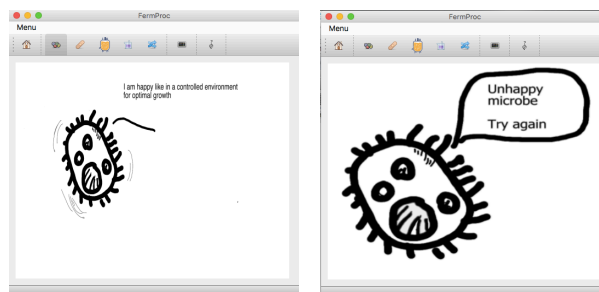


Fig. 2. On the left, the positive extrinsic feedback in which a microorganisms is saying “*I am happy like in a controlled environment for optimal growth*” and on the right, negative extrinsic feedback.

It is important to highlight that the platform has been designed with a constructive learning design aimed and therefore this feedback will be modified into an intrinsic feedback.

3.1.2 Decision making, introduction of game elements and creation of “What if” scenarios

FermProc aims to provide tools for decision-making and critical thinking to the students. In order to do so, it is designed a series of choices with an interactive respond from the software. This can be seen in *Fig.3* and 4.

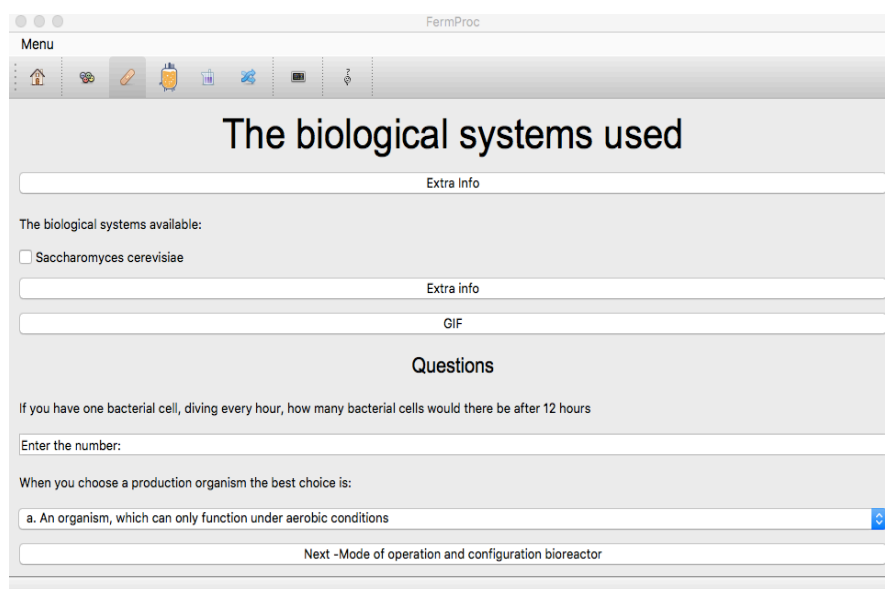


Fig 3. Capture of the screen for the biological system used. It integrated the choice of the biological system to simulate, its information, a gif and, independently of the biological system, a series of questions.

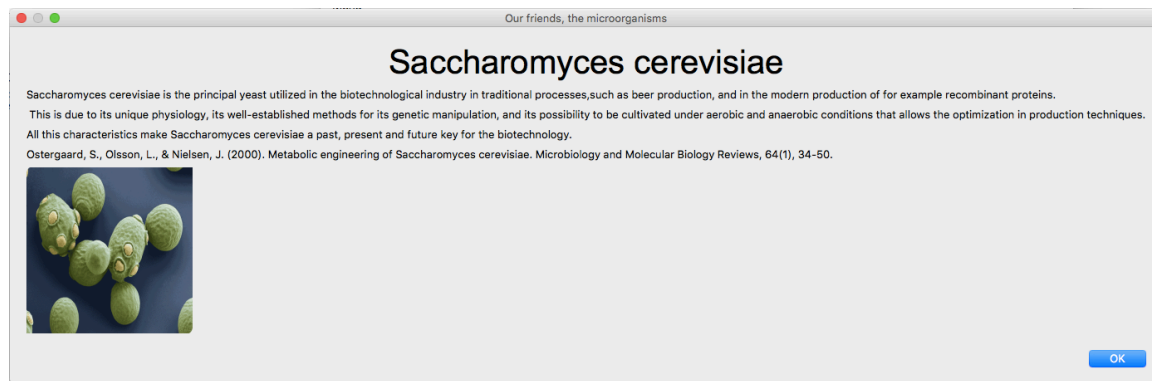


Fig 4. Learning hint about *Saccharomyces cerevisiae*. The information can be found in [17] Furthermore, apart of questionnaire with score system and rules, it is implemented in the current state of the project a mini-game in *Fig 5*.

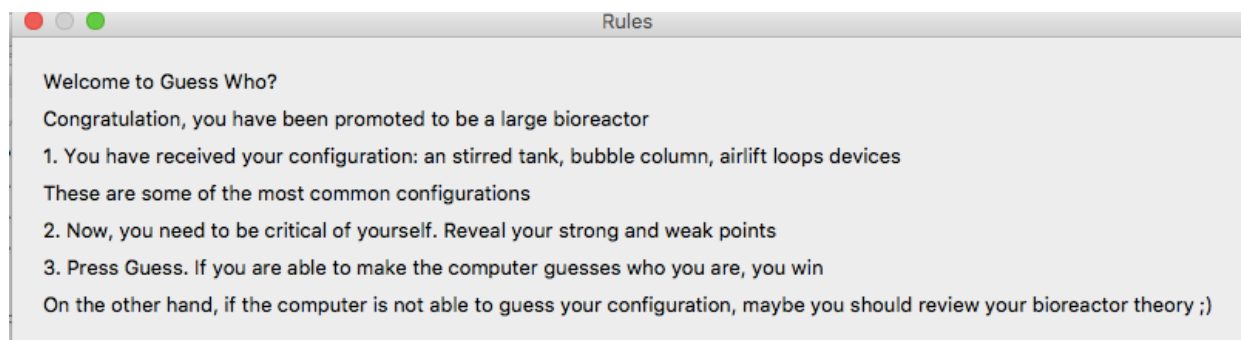


Fig 5. Capture of the rules of the Guess Who? mini-game

Finally, once a student has provided all the information required to describe fermentation conditions, the student can briefly see and modify the mathematical model as it can be seen in *Fig 6*. And 7.

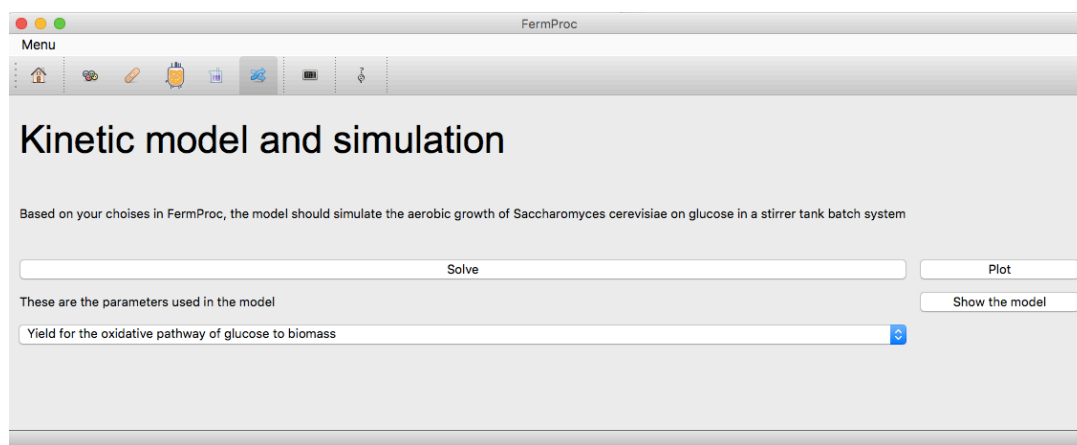


Fig 6. Capture of the screen of "Kinetic model and simulation". In this screen, students will see the mathematical model if they press show the model, or will plot it if they press plot or they can see the different parameters of the model, select them and modify them.

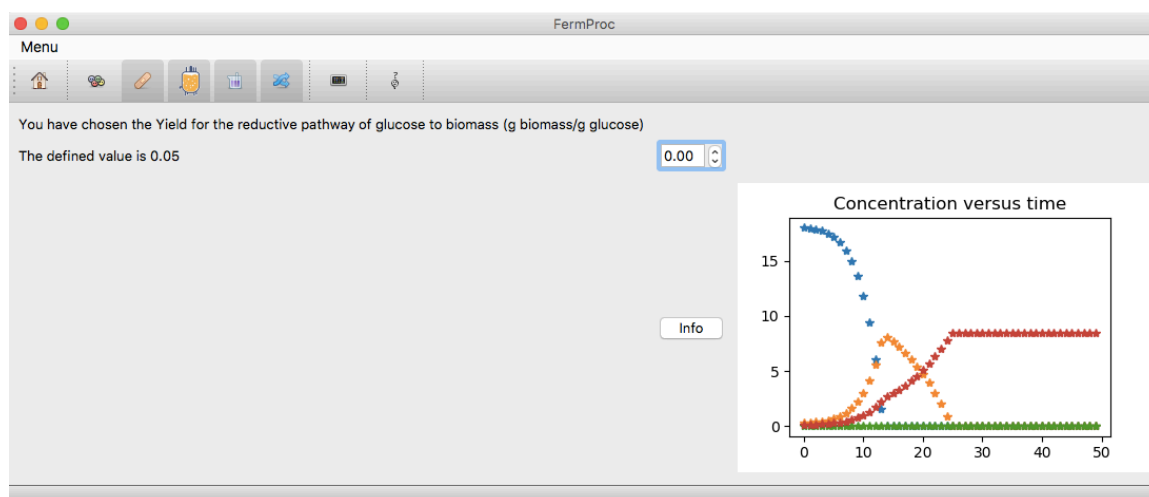


Fig 7. First screen for the modification of the kinetic model. In this example the yield for the reductive pathway of glucose to biomass is chosen. The color code is blue for the concentration of glucose, orange for the concentration of ethanol and red for the concentration of biomass. Y-axis corresponds to the concentration (g/L) while the X-axis is the time (h).

Furthermore, the platform integrates educational videos that so far provide information for the dissembling of a fermenter and the pieces that form it.

Although it was not possible to test the resulting software with a group of students, previous works have shown benefits in the use of simulators with game elements as a complement for the traditional lectures like in mechanical engineering [18] and computer science [19]. It is important to highlight that *FermProc* is still in development and will undergo several changes based on the feedback from future user experiences.

4 CONCLUSIONS AND FUTURE WORK

Based on a literature research and a student need survey, a computer-aided tool with the integration of game elements and a thoughtful learning design was developed using a framework for the development of pedagogical simulators. Therefore, this tool presents an interactive information flow for the display of learning hints, questionnaires, and the modification the model. Furthermore, *FermProc* provides predefined intrinsic feedback and the possibility to try different kinetic scenarios, along with hints and theory behind every choice of the user, multimedia content, and a mini-game.

5 SUMMARY AND ACKNOWLEDGMENTS

The project partly received financial support from Innovation Fund Denmark through the BIOPRO2 strategic research center (Grant number 4105-00020B).

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Technological Volunteering as an Approach for Service Learning

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Conference Key Areas: Sustainability in engineering education, Developing professional skills

Keywords: Service-Learning, Student Engagement, Changing Engineering Perception

INTRODUCTION

Entities with social purposes perform an essential task in our Society. They are often obliged to work with insufficient budgets that do not allow them to develop their projects with the necessary guarantees. In particular, they require computers and support from ICT experts in order to be able to fulfil their objectives in a society as technological as ours, in which changes in technology occur at a dizzying speed. In September, 2015, the Universitat Politècnica de Catalunya - BarcelonaTech launched an ICT volunteer program in the form of a pilot experience with students from the Schools of Informatics and Telecommunications. This program is an extra-curricular activity called Vol-ICT currently in its third edition and forms part of a more ambitious undertaking in which we aim to increase student retention by using Service Learning as a part of our university educational policy [1].

1 SERVICE-LEARNING

Service-Learning (SL) is an educational practice in which the learning process (content, competences and values) is combined with the detection, analysis and eventual solution of

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community needs. It is conducted by means of a project in which students are trained while working on a real project.

For Robert Sigmon [2], the SL methodology is an experimental approach in which a reciprocal benefit exists. According to the author, SL differs from other educational approaches in its intention to benefit both the provider and the recipient of the service, and to ensure that the objectives are twofold: learning and service.

The Corporation for National and Community Service [3] defines SL as a methodology where students learn by performing a useful service for the community. In this service, they must develop a work which can be integrated into the curriculum, is well structured, moves students to reflection and extends what they have learned in their studies.

SL is a meeting point between solidarity intentionality and pedagogical intentionality [4], and as such goes beyond what a simple social volunteering involves. Learning can take place as part of a voluntary service, but without necessarily expressing intentionality or without explicit mechanisms. For example, students of a Bachelor Degree in Informatics Engineering may participate as volunteers in an entity dedicated to distributing food to families in need, but this does not mean that they will be better trained as ICT Engineers, even though they will probably improve their skills as individuals. Thus, this activity may be classified according to whether it is focused on the service, on learning, or on both in an integrated manner:

- If it is focused on the service, it is fundamentally an act of solidarity. The above-mentioned case of students who collaborate with an entity that distributes food to families in need is a clear example of an activity focused on service.
- If it is focused on learning, it is an educational activity that can help raise student awareness, but without necessarily having a real impact on the community. For example, completing a Final Degree Project (FDP) that takes into account the project's sustainability is a learning task, but it is not SL.
- An activity that is focused on both learning and service constitutes authentic SL. Students develop or extend technical competencies specific to their studies, as well as professional skills such as commitment or responsibility, by means of a solidary activity that must be integrated into the curriculum and have a direct impact on the community. For example, the completion of an FDP devoted to a software that enables the (real) management of an agricultural cooperative in Morocco. This project presents students with an engineering problem involving multiple restrictions: they are required to create a complete product that is both robust and adapted to the client.

In SL, it is vital that an alliance between the university and the community is established. This alliance should serve to identify real needs that can be addressed either totally or partially by students. Furthermore, such a process should encourage students to reflect on the opportunities and risks of their profession, while at the same time entering into the emotional dimension of student engagement [5] [6] and increasing their academic commitment, all of which is intended to increase academic performance [7]. Some experiences involving SL in ICT Degrees can be found in [8].

2 THE PROJECT

In the Vol-ICT program, students carry out an ICT project in a solidary entity for a minimum of 60 hours. The project is defined by an entity with social purposes and supervised by a

member of the entity and by a professor from our university. Two ECTS credits are awarded to students for the completion of the project, one for every 30 hours of work. This number can be increased up to 6 ECTS credits if the size of the project justifies it.

2.1 Objectives of the program

The main objectives of the Vol-ICT program are as follows:

- To transform the vision that students have about society while discovering the real impact that their future profession may have on the world.
- To develop competencies that students are expected to acquire. In projects such as the Vol-ICT program, students work on 8 out of the 11 outcomes proposed by the ABET: (c) the ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability and sustainability; (d) the ability to function as part of a multidisciplinary team; (e) the ability to identify, formulate, and solve engineering problems; (f) an understanding of professional and ethical responsibility; (g) the ability to communicate effectively; (h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context; (j) a knowledge of contemporary issues; and (k) the ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.
- As a public university financed mainly by taxpayers, part of what we receive is returned to society through this project by helping entities with social purposes that otherwise could not afford the cost of this engineering work.

2.2 Design of the project

The UPC Vol-ICT program is managed by the Center for Development Cooperation (CCD), an office of the university devoted to organizing and supporting cooperation and volunteering initiatives undertaken by members of our community. It can also count on the participation of Technology for All (TxT) an NGO consisting of personnel and students from our university. The program works as follows.

- The selection of entities is based on a call that is published on the program's website in May. Entities must submit a project that clearly identifies the objectives to be achieved and the benefits that volunteers will receive in terms of experience and/or learning. A dialogue is established between the entities and the CCD to refine the proposals and adapt them to the objectives of the program and the expected learning outcomes.
- The projects are published in September. Students then select three projects, indicating their order of preference. A second call is issued in January to cover vacant projects or occasional volunteer dropout. In September, we also contact the professors who wish to volunteer as academic tutors for the projects.
- During the last week of September, those responsible for the program assign volunteers to projects, taking into account student preferences as well as the overall perspective of the program. A project may be assign more than one student from the same or from different schools, depending on the requirements. The assignment of professors as project tutors is also conducted according to their availability and their preferences.

- The volunteers receive training during the first week of October. A series of formative videos is made available and a face-to-face session is organized to determine the responsibilities involved in their participation. During the rest of October, specific meetings are held to launch each project. The volunteers and their academic tutors attend each meeting, as well as a member of the entity and a member of the CCD. These meetings enable us to set realistic objectives for the project and plan its implementation. From this moment on, the project progresses asynchronously according to the needs of the entity and the availability of the volunteers. The students and the entity jointly define a schedule that is compatible with the students' academic needs. During the meeting, the project may sometimes be redefined in terms of the objectives initially proposed in the call.
- On completion of the project, a survey is submitted to the entities, the students and the tutors in order to identify factors which can be improved in the following edition.

3 RESULTS

3.1 Quantitative results

In the pilot phase (2015-2016 academic year), 5 entities and 11 students participated in the Vol-ICT program to work on 8 projects. In the 2016-17 academic year, 6 entities and 11 students participated, working on 8 projects. In the current 2017-18 academic year, 12 entities and 21 students are working on 16 projects. In the first year there was only one call for volunteers in September, while in the following two editions two calls were issued, one in September and the other in January, which produced better results. We believe that this was due to the fact that this call was made at the end of January, when the students have already finished the first semester and have not yet enrolled in the second semester. In addition, the "New Year effect" seems to be very positive for the Vol-ICT program, since it appears that students start the year with a desire to undertake new projects, especially those with an altruistic purpose, which seem to be highly attractive.

With respect to the projects already carried out, most entities request the help of volunteers for three types of generic projects: (1) the design or improvement of the entity's website, (2) the design or improvement of an app aimed at fulfilling the objectives of the entity, and (3) training activities. The training activities are of two types: those aimed at improving the technological training of the entity's members (to provide a better service for their customers), and those whose purpose is to improve the technological training of the people who may benefit from the entity's activity. In the latter case, training is almost always focused on improving the employability of these beneficiaries, who belong to groups at risk of exclusion.

The call for volunteers is open to all students, in particular, those from the Informatics and the Telecommunications Schools doing both BSc and MSc degrees, although according to current UPC regulations recognition of ECTS credits can only be accorded to BSc Students.

Table 1 summarizes the number of entities, projects and volunteers that have participated in each edition of the program. It also differentiates between the number of men and women who have participated as volunteers in the program. We wish to highlight that the percentage of female volunteers exceeds by far the percentage of women enrolled in all the schools: the Informatics School (15% volunteers, 9% enrolled), and the Telecommunications School (42% volunteers, 18% enrolled).

Table 1. Summary of entities, projects and volunteers that have participated in each edition of the program

Edition	Num. of Entities	Projects Total (Web / App / Training / Others)	Volunteers			
			Total / Male / Female	By school (Total / Male / Fem.)		
				Informatics	Telecom.	Other
2015-16	5	8 (2 / 2 / 2 / 2)	11 / 6 / 5	4 / 4 / 0	7 / 2 / 5	0 / 0 / 0
2016-17	6	8 (0 / 2 / 4 / 2)	11 / 9 / 2	8 / 7 / 1	2 / 2 / 0	1 / 0 / 1
2017-18	12	16 (2 / 3 / 6 / 5)	21 / 14 / 7	8 / 6 / 2	10 / 7 / 3	3 / 1 / 2
Total	23	32 (4 / 7 / 12 / 9)	43 / 29 / 14	20 / 17 / 3	19 / 11 / 8	4 / 1 / 3

3.2 Qualitative results

In order to obtain qualitative information on the level of SL achieved by the program, and in addition to the survey conducted annually on entities, students and tutors (with the purpose of improving the next edition of the Vol-ICT), a new specific survey has been designed during the present course. It has been distributed to all entities and students who have participated in the program since its first edition. Furthermore, in order to assess the evolution of students' perspective, a distinction has been made between those who have yet to start their projects and the rest. The questions in the surveys are as follows:

Survey to students, prior to carrying out the project:

- Describe briefly the reasons that have motivated you to join the Vol-ICT program
- What do you hope to learn from the experience?
- What do you hope to contribute with your collaboration?
- What do you think the university should do to endow its activity with a greater (positive) impact on society?

Survey to students, after the completion of the project:

- Apart from the final outcome of your project, what do you think you have contributed to the entity?
- Do you think the project has improved your professional skills? Why?
- What has the realization of the project contributed to you personally? Has your way of seeing society and/or ICT changed?
- What recommendations would you give to a student starting a Vol-ICT project?

Survey to entities, after the project

- Has the project changed your point of view about ICT projects? How?
- Apart from the final outcome of project, what do you think the students have contributed to the entity?
- Do you think UPC students have undergone a personal transformation because of their participation in the project? Why?
- What recommendations would you give to an entity that wishes to propose a project for the Vol-ICT program?

To date, we have received 5 responses from entities and 13 from volunteers, a sample too small for a quantitative analysis, so we will provide a qualitative one. With respect to the entities, they indicate that a process of “mutual learning” has been achieved between students and the entity, and that the work carried out by the volunteers is something that “otherwise wouldn’t have been done due to a lack of resources”. The entities stated that “some projects can benefit from ICT more than we expected”. One entity also indicated that the volunteers “provided us with a fresh point of view and helped us to be more open-minded about ICT”. The entities consider that students “learned about social issues of which they were previously unaware”, as well as “learning to recognize the need to empower ICT tools in society”. Moreover, in one case a volunteer joined the entity’s permanent staff. Other entities have recommended their counterparts that are thinking about joining the program to “trust in the abilities of students and in their capacity to carry out projects of this nature”, as well as to “clarify the project with the help of the experts from the university” and to “define clearly the work that students are to undertake”.

With regard to the students, before joining the project they indicated that they wished to “do something useful with the knowledge I’m acquiring” and to “help people while acquiring some real experience”. In addition, they wanted to “learn to deal with people”, “learn about social entities and what impact they have on society” and “learn to work with different kinds of people”. They also expected to have an “enriching experience” and to “help others with personal growth”. They believe that the university should “help students to deal with real problems facing society” and that the experience “made us aware of our usefulness as engineers in helping people, above and beyond materialistic concerns”.

Students who completed the project considered that they had helped entities to “discover different ways of doing things”, to “adopt another mentality”, and had “provided a technical and realistic vision of what an ICT project really is and what it can become”. Basically, apart from technical issues, they had learned about “time management, sharing duties as part of a team and the need of periodic meetings”, as well as how “to communicate with non-ICT people” and how to “put myself in the shoes of someone who hasn’t had the same opportunities that I have”. For some it has been a transforming experience: “I’ve seen the real complexity of society at first hand”; “I now realize how privileged I’ve been all my life”; “I’ve seen the digital divide between different social classes”; “I’ve witnessed how young people at risk of social exclusion are able to accomplish many things when an opportunity is offered”. When it comes to giving advice to future volunteers, the opinion is unanimous: “try hard”; “don’t give up”; “work with a passion”; “do it with the desire to help or don’t do it”; “when you start, you acquire a commitment”; “make the most of the experience - the most important thing is not necessarily the project itself, but getting in touch with people”; “it is hard work, but rewarding”; “enjoy it”, and “collaborate widens the soul”.

4 DISCUSSION

Given the responses to the surveys, we believe that all our objectives have been fulfilled. We are deeply satisfied with the feedback from the entities, but especially with the way in which students have learned from the human point of view. The reports by the academics involved in the projects also indicate that the learning outcomes have been fulfilled. The number of volunteers is growing, and more are expected in future editions, and the aim is to ensure that the project remains voluntary rather than mandatory, since we believe that volunteer commitment is essential for the success of this type of project. In the light of this three-year

experience, we believe that some aspects of the program have worked really well, while others still require some improvement. In the following paragraphs we set out what we have learned from this experience.

Keeping bureaucracy to a minimum: during the design of the program, we gave great importance to formalizing documents at each step of the process, which resulted in volunteers feeling overloaded with the obligation to prepare numerous follow-up reports. Most of these reports have now been eliminated, thereby alleviating part of the process and concentrating attention on what is truly important and essential. The purpose of the monitoring system is to simply ensure that communication between the volunteer, the tutor and the entity is maintained without the impediment of unnecessary procedures.

The importance of timing: in the first edition, we did not pay enough attention to some transitory aspects, such as collecting the proposals from entities before starting the course. This led to a delay in the program to the extent that some projects were not completed until after June. The process has now been improved by adapting the program cycle to the academic calendar. In addition, the excessive elapse of time between enrolment and the actual start of the project led in some cases to demotivation. Furthermore, some volunteers have expressed a desire to participate in the program during other periods, and while this implies a more complex management of the projects, the introduction of a more flexible calendar should also be taken into account.

Specific training: we began the first edition with an initial general training in volunteering and on the relationship of ICT with society. However, the volunteer students expressed their need for specific training on the issues most closely allied with the technical work to be undertaken; for example, the creation of apps or webs.

Greater stress on the project definition: some entities may not have the technical knowledge to enable them to clearly define the requirements of the project, which sometimes gives rise to proposals that are too generic or too ambitious. Thus, more meetings were held with the entities in order to define from the outset projects based on clear and achievable objectives.

Commitment is the key: the commitment of all those involved is the only really essential factor for carrying out the tasks. In this sense, the key to success is sustaining the participants' motivation and clarifying the role of each one from the very beginning. Moreover, it is highly advisable to assign more than one student to each project in order for students to share responsibility and feel that they have more support, while the risk of a failed project due to student dropout is also reduced.

Small but safe steps: although processes may be simplified, program management still requires a wholehearted commitment in terms of human resources. While one of the goals of the program is to increase both student and teacher participation, it would be counterproductive to accelerate this process if an effective response to the expectations of the entities cannot be provided. In this regard, there is a long way to go before the program can be considered as consolidated.

5 SUMMARY AND ACKNOWLEDGMENTS

It is our aim to encourage other universities to put the Service Learning methodology into practice, not only as a service to the community, but also to enrich the learning experience of

students, since these projects deepen and extend their relations with their teachers, their schools and their future profession, thus creating a sense of belonging and a greater emotional commitment to their studies, which in turn results in a better academic performance. The idea behind this paper is to share our experience in an ICT volunteer program with other universities and entities that wish to undertake a similar volunteer program, in order to encourage them to build on our successes and avoid our mistakes. We wish to thank all the lecturers and entities involved in the project, and especially our students, since they are the ones who have made these dreams a reality.

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What are the engineering professional competences?

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Conference Key Areas: Graduate employability, Transversal skills, Reflective practice

Keywords: Graduates, Engineers, Employability, Competence

INTRODUCTION

The EU Skills Panorama [1] an European commission lead study into the labour markets of Europe found that a large number of member states experience recruitment difficulties in relation to STEM skilled labour. As part of this study, in 2016 a number of shortage occupations in Ireland were identified, with engineering professionals and technicians being listed as a mismatch priority occupation [2]. It is clear that there is an ongoing shift in the manufacturing industry as it moves away from traditional manufacturing sectors and take a larger stake in the service sector [3]. This shift has resulted in firms seeking graduates who possess not only the technical skills they have come to expect from an engineering graduate but also the professional or transversal skills required to work in the industry. This lead to an investigation of the literature surrounding competences deemed important in the existing literature followed by a report on an expert panel carried out with ESB International (ESBI) one of Irelands' leading engineering consultancies as part of the Professional Roles and Employability of Future Engineers (PREFER) project.

RESEARCH QUESTION & METHOD

The aim of the research was to capture papers which reported on the competences which were viewed as important for success in the labour market in pursuit of the question: what are the *most* important of these professional competences and is there agreement among experts on what they are? This was achieved by examining the studies carried out on:

- 1) Professionals working as practicing engineers and engineers working in management and supervisory roles.
- 2) Professionals working in HR and in executive positions in the industry

A systematic literature review was carried out utilising online data bases provided by:

- 1) Taylor and Francis
- 2) Wiley online Library
- 3) Springer international publishing
- 4) ASEE Peer

The search terms used were “engineering competences”, “generic competences”, “graduate competences” and “graduate engineer”, searching in all fields of the paper. The selection criteria were then applied, limiting the paper to those published from 2010 onward and removing overlapping papers. This lead to the identification of 40 papers. Papers were drawn from published sources from 2010 onward to frame the research in the current decade. In doing so it was hoped to identify areas of skill mismatch between what the institution can provide and what is expected from industry. Of the initial 40 papers identified, 31 papers were removed as they did not contain any Likert data on competences or they contained this data but the data pertained to undergraduate student responses. This left 9 papers which pertained specifically to industry expectations of transversal skills. Data were collected from Likert scales generated from survey [4–9] and two papers which utilised a mixture of survey and interview to gather data [10,11].

FINDINGS

Table 1 shows a breakdown of the papers utilised in the review process. The papers were profiled based on the country in which the study took place, the type of engineer or professional taking part in the survey, the framework used to compile the lists of competences in the survey and the publisher of the paper.

Comparison of the papers published in this area reveal that most authors opted to generate lists of competences inspired by either literature review or utilising various frameworks such as the ABET and Washington Accords. There is no standardised list of competences used in this type of investigation which presents a number of issues when comparing the perceptions of engineers an interdisciplinary and international level. For a meaningful comparison of engineering competences to take place,

international and interdisciplinary differences must be examined not by examining the spectra of competences that exist internationally and across disciplines, but rather by the importance a particular group places on a shared set of competences. In this way results collected from various nations and disciplines become comparable. Data collection for these studies relied on the assumption that the engineers and other professionals taking part in the surveys possessed expertise on the important competences in their professional area. Only one of the nine studies considered in this review utilised a panel of experts in the survey, the remainder were surveys sent to hundreds and in some cases thousands of engineers, creating a selection bias and poor response rates. It also assumes that Likert scale data about the relative importance of one competence over another is in some way meaningful. This raises questions over how a researcher could decide *how much more important* one particular competence was over another, when the papers' authors are quoting 2 decimal places of accuracy on a scale of 1-5. To summarise. International comparison of competences important for success in engineering could only occur with a list of shared and well defined competences. The studies considered in this paper rely on the self-report of a group of individuals we must presume are experts on what competences are most important for success and that there is something meaningful about the rating of these competences on a Likert scale. Due to the wide variation in the lists of competences utilised in these studies, little agreement was found on what competences were most important for success in the labour market.

Taking a new approach to this will be essential if we are to extract meaningful insights into the competences that will be required of future engineers on an international scale. To this end, the European commission have funded a project to investigate engineering professional practice and future employability of engineers. As part of the PREFER project the Dublin Institute of Technology, KU Leuven & TU Delft in collaboration with its' partner BDO have carried out 12 expert panels across Belgium, Ireland and The Netherlands in order to evaluate what competences will be most important for a young engineer to succeed in the labour market. As outlined in this paper a considerable amount of research has explored the transversal skills important for an engineer to succeed in the labour market but there is a scarcity of research regarding the types of roles that an engineer can fulfil after graduation [12]. To this end, a model of professional roles was developed to frame the types of jobs which are available to engineers after graduation. The model selected as the prototype was the Treacy Wiersema model [13] this decision was made in prior research, utilising structured interviews with industry officials to decide between two proposed models. The model was initially validated using a cohort of 121 industry officials, 91% of which could identify the role model in their own company [14]. The model is broken into three distinct roles and it was posited that a unique set of competences may be attached to each. All 12 panels were carried out utilising 3 engineers who fit into one of the professional roles, 2 members of HR, 1 HR manager and 1 senior manager. Participants were presented with the list of competences and asked to pick the competences they felt were of particular important to each of the professional roles. This was followed by a round table discussion about the competences and their definitions in order to distil a final list of competences for each of the three professional roles. Table 2 presents the results of the expert panel carried out with the ESBI in Ireland

Operational Excellence	Product Leadership	Customer Intimacy
Stakeholder engagement	Conceptualisation	Client focus
Focus on results	Creativity	Stakeholder engagement
Clear communication	Innovation	Solution orientated
Solution oriented	Solution-Orientated	Integrity
Work organisation	Client focus	Focus on results
Responsibility	Initiative	Persuasiveness
Client focus	Clear communication	Conflict management
Networking		Initiative
Performance motivation		Clear communication
		Stress resistance

Table 2. Results of expert panel with ESBI

DISCUSSION

The major difference between this research and previously conducted research in this area is a move away from quantitative data gathered through survey and towards a more meaningful description of the functions of an engineer and the types of competences required to fulfil those functions. Utilising the data drawn from these 12 expert panels and collated by one final review panel of experts, the PREFER project will be working closely with BDO to develop and validate a psychometric test aimed at aligning an engineering student or graduate to one or more of these engineering role(s).

It should of course be considered that the results from the ESBI expert panel are representative of the competences deemed important for success *within* the ESBI, who deal predominantly with electrical engineers. The results had to be compared with the results from other expert panels; from companies involved in a variety of economic activities, including both small, medium and large firms, across a variety of geographical locations. Pivotal to this process was the list of competences and their definitions, which came directly from BDO and were the competences utilised in all three countries to carry out the expert panels, allowing for more meaningful international comparisons.

ACKNOWLEDGMENTS

This work was supported by Erasmus+ programme of the European Union (grant agreement 575778-EPP-1-2016-1-BE-EPPKA2-KA) and is part of the PREFER project. The authors would like to thank the ESBI for their cooperation in the process.

Papers at a glance

#	Author	Year	Country	Cohort	Methods	Competence list	Data type	Publisher
1	Baytiyeh [4]	2010	Lebanon	Civil engineers Mechanical Engineers Electrical Computer Engineering management	Survey	ABET	Likert	ASEE/IEEE
2	Han Ahn et al [7]	2012	USA	Project manager Project engineer HR manager Director Vice President Other	Survey	Generated	Likert	Journal of professional issues in engineering and practice
3	Hinchcliff and Jolly [11]	2011	UK	HR & other management HR & other management	Survey Interview		Likert Qualitative	British Educational Research Journal
4	Husain et al [5]	2010	Malaysia	Managers (Engineers) Supervisor (Engineers) Others	Survey	SCANS Model	Likert	Procedia Social and Behavioral Sciences
5	Robles [15]	2012	USA	CEO's, presidents	Expert panel	Generated	Likert	Business Communication Quarterly
6	Warnick [6]	2011	USA	Mechanical Engineers	Survey	Generated	Likert	American Society for Engineering Education
7	Ortiz-Marcos [10]	2013	Spain	Engineers	Mixture	PMI Framework	Likert	Project management journal
8	Peiro et al [9]	2016	Jordan	Telecom engineers	Survey	Generated	Likert	European journal of engineering education
9	Pons [8]	2015	New Zealand	Engineers	Survey	Washington Accord	Likert	European journal of engineering education

Table 1: The sample of papers collected from the literat

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Impact of engineering roles in a design process for solving complex problems

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Conference Key Areas: Engineering Skills, Continuing Engineering Education and Lifelong Learning, Innovation as the context for Engineering Education

Keywords: engineering roles, design thinking, complex problems, problem space, solution space

INTRODUCTION

The last decades the world is changing at an even faster pace because of globalization, digitalisation, and the result of many recent innovations. The result of these rapid changes is an uncertain and unknown future. Universities have to make sure that what first year students need to learn, is still relevant after 5 years after graduating. Companies look for employees with both in-depth knowledge and skills that go beyond the current basic engineering skills. Solving complex problems for real-life challenges is necessary to make actual impact in the society. Complex problem solving requires interdisciplinary collaboration with multiple stakeholders and is challenging with only technicians with a monodisciplinary focus [1].

Future employees require creativity, organisational skills, international orientation and an entrepreneurial mind-set. This entails a different type of engineer, skill-set and a new

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engineering vision. A Think Tank has been setup to explore the future education vision of the Delft University of Technology [2]. One of the main findings were four new engineering roles with specific knowledge and skills to withstand the rapid changes and to solve complex problems. Each role has their own specific skill-set, language, problem approach and a description of their purpose and drivers within a company or academia context. For a short impression of the proposed engineering roles see table 1 or click on this [link](#) for the extended online version in booklet format.

Table 1. Short impression of the four proposed engineering roles

<i>Engineering role</i>	<i>Explanation</i>	<i>Heuristic question</i>
Specialist	The engineer who does fundamental research into a particular topic needed to contribute to the project.	How can we advance and optimize technology for innovations and better performance using scientific knowledge?
System Integrator	The engineer who brings components and people together to realise bigger integrated systems.	How can we bring together disciplines, products or subsystems into a functioning for a complete solution?
Front-end Innovator	Bridging the gap between user, user needs and adaptive design for projects.	How can we advance and apply knowledge and use technology to develop new products for the benefit of people?
Contextual Engineer	Exploring and preparing the environment, while taking into account the cultural, legal, ethical issues for implementation of the technological solution in society.	How can we develop and implement technology safely, ethically and internationally in society and industry?

After the development of these engineering roles, it is unclear how these roles can be used in education and the impact on complex problem solving. This paper presents the results of five experiments that have been developed and evaluated via a design-based approach. During the experiments the engineering roles were used to solve complex problems via an interdisciplinary team-based design thinking process. The focus of this research was on the experience of the roles within the different design activities, recognition of the roles and the relevance of the roles in education and work environment. This paper gives the first insights for teachers using the engineering roles within their own curriculum that include a project-based setup.

1 THEORETICAL BACKGROUND

Complex problem solving can be achieved via design thinking processes. This process is known for its effective experimental approach that addresses human-centred problems consisting of many unknown and little objective data [3]. It shifts the perspective from “designing products” to create “ideas that better meet users’ needs” [4]. Brown [4] describes the design thinking approach in three different stages inspiration (stakeholder collaboration in identifying problems), ideation (brainstorming, primary prototyping e.g. sketching onto paper) and implementation (creating a workable prototype for testing). Stanford d.school widely uses design thinking to stimulate radical collaboration for real-world projects to solve complex problems from any field. They translated the design thinking stages from Brown into five steps: emphasize, define, ideate, prototype and test [5]. The iterative cycles within the process and the experimental characteristics makes design thinking a good method to

explore complex problems in a fast pace. During each process step different predetermined activities foster design thinking.

Depending on the process step and design activities two additional thinking processes are stimulated namely; diverging and converging [6] (Fig. 1.). Divergent thinking is important as it can explore and extend the problem and solution space in the process. It is the ability to extend the data collection to a particular problem or to explore concepts for possible solutions. Convergent thinking deals with revealing the facts based on the known knowledge of the concepts. It supports the decision process and focus on specific problems and solutions.

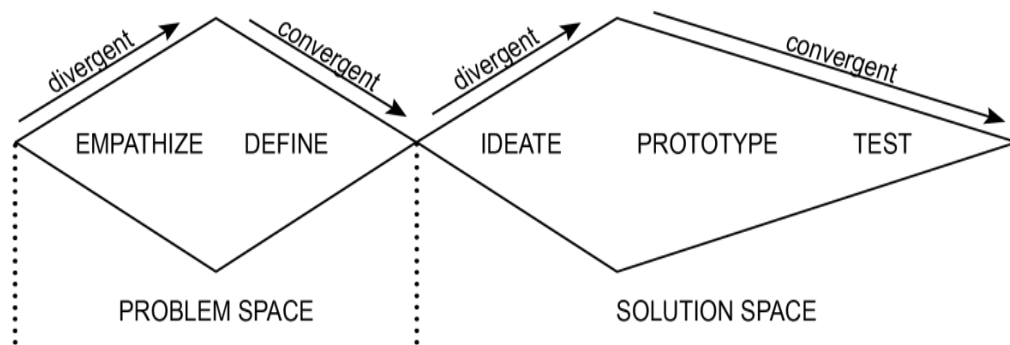


Fig. 1. Design thinking process including divergence, convergence and the problem and solution space

One of the design activities that enhances convergent thinking and increasing creativity is synectics. Synectics is a theory for the conscious use of the preconscious psychological mechanisms present in a person's creative activity [7]. It allows moving away from the original problem via an "analogy" and using "forced fit" to develop original solutions. Forcing to use the analogy as a stimulus can generate other ideas or solutions.

2 RESEARCH SETUP

The theoretical background has resulted in the development of design experiments using design thinking activities with engineering roles as synectic stimulus to evaluate the engineering roles. So-called "pressure cooker workshops" have been developed to execute the design thinking process in a fast-pace format. Pressure cooker workshops have been used in the field by (SME) companies to stimulate innovation and product development activities [8].

Participants of these workshops go through each design thinking process step under time pressure of around 3-6 hours. The time pressure encourages attentiveness, focus and creativity once creating a professional atmosphere as if the participants are on a mission [9]. With the support of proper facilitation it is possible to finish a complete design thinking cycle without the need to master design thinking skills. During this experiential learning process participants learn about the process, engineering roles as well as the content of the complex problem [10].

From 2016 – 2018 in total five pressure cooker workshops have been successively co-created with teachers. They were responsible for courses or projects that deals with real-life complex problems within an interdisciplinary setting. Each workshop consisted of the design thinking structure with each altered design activities depending on the course goal.

Within each workshop participants worked on a real-life problem in teams of a minimum of four participants interacting in four different engineering roles. Before the workshop started all participants had to fill in a questionnaire to determine their personal engineering roles. An example of a workshop and the activities can be seen in table 2. The design activities have been structured on a large worksheet and have clear instructions which is necessary to complete a design cycle within a pressure cooker workshop. The worksheet gave a professional and structured feeling for the workshop.

Table 2. Example of a workshop process

Course description:	"Interdisciplinary honours class next generation robotics. Robotics is a multi- and interdisciplinary engineering domain. The creation of innovative robots needs high level research in all disciplines involved. It is a "mission" in which top level engineers of these disciplines work closely together. Currently the TU Delft does not offer bachelor programmes with this "mission" scope. It is expected that industry will need more and more these broadly educated and mission driven engineers."	
Workshop goals:	This workshop is executed during the kick-off of the honours programme. During the workshops the participants go through a complete design thinking process to develop an alternative for a "reading mom volunteer" using robots. Participants are introduced to the engineering roles and are encouraged to use these roles throughout the programme.	
Process step	Goal	Activity
<i>Emphasize</i>	Emphasizing in different target groups and their explore their concerns via interviewing the 3 stakeholders that are present at the workshop using each engineering role.	Empathy mapping [11]
<i>Define</i>	Formulate the most challenging problem for each engineering role including stakeholders.	Problem definition [12]
<i>Ideate</i>	Develop as many ideas as possible and translate the most inspiring idea from an engineering perspective.	Ideation [13]
<i>Prototype</i>	Integrate the ideas from the 4 engineering roles to one final concept and sketch the idea.	Minimum viable product [14]
<i>Test</i>	Present the concept towards the stakeholders and reflect on your defined problems.	Sketching

The five workshops have been evaluated via a design based approach [15] and the structure, materials and engineering roles were iterated on basis of the data collection: observations, field notes, open discussions and (open) questionnaires.

3 MAIN FINDINGS

The five workshops, topics and the amount of participants can be seen in table 3. The workshop results are discussed via description, supported by quotes and numerical results of workshop 3 and 5 (descriptive frequencies, Likert scale 1-5 strongly disagree to strongly agree).

Table 3. Workshop themes and participants

Ws	Theme	Participants	Year
1	Sustainability	13	2016
2	Robotics	12	2017

3	Building with Nature	25	2017
4	Communication and Education	11	2017
5	Building with Nature	26	2018
Total:		87	

3.1 Understanding roles

The explanation of the roles was not clear and limited according to some participants at the start of the workshop or via the provided information. This problem has been encountered during the first workshops but improving the communication may not work for each participant. *“More detailed explanation needed in order to work with it”* (participant 21, ws5). Although 11 participants of ws5 agreed that the booklets provided a clear explanation of the engineering that the participants used during the design session. Furthermore, 11 participants of ws5 strongly disagreed to thoroughly prepare for the workshop. After ws5 only 1 participants did not agree to recognize herself in her own engineering role.

3.2 Added value

The roles were useful to generate ideas from a broader perspective in addition to their own disciplinary background. Particularly within the problem space of the design thinking process. The front-end innovator and the contextual engineering roles stimulated the emphasize phase even more. It enhanced the focus on human-centered design according to the participants: *“Normally I think more about how the products, in this case the robot, is done and don't really care about society will react to it.”* (participant 11, ws2). Three workshops (ws2, ws3 and ws5) involved access to stakeholders and end-users experiencing the real-life problem and this supported the steps in the problem space even more (Fig. 2.); *“You can define the technical problems you need to solve based on user experiences”* (participant 1, ws2), *“it is a good exercise to view problems or challenges from a certain perspective”* (participant 2, ws1) and *“the roles have an added value in analysing the problem from different perspectives”* (participant 12, ws2). Participants thought working from an engineering role is *“very useful because you are more conscious about your way of thinking; more organised”* (participant 11, ws1).



Fig 2. Interviewing end-user using empathy mapping (ws2)

During the idea generation step the different engineering roles are experienced very well; *“multiple views on the same subject are needed to come to a good product”* (participant 2, ws2) and *“seeing the opinion of people from other perspective while maintaining my own*

perspective made me think in a very different way" (participant 8, ws2). However, we noticed during the discussions and from the content of the ideas that not every participant maintained in their specific role. One participant stated: *"there is lots of general discussion hence there is no need for a specific role" (participant 11, ws2).*

In total 12 participants agreed and 3 strongly agreed from ws5 that the engineering roles did result in more integrated solutions. The system integrators felt more responsible during the prototyping phase once all the ideas become one integrated concept; *"The point of view of an system integrator with respect to the whole system is important to bring everything and everyone together" (participant 2, ws2)* and *"there are still a lot of problems that arise when trying to combine different systems. A system integrator can constantly work on this" (participant 1, ws1).*

Testing the prototypes from an engineering perspective was *"experienced as more difficult from your own engineering role" (participant 6, ws2).* Due to the pressure cooker format there was no extensive time to test the prototype via all four engineering roles. Reflecting the prototypes using the engineering roles during the presentation revealed that all engineering roles had a part in the solution.

3.3 Usability

Participants that were working from their personal engineering role experienced it as natural; *"I played the role that came out of the test I experience as something that felt natural" (participant 3, ws2).* However, "forcing" participants using only their assigned engineering role felt limiting and gave a compartmentalized experience. As stated before, some exercises were a better fit for specific engineering roles than others. During ws5 it was communicated that the participants were "responsible" for their assigned engineering role and could work from their personal or other engineering roles. Nonetheless, during ws5 8 participants agreed and 8 strongly agreed that working from the engineering role felt limiting.

3.4 Relevance

8 participants agreed and 12 strongly agreed from ws3 that the engineering roles were relevant for their disciplinary field. 10 participants agreed and 10 strongly agreed of w3 that the engineering roles were relevant for the building with nature session. Only 2 participants disagreed that the engineering roles were relevant for the technical working environment. The participants of ws5 were less positive compared to ws3. It was observed that it was difficult to enthuse them during the whole pressure cooker session.

4 DISCUSSION AND CONCLUSION

Experiencing the engineering roles within the pressure cooker workshops was challenging at first. It could be clarified due to the characteristics of our fast-paced pressure cooker workshop and the limited time we got to explain the engineering roles. After working with the engineering roles the participants got more acquainted with the roles. Improvement on communication and time management is necessary to tackle these problems.

Solving complex problems using a design thinking process can be enhanced using the engineering roles. It supports future engineers to make their natural role more explicit and to think outside their own technological discipline to develop social responsible solutions. The design process and the engineering roles stimulates interdisciplinary collaboration and results in more holistic and integrated solutions for real-life problems. Using the roles as an analogy synectics technique can extent the problem and solution space of the students during a design thinking process (Fig. 3.). However, it has not been proven that the roles extended the data collection in the divergence phase and supporting the selection process in great extent. As this is a design based research and the sample size is small, the effect has

not been measured extensively and the questionnaires changed over time. Further research is necessary via an embedded case study.

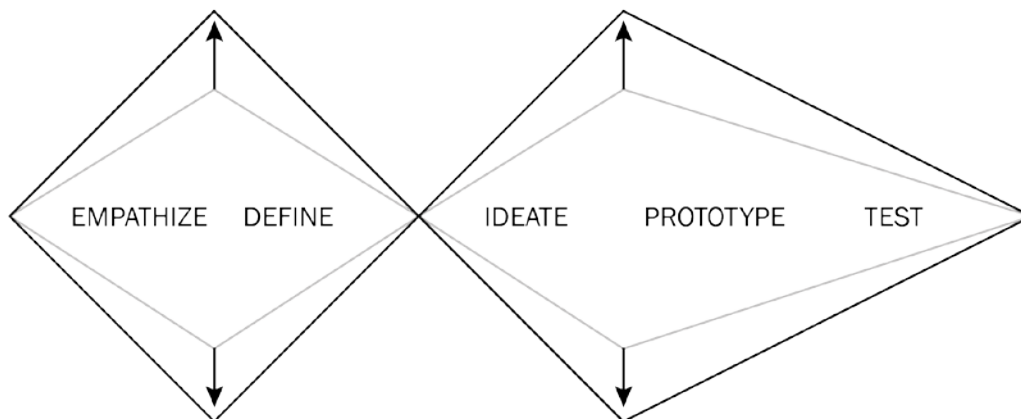


Fig 3. Extending the problem and solution space

The success of the solved complex problems using the engineering roles need to be evaluated in a real-life context. The 4TU.Centre for Engineering Education is currently developing an interdisciplinary course in collaboration with companies to examine the engineering roles solving real-life complex problems during a 10-week design thinking process.

5 RECOMMENDATIONS

If teachers would like to use the engineering roles during an experiential learning environment, such as a pressure cooker workshop, it is recommended that students prepare properly to become acquainted with the engineering roles. Communication about compartmentalization is key for a motivated mind-set to think and act from the engineering roles. It is important facilitating the students in the process reminding them using the engineering roles as analogy. Stimulating the students with engineering roles booklets and teacher facilitation might not be sufficient. Additional probes and (heuristic) questions need to be developed to improve the stimulus.

Specific engineering roles seem more beneficial in certain exercises or design thinking process steps. These steps could be enriched while enhancing the responsibility of the specific engineering role. Additional research is necessary to analyse which engineering roles are more beneficial in each process step.

6 ACKNOWLEDGEMENTS

We gratefully thank all teachers and students of the Delft University of Technology who actively participated in the workshops. A great thanks goes to PhD students Eva Frese and Frithjof Wegener to inspire us about the design thinking process. This research was supported by the 4TU.Centre for Engineering Education.

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Three-cycle Engineering Education based on the CDIO-FCDI-FFCD Triad

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Conference Key Areas: Philosophy and Purpose of Engineering Education,
Curriculum Development, Open and Online EE

Keywords: Three-cycle Engineering Education

Introduction

One of the principle objectives for improving quality of engineering education (EE) of the three-cycle structure formed within the framework of the Bologna process, is to ensure EE compliance with the labor market demands and continuity of the relevant programmes. First, it concerns the definition of programme learning outcomes (LOs). It is necessary to bring them into line with the peculiarities of the division of labor in the engineering profession. Further, it is important to design programmes that ensure the achievement of intended LOs using appropriate content and technologies.

The CDIO model developed at the turn of the 20th and 21st centuries allowed the modernization of the basic EE by establishing a consensus between theory and practice [1]. The CDIO model focuses BEng programme LOs on complex engineering activity of graduates at the following stages of the life cycle of products, processes and systems: “Conceive”, “Design”, “Implement” and “Operate”. The CDIO approach has proved its effectiveness, and many universities around the world successfully applied the approach in practice (<http://cdio.org/>). The CDIO model has become also of great importance for the development of the theory of EE [2].

However, the practice of applying CDIO Standards to the design of MSc and PhD programmes aimed at preparing graduates for research and development of innovative products has shown the need for adaptation of the CDIO Standards to the specifics of research and innovative activities [3]. Thus, it became necessary to further develop the CDIO approach for the modernization of the three-cycle EE, taking into account the various graduate competencies required for successful research, innovative and complex engineering activities.

To clarify the competencies which should be formed on the three cycles of EE, a thorough comparative analysis of the main documents defining international standards of EE was made, including the qualifications requirements: The Framework for Qualifications of the European Higher Education Area (<http://ecahe.eu/w/index.php>), FEANI Register (<https://www.feani.org>); criteria of engineering programme accreditation: EUR-ACE Framework Standards and Guidelines (<http://www.enaee.eu>), IEA Graduate Attributes and Professional Competences (<http://www.ieagreements.org>); basic principles of quality assessment of PhD programmes in European universities: Quality Assurance in Doctoral Education – results of the ARDE project (<https://www.researchgate.net>), as well as LOs of three levels of higher education (bachelor, master, doctor) at universities in Europe, the US and Russia.

The lists of the core competences of graduates of engineering BEng, MSc and PhD programmes have been composed as a result of system analysis of the documents mentioned above and synthesis of the most relevant competences required for complex, innovative and research engineering activity, respectively.

1 The FCDI model for engineering MSc programme design

Based on the core competences of graduates of MSc programme required for innovative engineering activity the FCDI (Forecast, Conceive, Design, Implement) model for the design of engineering MSc programmes was developed [4]. A FCDI programme is based on the principle that innovative product, process, and system lifecycle design and development – Forecasting, Conceiving, Designing and Implementing is an adequate competence model for MSc degree in engineering. The “Forecast” stage includes analyzing the market trends; making predictions of future customer needs; estimating risk and uncertainty; determining the most demanded and competitive innovative products, processes, and systems. The “Conceive” stage includes feasibility study; modelling and simulation; development of advanced technique and technology; assessment of the economic impact of innovations; planning and creation of R&D resources for innovative product, process, or system design. The “Design” stage focuses on designing & developing of innovative product, process, or system taking into consideration severe limitations. The “Implement” stage mainly refers to the production management when implementing innovative projects, as well as controlling of the advanced technology when manufacturing and coding. The absence of “Operate” stage (one of the CDIO components) in the FCDI model indicates that this kind of engineering activity (operation and maintenance of products, processes and systems) is not a priority for MSc programme graduates.

The FCDI Syllabus v1 and FCDI Standards v1 were developed as a result of evolution of the list of LOs presented in the CDIO Syllabus v2 and CDIO Standards, respectively [1]. The FCDI Syllabus v1 focuses the attention of the MSc programme designers on the need to provide Masters with a deeper interdisciplinary scientific and technical

knowledge, and professional competences to forecast customer needs in innovations and to conceive, design and implement new products, processes and systems. The FCDI Standards v1 focus the attention of the MSc programme designers on integrated curriculum with mutually supporting interdisciplinary courses, innovation activity with an explicit plan of integration of personal and interpersonal skills, as well as innovative product, process, and system design and development skills based on forecasting the stakeholders' needs (Standard 3 FCDI). The essential elements of the curriculum should be an introductory workshop that provides the framework for engineering practice in innovative product, process and system design and development based on forecasting the needs of stakeholders (Standard 4 FCDI); innovation-design experiences (Standard 5 FCDI); teaching and learning based on active learning and innovative methods (Standard 8 FCDI).

2 The FFCD model for engineering PhD programme design

Based on the core competences of graduates of PhD programme required for research engineering activity the FFCD (Foresight, Forecast, Conceive, Design) model was developed for the design of engineering PhD programmes [4]. A FFCD programme is based on the principle that creation of scientific basis for the development and design of innovative product, process, and system lifecycle – Foreseeing, Forecasting, Conceiving and Designing is an adequate competence model for PhD degree in engineering. The “Foresight” stage includes future study; long-term vision; analyses of the society needs; research & innovation planning; technological foresight; analyses of “critical” technologies. The “Forecast” stage includes knowledge management; research and new knowledge generation; critical analyses of scientific data; assessment of knowledge-intensive technology needs. The “Conceive” stage includes creation of scientific basis for the development and design of innovative product, process, or system; development of new technique and technology based on up-to-date knowledge. The “Design” stage focuses on scientific support of knowledge-intensive innovative product, process, or system design and development. The absence of “Implement” stage (one of the CDIO components) in the FFCD model indicates that participation in manufacturing of products, processes and systems is not a priority for PhD programme graduates.

The FFCD Syllabus v1 and FFCD Standards v1 were developed as a result of evolution of the list of LOs presented in the FCDI Syllabus v1 and FCDI Standards v1. The FFCD Syllabus v1 focuses the attention of the PhD programme designers on the need for PhD-holders to acquire new scientific and technical knowledge, as well as professional competences to create scientific basis for the development and design of innovative product, process, and system. The acquisition of pedagogical competences is also important for graduates of PhD programmes. The FFCD Standards v1 focus the attention of the PhD programme designers on integrated curriculum with mutually supporting transdisciplinary courses, research and pedagogic activities with an explicit

plan of integration of personal and interpersonal skills, abilities to create scientific basis for innovative product, process, and system design and development using the methods of technological foresight (Standard 3 FFCD). The essential elements of the curriculum should be an introductory seminar that provides the framework for engineering practice in creation of scientific basis for innovative product, process, and system design and development (Standard 4 FFCD); research-design experiences (Standard 5 FFCD); teaching and learning based on active and research methods (Standard 8 FFCD).

3 Three-cycle of EE based on the CDIO-FCDI-FFCD triad

Table 1 shows the key roles of graduates of three cycles of EE at various stages of engineering activities (F_1 – Foresight, F_2 – Forecast, C – Conceive, D – Design, I – Implement, O - Operate). The table helps to better understand the system of division of labor between representatives of the engineering profession with higher education of various levels.

Table 1. Key roles of graduates of BEng, MSc and PhD programmes

Key roles of graduates of three cycles of engineering education			
Stage	BEng	MSc	PhD
F_1	Non-priority activity	Non-priority activity	Future studying; long-term visioning; analyzing the society needs; research & innovation planning; technological foresight; “critical” technology analyzing.
F_2	Non-priority activity	Analyzing the market trends; making predictions of stakeholder needs; estimating risk and uncertainty; defining the most competitive innovative products, processes and systems.	Knowledge management; research and new knowledge generation; critical analyses of scientific data; assessing the needs of knowledge-intensive technology.
C	Defining customer needs for products, processes and systems; considering technology; developing enterprise strategy, and regulations; developing conceptual, technical, and business plans.	Feasibility studying, modeling and simulation; developing advanced technique and technology; assessment of the economic impact of innovations; planning and creating resources for innovation design and development.	Creating scientific basis for the development and design of innovative product, process, or system; developing new technique and technology based on up-to-date knowledge.
D	Creating the design, that is the plans, drawings, and algorithms that describe what will be implemented.	Designing & developing of innovative product, process, or system taking into consideration severe limitations.	Providing scientific support of knowledge-intensive innovative product, process, or system design and development.
I	Transformation of the design into the product, process, or system, including	Production management when implementing innovative project; controlling of	Non-priority activity

	manufacturing, coding, testing and validation.	advanced technology when manufacturing and coding.	
O	Using the implemented product, process, or system to deliver the intended value, including maintaining, evolving and retiring the system.	Non-priority activity	Non-priority activity

Table 1 indicates that for graduates of BEng, MSc and PhD programmes, activities at some stages are not a priority. However, this does not mean, for example, that Bachelors cannot participate in the engineering activity at “Foresight” and “Forecast” stages. If necessary, they should be able to do this under the guidance of Masters and PhD-holders, performing auxiliary functions. Also Masters should assist PhD-holders at “Foresight” stage and, in some cases, should lead Bachelors at “Operate” stage. In turn, PhD holders, if necessary, should also not shy away from activities at “Implement” and “Operate” stages, assisting Masters and Bachelors.

In practice, as a rule, engineering specialists with higher education of various levels work in a team (together with engineering technicians and technologists), performing various functions when creating technical products, processes and systems. At the same time, the highest productivity of labor is achieved if each specialist is engaged in its priority business at various stages and successfully fulfills its key roles indicated in Table 1. In order to prepare graduates of engineering BEng, MSc and PhD programmes to perform their functions with maximum efficiency, it is recommended to design three-cycle programmes on the basis of the CDIO-FCDI-FFCD triad.

4 Piloting the CDIO-FCDI-FFCD triad in Kuban State Technological University

Kuban State Technological University (KubSTU) is one of the largest research, educational and cultural centers in the South of Russia (<http://kubstu.ru/en>). The University trains engineers for high-tech industry and offers undergraduate, graduate and postgraduate programmes.

In 2017 the new version of the Russian Federal State Educational Standards (FSES 3++) was introduced (<http://fgosvo.ru/fgosvo/151/150/24>). In this regard, the University developed a strategic plan for the modernization of three-cycle engineering programmes. Engineering programmes leading to BEng, MSc and PhD degrees in food production technologies were selected as pilot programmes to be redesigned based on CDIO-FCDI-FFCD triad. Author of the paper was invited to lead the design process as KubSTU Rectorate Advisor.

First of all, the objectives and intended LOs of the BEng, MSc and PhD programmes were clarified based on KubSTU mission, FSES 3++ requirements, stakeholder needs and CDIO-FCDI-FFCD Syllabuses. Next, LOs of the three-cycle programmes providing graduates with competences required for activity at the five stages: “Foresight”,

“Forecast”, “Conceive”, “Design”, “Implement” and “Operate” were defined (Table 1). The diagram in the Fig. 1 illustrates orientation of the 4-year (240 credits) BEng programme LOs, 2-year (120 credits) MSc programme LOs and 4-year (240 credits) PhD programme LOs to F₁ - F₂ - C - D - I - O stages of engineering activity.

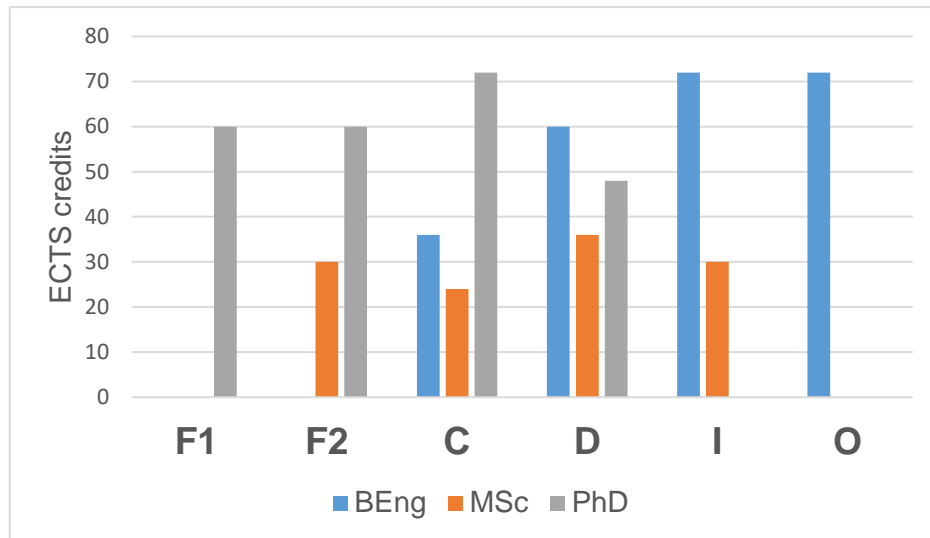


Fig. 1. Orientation of LOs of the three-cycle engineering programmes to F₁-F₂-C-D-I-O stages of engineering activity

The BEng, MSc and PhD engineering programmes were redesigned taking into account different orientation to complex, innovative and research engineering activities at various stages as shown in the diagram. The updated programmes have a modular structure.

The BSc programme consists of seven modules (Fig. 2): BEng1 – disciplinary module of social sciences & humanities, BEng2 – disciplinary module of natural sciences & mathematics, BEng3 – disciplinary module of basic engineering science, BEng4 – module of mandatory cross-disciplinary courses, BEng5 – module of variable cross-disciplinary courses, BEng 6 – module of internships & placements, BEng7 - module of final project & exam. The greatest contribution (ECTS credits) to the preparation of graduates for activity at the “Conceive” and “Design” stages is made by courses of natural sciences & mathematics (43 credits), followed by courses of social sciences & humanities (14 credits) and courses of basic engineering sciences (13 credits). The greatest contribution to the preparation of graduates for activity at the “Implement” and “Operate” stages is made by variable courses (57 credits), followed by internship & placement (20 credits). At the same time, each block of the integrated curriculum contributes to the preparation of BEng programme graduates for complex engineering activity at all stages.

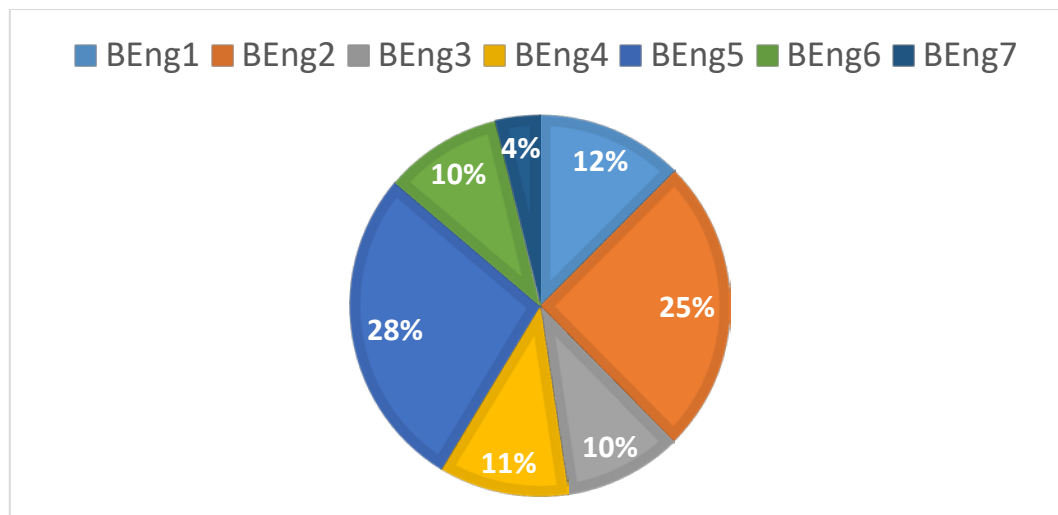


Fig. 2. ECTS Credits (%) by BEng Modules

The MSc programme consists of six modules (Fig. 3): MSc1 – disciplinary module of fundamental sciences, MSc2 – disciplinary module of fundamental engineering, MSc3 – module of mandatory interdisciplinary courses, MSc4 – module of interdisciplinary variable courses, MSc5 - module of internships & research, MSc6 - module of final project (thesis) & exam. The greatest contribution to the preparation of graduates for activity at the “Forecast”, “Design” and “Implement” stages is made by internships & research (48 credits), followed by mandatory courses (17 credits). The contribution of fundamental science & engineering courses (22 credits) is very important to the preparation of graduates for activity at the “Conceive” and “Design” stages.

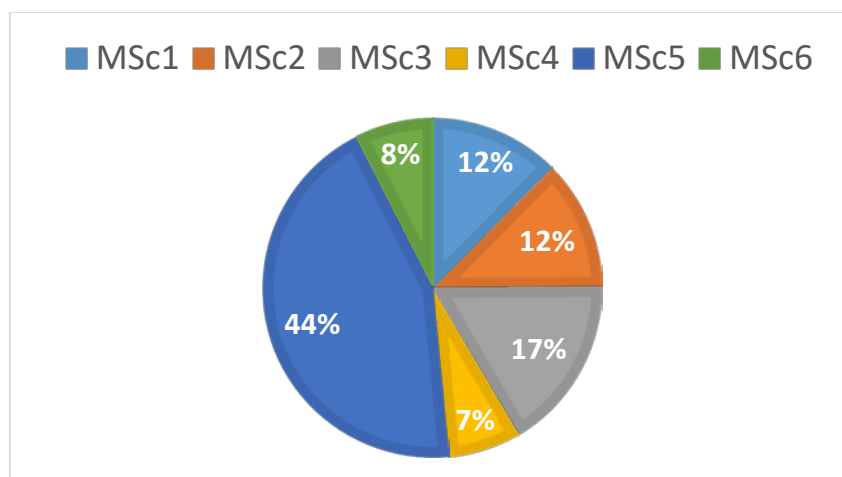


Fig. 3. ECTS Credits (%) by MSc Modules

The PhD programme consists of seven modules (Fig. 4): PhD1 – disciplinary module of fundamental sciences, PhD2 – disciplinary module of fundamental engineering sciences, PhD3 –module of mandatory transdisciplinary courses, PhD4 – module of variable transdisciplinary courses, PhD5 – module of pedagogic internship, PhD6 – module of research, PhD7 - module of final work (thesis). Research (199 credits) is dominant in the preparation of graduates for activity at all stages. However, all modules of

the PhD programme curriculum contribute to integrated learning experience of PhD students. The main idea of the programme is to prepare PhD students for careers in academic institutions, as well as industry research and development.

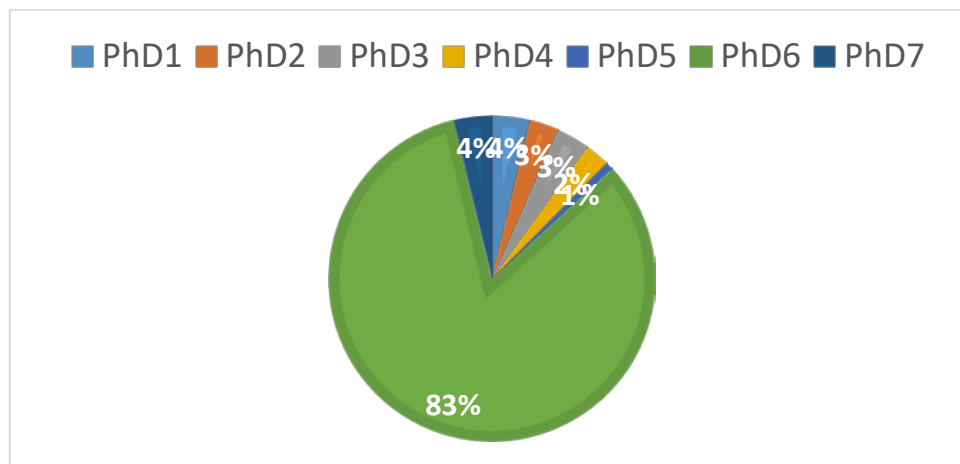


Fig. 4. ECTS Credits (%) by PhD Modules

CONCLUSION

The modernization of three-cycle engineering programmes in KubSTU based on the CDIO-FCDI-FFCD triad is the first experience of practical application of the FCDI Standards and FFCD Standards developed by analogy with CDIO Standards. The programmes including face-to-face and online teaching and learning materials are being prepared for implementation in the next academic year. The results of the implementation of the programmes redesigned as engineering “triad” will be discussed with SEFI and CDIO Worldwide Initiative community in the future.

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Comparative analysis of teaching methods for large classes

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Conference Key Areas: Innovative Teaching and Learning Methods

Keywords: Large class teaching, Team-based learning (TBL), Problem-based learning (PBL), Active learning exercises (ALEx)

INTRODUCTION

Studying engineering has never been more popular and the societal need for engineering skills is immense. As a consequence, we are accepting more and better skilled students to many of our programmes and our classes have become larger and larger over the years. Large classes are defined in this study as classes of more than 100 students and up to a 1000 students. Teaching large classes and running laboratory training exercises with a great number of students poses a series of challenges that may hamper learning in general and specially that of high-skilled students in specific and hence these are important to address. These challenges include decreasing teacher-to-student dialogue, promoting student disengagement and erosion of sense of responsibility for learning [1][2].

As noted by Ramsden [3], “many lecturers in the 1980s handled classes of 30 to 50 students, they are now faced with groups in the hundreds. Widening participation means that today’s academics are also expected to deal with an unprecedentedly broad spectrum of student ability and background. They can no longer rely on students having detailed previous knowledge, especially in mathematics and science.”

More recently, Graham [4] identified delivering student-centered learning for large classes as one of the key future challenges in engineering education. However, little research has so far been performed with regard to what constitutes “good teaching” when it comes to large classes and little work has been done with regard to evaluating existing and innovative teaching methods (TM) when it comes to address the challenges that large classes pose.

In order to address these research needs, we first reviewed the literature on what constitutes good teaching and reflect upon identified criteria and their feasibility when it comes to large classes. Second, we identified TMs which traditionally have been used or proposed in the literature, including: lecture-based learning (LCL), team-based learning (TBL), problem-based learning (PBL) and a combination of lecture capturing and active learning exercises (LC/ALEx). TBL, PBL and LC/ALEx were selected as they are all represented by the consortium and thus have high priority to us and that they have all been proposed and frequently cited in the literature as alternative to conventional teaching or LCL. Furthermore, these innovative TMs may have potential for widespread implementation in university teaching. Third, we analyzed and evaluate each of the identified TMs up against the seven identified criteria for good teaching of large classes and we discuss the limitations of our study and how the pros of each method can, in theory, be used to optimize student learning. Finally, we provide a number of recommendations on how our findings can be further explored and validated. This paper is the first to complete a comparative analysis of innovative teaching methods across universities on three different continents, when it comes to addressing the specific challenges that teaching large classes pose and therein lies the novelty of our work.

1 CRITERIA FOR GOOD TEACHING

Putting forward criteria for what constitutes good teaching is challenging and arguably context and student dependent. When it comes to undergraduate teaching, Chickering and Gamson [5] has proposed seven principles of effective teaching: 1) Encourage contact between students and faculty in order to keep students motivated and involved; 2) Develop reciprocity and cooperation among students in order for the students to sharpen their cognitive process and promoted deeper learning; 3) Encourage active learning as passive students do not learn as effectively as active ones; 4) Provide prompt feedback as formative and summative feedback is key to support ongoing student learning; 5) Emphasis time on task in order for the students to develop time-management skills; 6) Communicate high expectations in order to motivate to expend an extra effort to meet these expectations; and 7) Respect diverse talents and ways of learning acknowledging that all student and unique and required a variety of learning experiences to facilitate their learning.

Acknowledging that there is “no best” to teach, Ramsden [3] has similarly proposed thirteen important properties of good teaching: 1) A desire to share your love of the subject with students; 2) An ability to make the material being taught stimulating and interesting; 3) A facility for engaging with students at their level of understanding; 4) A capacity to explain the material plainly; 5) A commitment to making it absolutely clear what has to be understood at what level and why; 6) Showing concern and respect for students; 7) A commitment to encouraging independence; 8) An ability to improvise and adapt to new demands; 9) Using teaching methods and academic tasks that require students to learn actively, responsibly and co-operatively; 10) Using valid assessment methods; 11) A focus on key concepts, and students misunderstandings of them, rather than covering the ground; 12) Giving the highest quality feedback on student work; and 13) A desire to learn from students and other sources about the effects of teaching and how it can be improved.

Obviously, there is some overlap or alignment between the principles proposed by Chickering and Gamson [5] and the properties put forward by Ramsden [3]. For instance, Ramsden’s “showing concern and respect for student” and “using TMs and academic tasks that require students to learn thoughtfully, responsibly, and cooperatively” are similar to Chickering and Gamson’s “respects diverse talents and ways of learning” and “develop reciprocity and cooperation among students” [6]. The importance and relevance of many of the criteria put forward by Chickering and Gamson [5] and Ramsden [3] are independent of the size of a given class e.g. having a desire to share your love of the subject with students. *Table 1* provides an overview of the seven criteria for good teaching identified in this study as the most relevant for consider when it comes to teaching large classes. The seven criteria address a series of didactic issues relevant for teaching in general and especially for large classes. However, they do not address issues related to resources, economy and the overall feasibility of the TMs. To account for this, three additional criteria were added, *Table 2*, dealing with instructor and technical resources required and the flexibility with respect to facilities.

Table 1. Criteria for good teaching practices in large classes independent of teaching form, the rationale behind including the criteria and the references for why the criteria are important to the comparison and evaluation of large class teaching.

Criteria	Rationale for including criteria and references for why the criteria are important.
1. Encourage contact between students and faculty.	<ul style="list-style-type: none"> - Student-faculty interactions within and out of classes promote student commitment and motivation [5] [7]. - Faculty members serve as inspiration and as partner of discussion improving the aspiration of the students [3] [5] [8]. - Learning requires cooperation between student and faculty. Enhanced student-faculty contact promotes the cooperation [9].
2. Promote student collaboration and responsibility for own learning.	<ul style="list-style-type: none"> - After graduation students will enter jobs where team-work-skills are often a requirement or at least appreciated [10]. - Collaboration promotes corporative learning [3] [11]. - Students learn from each other and learn from teaching each other [3] [12].
3. Promote active learning.	- Active learning is one of the major keystones assuring high academic gains [3] [5] [12] [13] [14].
4. Meet diverse ways of learning.	- Students do not learn the same way and they bring in different competences to learn. To meet these diverse ways of learning the educators must facilitate various styles of teaching so that all students have the opportunity to learn within their comfort zones but challenge themselves by learning in new ways [3] [5] [9].
5. Promote critical thinking.	- The literature is in consensus that the development of critical thinking is a vital skill for students. Students which master critical thinking have greater success in education and career and are of much more importance to society [3] [15].
6. Gives prompt feedback.	- Students need to know what they do not know in order to focus their learning [3] [5] [7].
7. Provide structure and guidance with respect time management.	<ul style="list-style-type: none"> - Structure helps students to recognize and improve deep learning [16]. - Students need help to learn effective time management [5].

Table 2. Other criteria important for the feasibility of the teaching methods

Criteria	Rationale for including criteria
8. Need for instructor resources allocated.	With large classes, the TMs require a lot with respect to instructor time allocated per student e.g. feedback, grading of assignments. This criterion assesses the overall instructor workload.
9. Need for technical resources allocated.	The technical feasibility of the TMs must be assessed. Does the approach require advanced technology? This criterion evaluates the economical investments required for the teaching approach to be feasible.
10. Flexibility with respect to facilities.	From an administrative point of view it is important to assess if the teaching approaches are tied to specific facilities. e.g. special class room features. This criterion assesses how likely it is to apply the teaching approach at any given location.

2 TEACHING METHODS

A range of different TMs have been proposed in the literature. In our analysis we included TMs which traditionally have been proposed as alternative to conventional teaching and which may have potential for widespread use in university teaching.

2.1 Lecture-based learning

The terms “conventional teaching” or LBL are not well-defined and are used for many different teaching approaches [17]. In this paper we define LBL as TMs which are educator-centred rather than student-centred and which are based primarily on lectures. The teaching approaches applied are often deductive of nature and a typical example would be an educator that prepares and presents the course curricula in shorter or longer lectures, broken into smaller sessions where students are activated by various exercises. In LBL communication is mainly one-directional but do offers possibilities for students to raise their hands and ask questions.

2.2 Problem-based learning

PBL was developed within medical education in the late sixties to face the problem that medical knowledge and new technologies constantly emerged [18]. The teaching approach places the student learning process in focus and students in small groups are confronted with a problem provided by the facilitator rather than with theory and exercises [19]. Barrows [20] describes six core elements of PBL. 1) Learning is student-centred, 2) Learning occurs in small groups, 3) Teachers are facilitators or guides, 4) Problems form the organizing focus and stimulus for learning, 5) Problems are vehicle for the development of problem-solving skills, and 6) New information is acquired through self-directed learning. PBL comes in various designs and with very different facilitator approaches [20] [21]. In its most pristine form, the students are presented to the “case of concern” with no further introduction. The task of the students is then to decipher the problem and the nature of it, derive a solution to the identified problem and implement the solution. In other approaches the facilitator might introduce key concepts before introducing the problem [21] or cut away or emphasize some of the learning tasks.

2.3 Team-based learning

TBL was developed at the University of Oklahoma in the late seventies to meet the challenge of increasing enrolment. It is an instructional method where the students, in small teams, apply conceptual knowledge following a three phases protocol [22]. Phase I is an individual pre-class study, where the students familiarize themselves with the knowledge needed for solving in-class challenges. Phase II is a readiness assurance test (RAT) consisting of an individual readiness assurance test (iRAT) and a team readiness assurance test (tRAT). First, the students complete the iRAT which typically is a multiple choice test. Then the students complete the tRAT by answering the same test as a group getting immediate feedback. In phase III, the facilitator can bring up issues identified by the RAT and the students can ask questions before the teams apply the knowledge gained in a decision-based exercise. Classical TBL holds seven core elements: 1) Team formation; 2) RATs; 3) Immediate feedback systems; 4) In-class team-based problem solving; 5) Application of the 4S-principle (**S**ignificant problem; **A**t a given time working at the **S**ame problem; **S**pecific choice and **S**imultaneous report); 6) Structure; and 7) Peer review [23].

2.4 Lecture capturing and active learning exercises

LC dates as far back as 1970 and is defined as “an umbrella term” that covers any technology that allows instructors to record, and make available instructional activities in their classrooms. The term is used to describe the use of software and hardware options which allow for a wide range of capabilities ranging from a simple podcasts (audio recordings) to more complex systems that allow students to personalize lecture capture by tagging, editing, annotating, and subsequently sharing the results with their peers [24]. LC can be both synchronous and asynchronous. Synchronous lecture capture occurs when the capture is live broadcast allowing remote students to be in sync with the local lectures. Asynchronous lecture capture is the recording of lectures and making those recordings available to the remote students after the local lecture is complete. Traditionally both versions of LC were lecturer-centered and a one-way conversation. More recently LC technologies have advanced to allow remote students to post questions during the recording and thereby interact with the lecturer and fellow student [25]. LC is often said to make out-of-class learning more productive but it is not intended to be used as a replacement for in-class instruction [26]. Instead the aim is to assist in making face-to-face class time more appealing [24] [25] [27] and to support students whose first language is not the language of instruction. ALEx or active learning activities (ALA) is an instructional method where pre-planned activities make the students put to use the content that they have just been taught. Many different ALA and ALEx exist [27] [28] which are either informal or graded.

3 COMPARATIVE ANALYSIS OF LBL, PBL, TBL AND LC/ALEX

In the final part of our study, we assessed the fulfilment of the various criteria for each of the four TMs on a scale going from “high”, “medium” to “low” (see *Table 3*). The assessment was done on basis of the literature review and is a qualitative reflection of the authors’ perspectives. In general, LBL scores low with regards to all identified criteria except for “providing structure and guidance with respect to time management” (High) and “flexibility with respect to facilities” (Medium). This is due to the fact that LBL is a teacher-centered one-directional TM which per definition is everything which modern innovative teaching is moving away from. However, it does hold some advantages like structure and limited resources allocation needed. PBL and TBL both scored medium with regard to “encouraging contacts between students and faculty” and high on: “promoting student collaboration and responsibility for own learning”; “promoting active learning; meeting diverse ways of learning”; “promote critical thinking”; and “need for instructor resources allocated”. Whereas TBL scored high and medium on “giving prompt feedback” and “providing structure and guidance with respect time management”, where PBL scored low on both. Whereas PBL scored low and high on the “need for technical resources allocated” and “flexibility with respect to facilities”, respectively, it was vice versa for TBL. The similarities in our evaluation of PBL and TBL are that they build upon many of the same key elements [19] [20] [22] [23]. Most importantly, both TMs are conducted in small teams which encourage collaboration, active learning, diverse learning approaches and critical thinking. The differences in our evaluation of PBL and TBL are due to the fact that TBL has incorporated direct feedback mechanisms in a repeated structure [22] and that it requires a substantial technical investment making TBL a rather non-flexible TM [29]. LC/ALEx scores medium for all criteria except for “providing structure and guidance with respect time management” and “need for instructor resources allocated” where it scores high and for “flexibility with respect to facilities” where it scores low. LC/ALEx

is an improved version of LBL which require a lot of instructor resources in terms of teaching assistants and technical resources in terms of LC-devices and large lecture halls. The lecture hall requirements make LBL non-flexible with respect to facilities.

Table 3. Comparative assessment of the four teaching methods according to the identified criteria.

Criteria	LBL	PBL	TBL	LC/ALEX
1. Encourages contacts between students and faculty.	Low	Medium	Medium	Medium
2. Promote student collaboration and responsibility for own learning.	Low	High	High	Medium
3. Promote active learning.	Low	High	High	Medium
4. Meet diverse ways of learning.	Low	High	High	Medium
5. Promote critical thinking.	Low	High	High	Medium
6. Gives prompt feedback.	Medium	Low	High	Medium
7. Provide structure and guidance with respect time management	High	Low	Medium	High
a. Need for instructor resources allocated.	Low	High	High	High
b. Need for technical resources allocated.	Low	Low	High	Medium
c. Flexibility with respect to facilities.	Medium	High	Low	Low

4 DISCUSSION

In this study, we set out to identify criteria for good teaching of large classes and compare these criteria up against features of traditionally used TMs and more recently proposed innovative TMs. Overall, we found that each of the analyzed TMs have pros and cons from a theoretical point of view. When considering our findings, it is important to have a number of aspects in mind. First of all, it is well acknowledged that there are not universally accepted criteria for what good teaching is and that good teaching is always context and student dependent [3] [30]. On the one hand, it seems that there are criteria for good teaching that are independent of the size of the class, e.g. clear communication with respect to expectations, guidance, feedback and evaluation, efficient announcement of high expectations to the students and securing of a good learning environment, where the students feel safe and where they are not afraid of “failing” [3] [5]. On the other hand, we have identified 7 criteria that we believe are influenced by the size of the class, but we might have overlooked important criteria and more research is needed to explore variation in preferences and criteria among broad spectrum of students and teachers considering their diverse abilities and backgrounds [3]. Second, it is important to remember that the TMs that we analyzed in this study are selected because they have been proposed in the literature and because they have potential for widespread implementation in university teaching. This does not mean that there might not be innovative TMs that we have not considered and should have included in our analysis e.g. flipped classroom and project-based learning. Furthermore, there are many variations of the TMs that we did not include in our analysis and it cannot be ruled out that variations of e.g. PBL have been developed in order to address the limitations that we have identified in our analysis. More work is needed in order to consider these and similar aspects. Finally, our evaluation of the four different TMs up against the seven criteria that we identified as important when it comes to teaching large classes is arguable theoretical and could

be more empirically based. For instance, application of the different TMs in the same teacher and discipline settings and with similar students with regard to ability and background could provide a basis for which to explore the hypotheses that we have generated with our analysis.

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Embedding the SDGs into Interdisciplinary Engineering PBL:

A Case Study: Structural Mechatronics Integrated Design Project

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Conference Key Areas: Engineering Skills, Curriculum Development, Sustainable Development Goals in Engineering Education

Keywords: SDG, Sustainability, Sulitest, Interdisciplinary, PBL

INTRODUCTION

Sustainability is an increasingly important part of an engineers' practice, requiring active participation to counter the global threats to humanity. Sustainability Engineering Education chiefly focusses on design considerations for emissions, energy and materials e.g. reducing pollution, renewable technologies and whole lifecycle analyses. Cultivating a broader working knowledge of sustainability in Engineering Education beyond the technological aspects risks being perceived as non-essential. We focus on the introduction of the United Nations 2030 Sustainable Development Goals (SDGs) into the curriculum and their potential role to encourage sustainability learning. We present a case study of how SDG knowledge is embedded into a multidisciplinary PBL experience – the Integrated Design Project (IDP), which involves designing real-world structural mechatronics applications for mechanical, electrical, civil, and materials disciplines. We use this case study to address 3 research questions in embedding SDGs into Education, which are derived from the broader set proposed in a recent review of this literature by Thüerer et al [1] :

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- 1) Implemented practice: Which approach is best suited to expose students to SDGs and what tools should be used?
- 2) Student's values versus knowledge: What is the relationship between student's SDG knowledge and their values?
- 3) Outcomes: How does the student adoption of SDGs outcomes evolve over time?

This paper proceeds as follows: Section 1 provides some background including a brief outline of SDGs and the Sulitest. Sections 2, 3 and 4 address the research questions using case study evidence. Section 5 concludes with a discussion of the key findings, impact, limitations and future work.

1 BACKGROUND

1.1 The SDGs and their Means of Implementations

The UN General Assembly adopted 17 Sustainable Development Goals (SDG) [2] in September 2015 as part of the "Transforming our World: the 2030 Agenda for Sustainable Development 2030 Development Agenda". The SDGs are underpinned by 169 targets with 231 progress indicators, and 7 "Means of Implementation" (MOI). The SDG titles are stated in *Fig.1* and *Fig.2*. The SDGs manifest through three perspectives: the environment, society and the economy. They are not legally binding, but public interest is rising; e.g. google trends data for global web searching of SDGs from January 2016 to January 2018 indicates a doubling of searches.

The SDG Agenda outlines several MOI categories: Trade; Finance; Technology; Capacity Building; Policy and Institutional Coherence; Multi-stakeholder Partnerships; Data monitoring and Accountability [3]. MOI categories can be grouped across three domains: Financial, Institutional and Technological. For Engineers, the Technological domain MOIs are most relevant, and are defined as i) general research and development of technologies, and ii) technology sharing with developing economies. All MOIs are interdependent e.g., the MOI Climate financing and Environmental Impact Assessments, would support the MOI Biodiversity technology developments and their transfer to developing countries [4]. Interdependencies are considered essential to realising any SDG, and consequently SDG017: Partnerships for Goals, is dedicated exclusively to identifying and cultivating them.

1.2 Sustainability knowledge and literacy

To successfully embed SDGs in Engineering Education, students must understand them. A tool to assist this is the Sustainability Literacy Test (Sulitest) [5], an online test comprising of 30 "core" Multiple-Choice Questions (MCQ) which address global sustainability issues, with an option for 20 further questions specific to locality or discipline. Responses provide an indication of knowledge against global and national benchmarks for individual SDGs, and, more reliably, four broader knowledge categories which are listed in *Table 1*. Sulitest questions are wide and varied e.g. scientific knowledge "*Which one of the following is NOT a greenhouse gas?*"; social

sciences *"In 2012, how many people around the world have been victims of forced labour?"*, and more broader systems thinking related to Engineering *"A complex system ... can operate important changes when acting on sensitive points called 'leverage points'... which is the least effective for achieving systemic changes?"*. Experiences in using the Sulitest at Nordic Engineering faculties acknowledge its value as a teaching tool despite variability in question type and quality, such as the varied use of statistics in MCQ answers [6].

1.3 Embedding sustainability into interdisciplinary PBL

Four approaches were evaluated for embedding general sustainability into curricula from several thousand module descriptions in [7]. These were i) exposure to environmental issues in existing modules, ii) specific sustainability modules, iii) as distinct programme-level specialisation and iv) intertwined as a concept into modules. The latter was found to be most effective. Likewise, in this work, we embed the SDGs into an Interdisciplinary PBL module – the IDP. This approach is discussed and endorsed by [8] with caveats: the need to consider underdeveloped group work skills and student difficulties in relating to other disciplines. Once taught the SDG framework, and taking the Sulitest, students can express how their work can progress each goal. E.g. Designing a large moving structure in a city such as an Observation Wheel, could address SDG08 (Decent Work and Economic Growth) via the target 8.9 (policies to promote sustainable tourism) which is measured by indicator (8.9.2 Number of jobs).

2 IMPLEMENTED PRACTICE

Which approach is best suited to expose students to SDGs and what tools should be used? To answer this, we present an outline of how the SDGs are embedded in the IDP and evaluate student performance.

2.1 The Integrated Design Project (IDP)

The Integrated Design Project (IDP) is a 200-hour 2nd year Interdisciplinary PBL module with the theme "Kinetic Architecture through Structural Mechatronics". Students collaborate in interdisciplinary teams to produce reference designs for large moving structures located across the world e.g. bridges, stadium roofs and observation wheels. The project specifications and assessments are developed with a leading global engineering consultancy (Arup) to ensure authenticity. The Learning Outcomes (LO) are designed to foster interdisciplinarity [9]. They are 1) Demonstrate skills in multidisciplinary team-based sustainable engineering design and 2) Develop an individual disciplinary identity and competence. Students undertake "Design Impact Sessions" in Project management; Sustainability; Health and Safety; Enterprise; Design process methods; Emerging technology research; Model-based Simulation and Design. The IDP is modelled on best-practice interdisciplinary PBL modules from other institutions e.g. [10].

2.2 IDP Sustainability Learning Outcomes

Sustainability is embedded into IDP via 3 LOs of which the first 2 relate to SDGs. These are: 1) Develop a broad understanding of sustainability via SDGs which achieved through background reading of materials and taking the Sulitest; 2) Develop an understanding of the SDGs and how the project could progress them which is achieved through group discussions about the value of SDGs to their project. For completeness, the additional LO is 3) Identify the main sources of embodied and operational carbon and energy and the end-of-life scenario for your project. Sustainability LO are assessed at the end module through answering the question *“What is your project’s impact on the wider world?”* with evidence to meet the following assessment criteria: *“The impact of the solution on the wider world is clear from how you propose to progress the SDGs. The conceptual and discipline-specific design summaries give clear evidence of full quantitative and qualitative consideration of open (energy) and closed (materials) ecosystems, and how your structure will help answer local people’s needs e.g. land use, gender equality, education, culture, production and consumption, life cycles, value chains, water, energy and food”*.

2.3 Sulitest Results

IDP Students (n=335) complete the Sulitest mid-way through learning i.e. after 100 study hours. Results from the 2017 cohort (*Table 1*) report their core knowledge is 56% correct answers, which is comparable to the national and worldwide average, and previously published results for Nordic Engineering students (53%, n=700) [6]. Scores for the four broader knowledge categories shows greatest positive difference in personal responsibility and the individual role to play. The weaker scores come from knowledge of the transitioning towards sustainability, which suggests to us that MOIs should be a focus of SDG learning.

Table 1. Students Sulitest performance (n=355) against benchmarks

Knowledge Category	% correct		
	Students	National	Worldwide
Sustainable humanity and ecosystems	63	64	59
Global and local human-constructed systems	56	58	54
Transition towards sustainability	49	51	51
Role to play, individual & systemic change	53	50	50
All Questions:	56	57	54

Sulitest performance against each SDG (Figure 2) indicates a cohort’s relative knowledge level with respect to an SDG, however it could also simply indicate relative question difficulty.

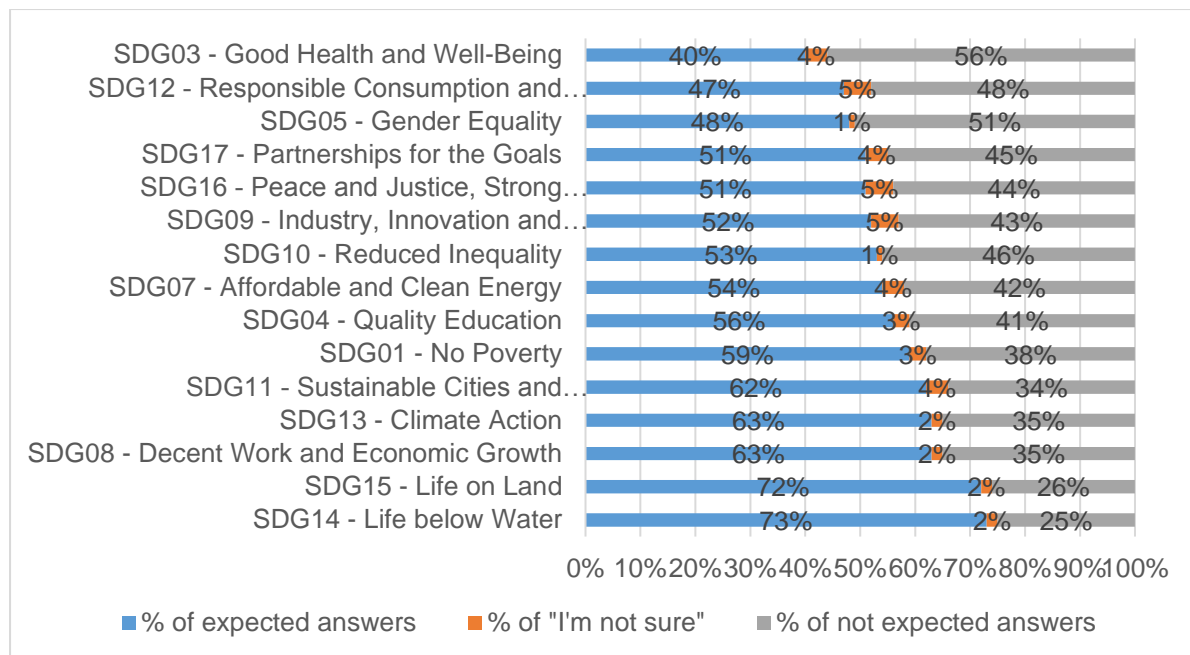


Fig. 1. Sulitest results measuring relative knowledge of 2nd year Engineering cohort (n=335)

3 STUDENT'S VALUES VERSUS KNOWLEDGE

3.1 SDGs valued by student groups as applicable to practice

What is the relationship between student's SDG knowledge and their values? Project groups (n=46) comprising 5-8 students are asked to select 3 SDGs they deem most valuable. There are 3 clear SDGs (Fig. 2) selected by over half of the groups: SDG08, SDG09 and SDG10. These popular SDGs are candidates for greater focus when teaching SDGs. Comparing knowledge against values (Fig. 1 vs Fig. 2) reveals some similar rankings e.g. SDG13 and SDG08, however, in general, similarities are weak.

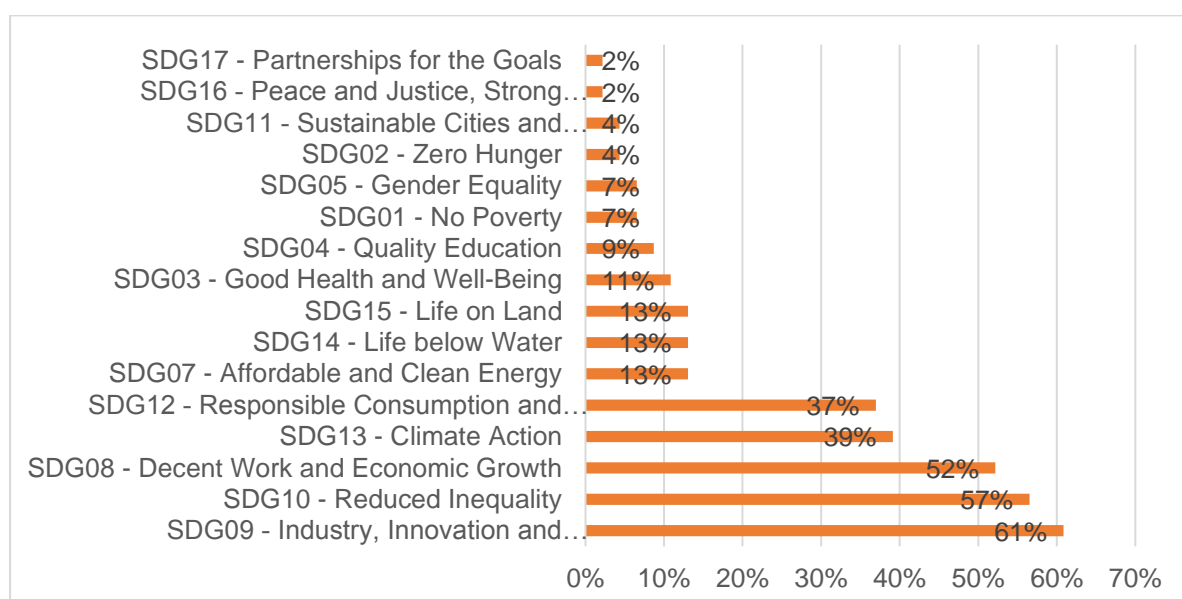


Fig. 2. SDGs valued by project groups (n=46)

Further insight comes from looking at the set of SDGs valued by each group. A Pearson correlation coefficient is calculated on the SDGs selected together. Focussing on the top 5 SDGs selected by groups students to improve reliability, the correlation matrix is shown in Table 2.

Table 2. Pearson correlation of valued SDGs by project groups (n=46)

SDG	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
8	0.1	0.0	0.1	0.2	0.0	0.2	0.1	1.0	0.1	0.3	0.0	0.0	0.2	0.0	0.2	0.1	0.1
9	0.1	0.0	0.3	0.1	0.1	0.1	0.3	0.1	1.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2
10	0.1	0.0	0.1	0.1	0.1	0.2	0.0	0.3	0.0	1.0	0.2	0.0	0.1	0.1	0.0	0.0	0.0
12	0.0	0.0	0.1	0.1	0.2	0.2	0.2	0.0	0.0	0.0	0.2	1.0	0.1	0.1	0.1	0.1	0.1
13	0.2	0.2	0.1	0.1	0.1	0.2	0.1	0.2	0.1	0.1	0.0	0.1	1.0	0.0	0.1	0.1	0.1

Overall there are more negative correlations than positive correlations between the most popular SDG choices e.g. Decent work and Economic Growth (SDG08) has a strong negative correlation (-0.27) with Reduced Inequality (SDG10). Reasons for negative correlations could be the omission of goals that are perceived to have similar meanings to those already selected. Conversely, Responsible consumption and production (SDG12) and Climate Action (SDG13) are positively correlated. Reasons for positive correlations could be the selection of complementary SDGs which have casual effects on each other. These observations highlight the need to relate SDGs to each other, ensure less technological SDGs are valued, and potential groupings.

3.2 Progression of valued SDGs by Means of Implementation (MOIs)

Groups are asked to describe how their projects would advance their valued SDGs to develop their MOI understanding. Their MOI responses are coded into logical sets and summarised in Table 3.

Table 3. Project group (n=46) identified MOIs and their SDGs

Group identified MOIs (coded)	Group Valued SDGs	Official MOI type(s)
Education/employment/Trade opportunities	1,2,3,4,7,8,9,11,	Capacity Building
Healthy lifestyle choices	3,11,	Policy and Institutional Coherence.
Profit reinvestment in public services	4,7,	Finance, Policy and Institutional Coherence.
Sustainable/green energies	7,12	Technology
Civic pride: provide inspiration	7,8,9,11	Multi-stakeholder partnerships
sustainable material sourcing and recycling technologies.	3,9,11,12,13,15	Technology
Environment protection: natural habitats and water conservation	1,3,6,14	Policy and Institutional Coherence.

Comparing groups identification of MOIs to official categories demonstrates that the students can intuitively identify MOIs from most categories. There are two MOIs that appear for several SDGs: Education/Employment and Trade Opportunities, and Sustainable Materials and Recycling Technologies. Interestingly, SDGs relating to Inequality (SDG05 and SDG10) are valued by groups but did not have identified MOIs; there is an ongoing challenge to relate non-technological SDGs to Engineers.

4 OUTCOMES

How does student adoption of SDGs outcomes evolve over time? We examine sample assessed output (Figure 3) from a high-achieving group at the end of their 200 hours IDP learning and compare it to a similar report they submitted midway through learning. The chief difference is the inclusion of SDG10 (Reduce inequality) with suitable MOIs, and SDG12 referring to specific design information. This demonstrates a successful integration of the SDGs into sustainability learning.

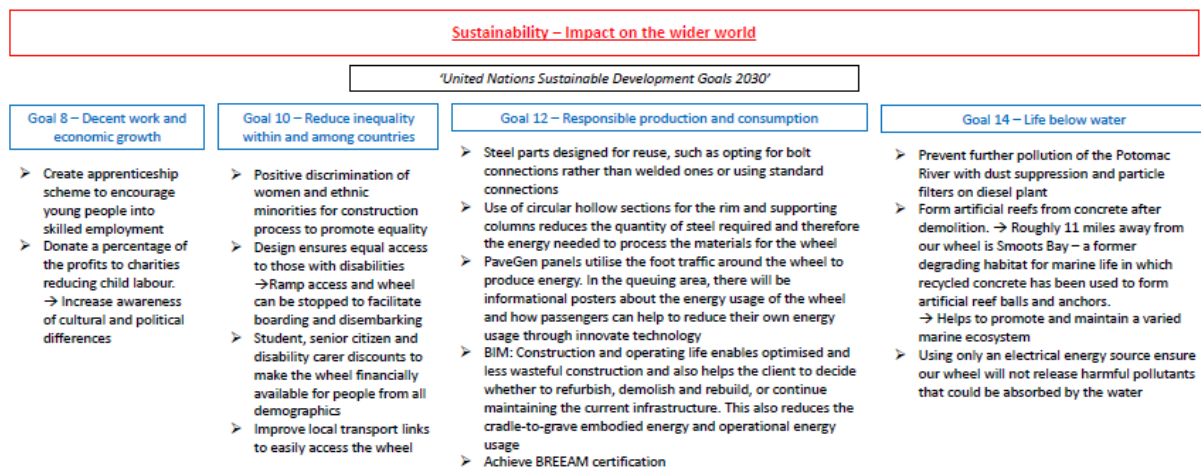


Fig. 3. Example of assessed Sustainability Learning Outcomes

5 DISCUSSION

Embedding SDGs into Engineering Education could fundamentally change Engineers thoughts and action for the benefit of the planet. A case study embedding SDGs in Interdisciplinary PBL addressed three research questions: “Which approach is best suited to expose students to SDGs and what tools should be used”, “What is the relationship between student’s SDG knowledge and their values?” and “How does the student adoption of SDGs outcomes evolve over time?”. Post-instruction Sulitest results measured SDG knowledge and compare it to national and international historical baselines to provide measures of student progression. Cultivating student engagement by relating valued SDGs to projects via implementation provides insights into how students relate them. SDG-oriented learning outcomes and assessment, logical groupings, and prioritisation are useful mechanisms and guidelines for engineering educators wishing to embed SDGs into their curriculum via interdisciplinary PBL.

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Design and Implementation of New Communication and Lifelong Learning elements in a Master Engineering Course

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Keywords: communication, lifelong learning, curriculum elements, engineering education

INTRODUCTION

In the last 20 years, engineering education has received calls from industry that graduates are not prepared for the labour market, because they do not have the transversal skills to be successful workers nor are they aware of their talents and weaknesses [1]. The gap between the competences of graduates and the competences required from the labour market has triggered researchers and educators to develop curriculum elements which focus on the acquisition of a particular set of transversal competences. The emphasis is on competences such as communication, problem solving, working in teams, and lifelong learning [2].

In this research, as part of the European PREFER project (Professional Roles and Employability of Future EngineerRs), importance is given to lifelong long learning and communication competences. Lifelong learning is the process of actively looking for continuous personal and professional development, thereby identifying own strengths and weaknesses [3]. Graduates who possess this continuous self-knowledge are most likely to be prepared to enter the labour market because they constantly look for improvement and adapt to different job requirements [4]. To stimulate this continuous

self-knowledge, we asked students to reflect on strengths and weaknesses, and on the contribution of the course to their student and professional careers.

Communication is often limited to oral and written exchange of information [5] and similarly university curricula restrict communication assessment to oral presentations and written reports. However, communication is more than that. It is an active process of listening, adapting conversation styles, and using feedback in terms of giving and receiving opinions and responses [6]. Therefore, in this paper, we discuss the development of a communication activity which takes account of a wide spectrum of ways to communicate, such as describing, listening, questioning, answering, and drawing.

To prepare students with the competences required from the labour market, we need to provide them with innovative methods to stimulate those competences. Herein, curriculum elements focusing on communication and lifelong learning competences are described and integrated in an existing Master course of the Aerospace Engineering (AE) faculty of Delft University of Technology. We report on the learning outcomes and the validation of the curriculum elements.

1. CURRICULUM ELEMENTS

1.1. Intended learning outcomes/objectives

At the end of this learning module, students will be able to:

- Experience different ways of communicating (e.g. describing images, effectively answering, asking questions, and drawing images)
- Understand the importance of communication for engineers
- Reflect on course contribution in view of their future student and professional career, on their strengths acquired and developed during the course, and on their concrete points for improvement.

1.2. Design and implementation

Two curriculum elements are integrated in an elective course of 7 weeks (84 hours study load) in the 1st year of the Master degree of the Aerospace Structures and Materials at the AE faculty of Delft University of Technology.

The first curriculum element focuses on communication and is based on the children's game, the Chinese whispers. This communication exercise lasts 40 minutes and allows students to practice their communication by describing, questioning, asking and drawing information. We expect that this activity prepares students for their final course examination where students have to communicate with witnesses and within the group in order to gather facts, to generate hypotheses and to draw conclusions about what may have happened in an accident scene. For more information about the Forensic Engineering course, previous publications can be consulted [7, 8].

The communication activity is conducted in the 5th lecture, in which students are divided in teams of 5. Each team is then divided into 3 roles as followed:

- Role A (2 students per group): students have access to an image (*Figure 1*) for 10 minutes, and after that have 2 minutes to describe it verbally to role B;

- Role B (2 students per group): students receive the verbal description of 2 minutes from role A (cannot ask questions to role A), and will only verbally reply to questions from role C for 10 minutes;
- Role C (1 student per group): students have to draw the initial image given to role A and to do that they have 10 minutes to ask questions to role B.

After a short explanation of the roles and tasks of the communication activity, role A stays in the room and roles B and C leave the room. Role B enters the room 10 minutes after the start of the activity and role C 2 minutes after that Role B enters.

At the end of the activity, a 10-15 minute brainstorm session is carried out where students are encouraged to reflect on the communication within the roles and between roles, and the whole team performance.

The second curriculum element centres on lifelong learning and the importance of self-knowledge for future development. This element is built around two moments of reflection, one at the beginning and another at the end of the course. The initial reflection focuses on expectations and possible learning contribution of the course to students' future career. The final reflection takes account of what students learn in the course and how they can apply that learning in the future, what strengths they acquired in the course, and what points need further improvement.

2. METHODS

To evaluate the curriculum elements, i.e. to understand whether the learning outcomes have been reached, the following methods were used:

- A self-assessment questionnaire delivered at the end of the communication activity to investigate how students perceive their communication competences. Students were asked about their communication performance during the activity, the points they can improve and the help of this activity to understand the importance of communication;
- A rubric (*Table 1*) based on [9] to assess the outcome drawings of the communication activity;
- A pre- and post-survey to find out whether students perceive the improvement of communication and lifelong learning over the period of the course. This survey was design based on the Siemens competence model ([3] Siemens proprietary information) and the data was anonymously analysed in SPSS. This survey is available upon request;
- A semi-structured interview simultaneously with the two lecturers of the course to explore students' performance and understanding of the importance of communication with the activity as well as to get feedback to improve the activity. This interview was recorded, transcribed, coded and analysed based on [10].

To meet the ethical board requirements of our university, permission of the board was sought and given, and students were asked to sign a consent to be part of this research. We informed students that their participation in the research would not influence their final grade and the lecturers would not have access to their individual results during the course. Of the 22 students, 21 students gave permission for us to use their anonymous data.

The study aimed at answering the following research questions:

Q1: How was the communication performance of the groups in the activity?

Q2: Did students understand the importance of communication with the activity?

Q3: Were students able to reflect on course contribution to future career, own strengths and weaknesses?

Q4: Did the self-perceived communication and lifelong learning competence level of students change over the running of the course?

3. RESULTS

3.1. Communication performance

To answer the first research question about the communication performance of the groups, both the self-assessment questionnaire, delivered to students at the end of the activity, and the final drawings of the four groups were analysed.

Of the 20 students who participated in the communication activity, 19 filled out and delivered the questionnaire after the activity. The findings showed that 17 students perceived that their communication skills were good (4 out of a 5-point Likert scale) during the communication activity. However, these students recognised that they should improve their communication skills mainly in terms of describing information (6 students), asking questions (6), paying attention to details (5), *Figure 2*.

The results of the comparison of the four drawings with the original image (*Figure 1*) using the criteria of the rubric (*Table 1*) showed that group 4 had the best communication performance (36 points out of 44), followed by group 1 (28 points). Group 2 and 3 had 24 and 25 points, respectively.

We can conclude that none of the groups could depict all objects with the right colour, position, shape and size, which means that their communication needs improvement. This corroborates the perception of student regarding their communication competences, which they thought were good but still need improvement.

From the observations during the activity and the final discussion with the students, we can point out some problems in the communication process which lead to miscommunication. For instance, the assumptions of the students in role C about the real world. In the words of two students: "Black was not in my mental view. It's difficult to not be biased about the concepts that we have in mind and change them." and "When I think about a cow, I imagined it to be white with black spots. The colours confused me. A black cow and black trees..."

Students also realised that the first step to take was to ask general questions to understand the image as a whole and then converge into more detailed questions. Some groups took their time to start with broad questions, and detailed questions were often missing. A comment of a student showed that: "I never thought about asking the sizes of the objects".

3.2. Importance of communication

Students were asked whether they felt this activity helped them to understand the importance of communication. 18 students out of 19 replied that they understood the

importance of communication with this activity (Figure 3). A lecturer on the other hand said that *parts of it* (the activity) *were useful in them* (students) *to thinking about what is important in communication, but I think the space meetings braked down, so students were diverging from the rules.*

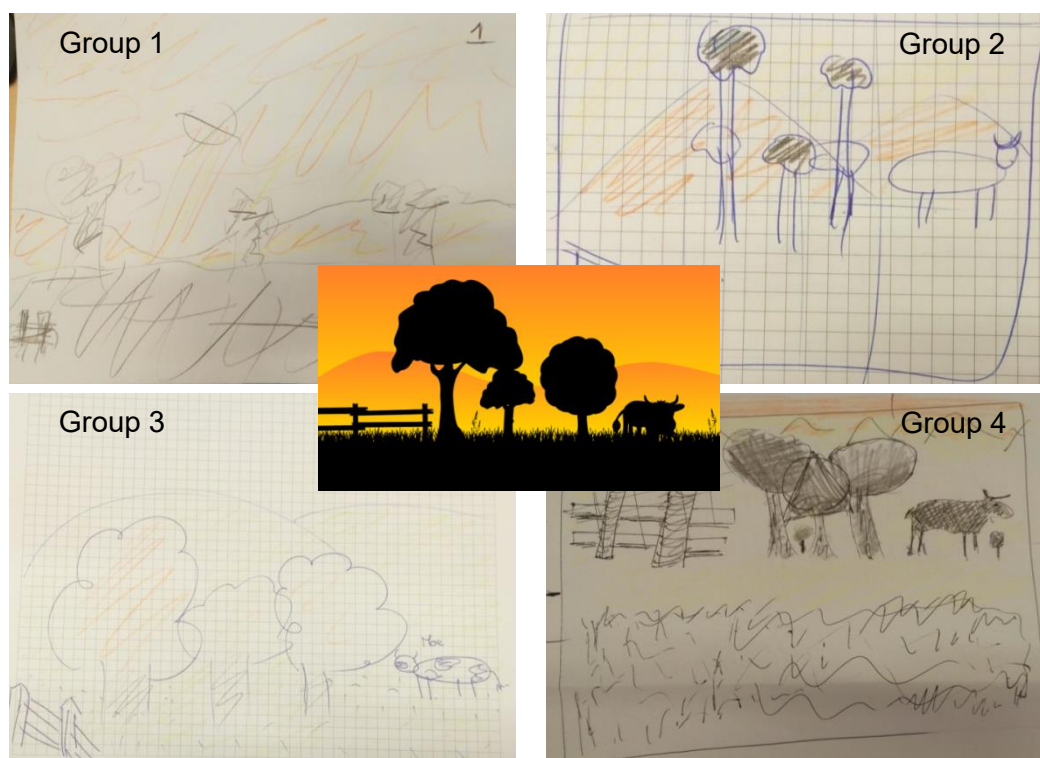


Figure 1 – Top: Image used in the communication activity and shown to role A. Bottom: Final drawings of the four groups in the communication activity.

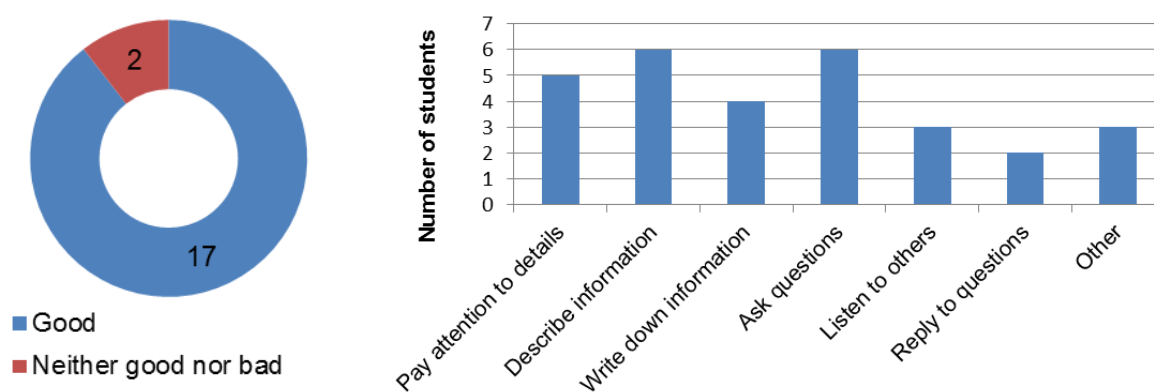


Figure 2 – Perception of students on their communication competences (on the left) in a 5-point Likert scale (very good, good, neither good nor bad, bad, and very bad), and on the competences they want to improve (on the right).

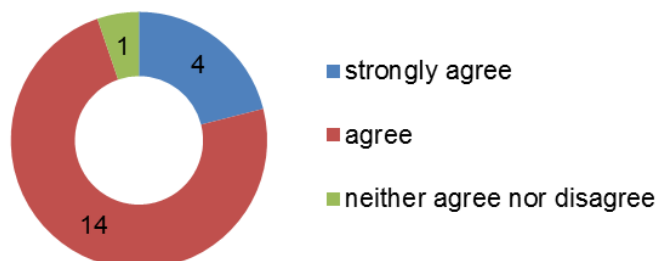


Figure 3 – Perception of students on whether this activity helped them to understand the importance of communication. A 5-point Likert scale (strongly agree, agree, neither agree nor disagree, disagree, strongly disagree) was used.

Table 1 – Rubric with detailed criteria used to compare the four drawings of the four groups to the original image.

Objects	Amount	Colour	Position	Details
□ Tree	□ 3	□ Black	□ Middle	□ The tree on the left is the biggest (at the front) □ The tree in the middle is the smallest (at the back) □ The tree on the right is medium size (compared to the other two) □ The tree on the left has triangular tree top □ The tree in the middle has triangular tree top □ The tree on the right is circular
□ Bull/cow	□ 1	□ Black	□ Bottom right	□ Tail □ Horns □ Hear □ Head to the right
□ Fence	□ 1	□ Black	□ Bottom left	□ Horizontal alignment □ 4 horizontal wooden sticks □ 2 vertical wooden sticks
□ Grass	-	□ Black	□ Bottom	□ ¼ of the image
□ Ears of wheat	□ 2 bunches	□ Black	□ 1 bunch between the 2 trees on the left □ 1 bunch on the right	□ Each bunch has 3 ears of wheat
□ Mountain	□ 2	□ Orange and yellow	□ Background	□ Rounded mountains □ Orange on the top and yellow on the bottom
□ Sky	-	□ Orange and yellow	-	□ Orange on the top and yellow on the bottom

3.3. Lecturers' feedback

Both the lecturers of the course liked the communication activity. They said *it was a really good activity* and that they think *it was for students a nice exercise*. Because students can *learn a lot about the communication aspects*, lecturers think that the activity would be very useful and could integrate it again in the course next year. However, they would try to deliver the activity before a specific exercise of the course so that students can apply the skills acquired during the activity to a concrete exercise of the course. Indeed, they intended to do it but, because of time issue, it was not possible.

Since this is a pilot study, we were interested to know what improvements could be done. Lecturers suggest that:

- The instructions of the activity could be more clear to students. To solve this issue, simple handouts containing the explicit times per roles, the precise rules of what students can and cannot do, and the available materials can be distributed at the beginning of the activity.
- Lager or different rooms are needed to avoid contact between groups.
- There should be an observer per group, who could be for example a student of another group, to make sure that the rules of the activity are kept.

There should be more oral feedback at the end of the activity where students can reflect on individual and group communication performance. In this way, it is possible to quantify what happened to the communication in between steps and to understand where communication does not properly work. The use of the observer can also be useful to find this out.

3.4. Reflections on strengths and weaknesses

The aim of the reflection exercise at the beginning and at the end of the course was to make students think about the influence of their present choices on their future life. For this reason, some questions to reflect on were given to students. The response rates of the initial and final reflections were 8 and 17 students, respectively. The low response rate of the initial reflection was because students were asked to do it at home in a voluntary basis. To encourage students' participation, the final reflection was done in class. In *Table 2* the students' strengths gained in the course and points that need improvement are illustrated.

Table 2 – Students' reflections on strengths and points to improve.

A strength that students discovered or developed over the course	Reporting information and communication (4 students) Taking time to evaluate the given data before taking hasty conclusions (2) Thinking outside the box (2) Problem solving (1) Critical thinking (1) Structuring/organizing groups/tasks (1) Look for additional information when needed (1) Listen to others (1) Understanding and valuing group capacity (1) Stay calm (1) Rely on team members (1)
A concrete point which students would like to improve	Management of team members (3 students) Patience (2) Technical knowledge (2) Leadership skills (2) Quick problem solving and decision making (2) Listen to others (1) Get rid of bias information (1) Assume that others have the same information (1) Adaptation to new situations (1) Personal contact (1) Personal feedback (1)

3.5. Communication and lifelong learning competence levels

To investigate whether students self-perceive improvement of communication and lifelong learning competences over the course, a pre- and post-survey was applied at the beginning and at the end of the course. We asked students to grade themselves on a 4-point scale (0: absent, 1: basic, 2: advanced and 3: expert with detailed level description) per competence. A Wilcoxon signed-rank test was carried out to evaluate whether there was significant difference in students' competence level before and after the course. Students' communication competence level were not significantly higher after the course ($Mdn = 18$) than before the course ($Mdn = 19$), $z = -1.446$, $p = 0.148$, $r = 0.36$ (medium effect size [11]). A reason for this result may be that the Bachelor degree of AE faculty already focuses on the development of communication skills and students perceived a high level when they enter the Master degree. On the other hand, students' lifelong learning competence level were

significantly higher after the course ($Mdn = 11.5$) than before the course ($Mdn = 13$), $z = -2.191$, $p = 0.028$, $r = 0.55$ (large effect size [11]).

CONCLUSIONS AND REFLECTION

Curriculum elements focusing on communication and lifelong learning were designed and implemented in the Aerospace Engineering Master of TU Delft. The pilot study results showed that students perceived an increase in their lifelong learning competences over the course. At the same time, reflections helped students to identify their own strengths and weaknesses.

Moreover, the communication activity helped students to understand the importance of communication, and made them realise that their communication skills still need improvement. Students, however, did not perceive an increase in communication shown by the pre and post-surveys. According to the lecturers this activity has a lot of potential and with small adjustments can be reintegrated in the course of next year.

From the results of the methodology triangulation used to assess student communication (with rubric, pre and post-surveys and lecturers' feedback) and lifelong learning (with reflections and a pre and post-surveys), we are confident that these new elements help students' competency development. Since these curriculum elements are engineering independent, easy to plug and play in existing courses and a step forward in very traditional engineering learning environments, they will be implemented in the universities of the other two partners of the project and comparisons will be made.

ACKNOWLEDGEMENTS

This work was supported by Erasmus+ program of the European Union (grant agreement 575778-EPP-1-2016-1-BE-EPPKA2-KA) and is part of the PREFER project (<http://www.preferproject.eu/>). The authors would like to acknowledge their colleagues in the project as well as Michiel Schuurman and Calvin Rans for allowing this curriculum elements to be implemented in the Forensic Engineering course, and all the students for taking part and allowing us to use their data.

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Microlearning to support authentic learning in continuing education and for engineering students

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Conference Key Areas: Continuing EE and Lifelong Learning

Keywords: Microlearning, authentic learning, workplace learning, Self-Directed Learning.

1 INTRODUCTION

In today's rapidly changing society, there is a growing demand for learning for innovation in organisations and engineering education. The increased global competition requires organisations and individuals to be qualified to quickly respond to changes in the market. Organisations and individuals must be capable of innovating - defining and solving novel, complex problems for which often no previous knowledge exists [1].

This paper is about microlearning as a format for learning in continuing engineering education to foster the use of authentic learning in dealing with real-world issues and

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innovation at the level of higher engineering education (HEE). The authors of this paper see learning as a contextual lifelong learning process which enables the construction of knowledge, finding new solutions to problems, creating connections between experiences, participation and learner control of the content and the process [2].

The microlearning method was developed to support predominantly informal learning activities in or close to the workplace, while avoiding the drawbacks of informality [3]. Microlearning helps to structure an on-demand approach to learning and performance in a flexible and self-directed way and facilitates organising short-cyclical learning practices at the workplace. From the experiences in the business environment it is assumed that microlearning has a lot of potential to stimulate the use of authentic learning in HEE [4]. Authentic learning practices in education have many benefits, as they bring real world problems, constraints and solution strategies in to the classroom. These learning practices though are not always easy to incorporate in existing teaching praxis, as they are time consuming, difficult to organise, expensive or too complicated. Microlearning supplies a format that help to facilitate authentic learning from a content and organizational point of view.

2 RESEARCH CONTEXT

2.1 The bigger picture

A daunting issue in Europe is skill shortages. Such gaps arise where the skills required are unavailable in the workforce, due to for example technological advance. If people are over- or under skilled, whatever their qualification level, their skills do not match the job [5]. One way to mitigate this mismatch is to forge stronger links between institutions and industry like structured partnerships such as 'knowledge alliances' to adapt curriculum to demands of society. Therefore, good engineering education relies on real life learning and the ability to communicate and collaborate, which demands students to be self-developers in a continuous improvement process [6]. Authentic settings can be helpful to augment the understanding of innovation and entrepreneurship in real life and microlearning can be a catalyser for the incorporation of authentic learning in the HEE context.

2.2 The focus of this paper

The focus is on exploring microlearning as a format to support authentic learning in HEE with the aim to acquire relevant knowledge, labour market skills and attitudes relevant for innovation in a workplace setting. To achieve this, we describe a series of microlearning experiences in a large energy company that were intended to support continuous innovation within the company and use this information to deduce lessons for HEE. In section 3 we describe the origins of microlearning and the basic structure of the method. In section 4 we report on the experiences within the company and in the final section there is a reflection on the lessons for HEE.

3 LITERATURE REVIEW

3.1 Learning for innovation

Technological innovation has made our society knowledge intensive and successful performance of individuals or groups heavily relies on the acquisition and utilization of relevant information and suitable communication to achieve task objectives. Many authors agree that innovation is rooted in people's tacit knowledge and arises through non-planned

bottom-up initiatives as a result of day-to-day experiences. Tacit knowledge is difficult to transfer without close personal contact, demonstration, involvement and to be communicated and shared within the organization, it has to be made explicit somehow [7]. Key element for learning for innovation is creating interaction that support social learning, participation and bridge the gap between employees with various responsibilities in the organization.

Learning within organisations is difficult, but vital not only for newcomers but also for experienced employees and for experts. Students often come to the workplace ill-prepared: their competences may not always match with the demands, demands change rapidly as a result of innovation, and the demands vary across Europe given the heterogeneity of industry, HEE and development policies. Furthermore, students often are not well-prepared to deal with the demands of innovation in organisations. It is of paramount importance that students are better prepared and have a firm understanding of practice when they leave their schools. The argument is that an authentic learning environment that mimics real life in the workplace is an effective way to improve the student's capability to cope with learning demands at the workplace. Microlearning is an authentic way of learning in the workplace and, as such, is a promising format for learning in today's HEE that aims to prepare students for an ever-evolving future.

3.2 Authentic learning and self-directed learning

Authentic learning gives learners opportunities to think and act like professionals in a learning or training context. Exposure to a real-life context with topics that are relevant and applicable in their prospective working environment prepares them with practical and useful knowledge and skills and has a beneficial effect on motivation [8]. Herrington and Oliver state that authentic learning environments enable students to feel involved in a project as part of a larger whole with tasks that could never be carried out individually and with a stimulus for (higher) thinking processes through communication and discussion [9]. The emergence of the internet and other new tools for communication, visualization, and simulation have lowered the threshold to develop and use authentic learning environments. In a physical sense it is easy to organize, but in a pedagogical sense it needs a clever design to deal with tasks and limitations imposed by the curriculum and institutional constraints [10].

Another important notion of authentic learning is the concept of self-direction. Self-Directed Learning (SDL) is not a clearly delineated, linear process, but a rather informal and self-directed way of meeting personal learning demands. It is a process of which the outcome will be evaluated by the learners themselves in the context of the workplace setting [11]. This ability for SDL is important for students but requires different behaviours in the setting of a workplace. To facilitate SDL, educational activities need to be designed in such a way that people, albeit individuals or groups, have space to discuss their own goals and work towards them.

3.3 Microlearning

The term microlearning, microteaching or microtraining, has been around in various forms and is currently viewed as a new way of responding to the growing need of learning on demand at the workplace and beyond [12]. Microlearning can be delineated as a pragmatic approach to lifelong learning due to its capability to support flexible learning that can be

easily integrated into everyday activities, supporting individual learning aims and needs [13]. Microlearning consists of a number of short, customized learning sessions for a group of employees with the focus on workplace-related learning demands with high practical relevance. The main goal of microlearning is to establish an effective way of active learning using short learning sessions with a minimum of interruptions of the regular workflow. Anyone at the workplace can initiate and organize microlearning on the basis of current needs and demands. The sessions are self-directed: the participants are not consumers of an activity but are expected to be highly involved in all parts of the process. This is essential to accomplish sustainable learning outcomes. Furthermore, to facilitate the active self-regulated learning activities, the organization needs to allow individual learning to take place as part of the daily workflow, rather than by hierarchical control and standardized set ups.

As presented in figure 1 a microlearning session typically comprises a time span of 15-20 minutes, which fits easily in the daily work process. It can activate and maintain learning processes for a longer period when they are bundled up in series, either face-to-face, online or in an e-learning situation (figure 2). Each session starts with an activating activity, followed by a demonstration or exercise. Next there is time for feedback or a short discussion on the exercise, and each session is concluded with directions for further development and a brief preview of the next sessions. Microlearning incorporates elements of the classic direct-instruction model but does not follow all the steps because of time constraints in the organisational context of the sessions.

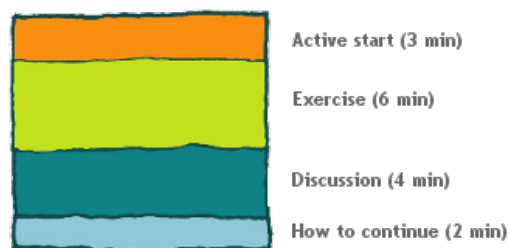


Fig. 1. The structure of a microlearning session (based on [14]).

Figure 2 shows how a series of microlearning sessions can be organized. A series of multiple short learning situations, bundled up to one microlearning series, can foster an active process of knowledge gathering and sharing.

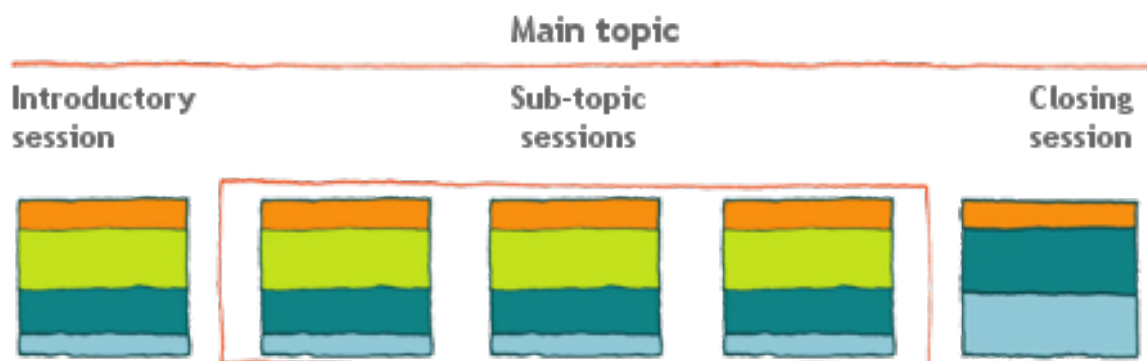


Fig. 2. A series of microlearning sessions (based on [14]).

4 MICROLEARNING: A CASE DESCRIPTION

The microlearning method has been developed and tested over a period of years in various organisations in an iterative improvement process. Previous to our current research there were three consecutive cycles of microlearning projects, following a step-wise approach in developing and testing the microlearning method to suit the context and focus of specific goals. This was done in close collaboration with over fifty partner organisations (universities and industries) in five European countries over the course of two Leonardo da Vinci Lifelong Learning projects. The microlearning method has been refined and applied in practice in the aftermath of these projects.

In this paper one of these microlearning experiences is presented to bring out the value for continuing and authentic learning, combining the issues of workplace learning, self-directed learning, and collective learning. This case study was executed in a large multinational energy company. The case-study research method as described by Yin [15] is applied here as a suitable method to study complex social and contemporary phenomenon in a real-life context and adheres as such to the organizational context which is a crucial condition for determining the success of the microlearning method. The main objective was to test microlearning for its usability in the operational business context and to develop insights in how to scale up and facilitate microlearning if the 'proof of concept' project was successful.

4.1 Set up of the evaluation

The purpose of the evaluation was to analyse the achievements in line with the goals of the 'proof of concept' phase. In the evaluation both the learning process of the participants as well as the organisation and execution of the microlearning method - were considered. The series of sessions carried out in the company were about lean production and maintenance.

Qualitative data were collected using a quick scan interview with the main stakeholders at the start and a concluding interview at the end of the experiments. A project diary was used to keep track of the experiences during the coaching activities of the researchers, their participation and observations. Quantitative data were collected using short questionnaires for the management, the initiator and the prime user. In addition, the initiators of the sessions prepared and described the design of the sessions on work sheets. In total six series of sessions took place. The employee's qualification of microlearning were summarized and used as input for the concluding interviews of the researchers with the employees.

4.2 Preparations

The prime users, the initiators and conductors of the sessions, were trained to use the microlearning method and coached in their first use of the method in practice. Each microlearning series of sessions was prepared with the initiator, being a change manager or co-worker, who organized the microlearning activities. Microlearning was introduced as a mechanism to support informal learning practices, adding flexibility and dynamism in a process where the employees were expected to be fully engaged throughout the process. A prerequisite therefore was to involve the primary stakeholders from the beginning on and familiarize them with the method in an operational way, having them acquiring the skill to convene a session. Tapping into motivational behaviour of employees was considered to be a prominent driver.

The prime users adapted the microlearning method and tools to the specific requirements of the maintenance department of a chemical plant. Different user groups were identified based on the kind of problems they wanted to work on using microlearning. In most cases the employees wanted to solve a specific inefficiency, like dust pollution, welding issues, and storage for machine parts. The selection of issues served as an example of how microlearning can be used for 'lean' purposes. The other employees, usually co-workers, were introduced to microlearning during an introductory session, mostly the first of a series of sessions on solving a shared problem.

4.3 Results

The employees experienced microlearning as a flexible method concerning the selection of issues to be addressed, the urgency or complexity of the issue and the organisation and planning. The microlearning method was considered a clear, easy-to-learn process structure with the capacity to take effective action. The series of sessions supported experiential learning, viewed as a process of making generalizations and conclusions about the learning experiences. The employees experienced a clear relation between the selected issue, their motivation and the learning process. In short, microlearning captured their interest, because of the direct link between the observed need, the process and the end-result.

The outcome of the questionnaires, the project diaries and interviews showed various relevant aspects for the use of microlearning as an alternative to existing learning practices on the work floor and in HEE.

Motivation: Microlearning motivated management and prime users and energized employees, who highly appreciated the lean solutions and the fact that their expert knowledge was addressed as a relevant input. Employees were reinforced and supported the knowledge sharing process.

Achievement of goals: The goals set for the microlearning sessions were achieved to a reasonable extent. For example: Employees used microlearning to solve an inefficiency related to dust pollution. The impact was easily measured by looking at the number of machine failures due to dust pollution over a period of time and compared to previous data.

Organizing microlearning at the workplace: The 'knowledge owners' communicated and gave feedback, the participants shared knowledge and took 'quick learning steps', which supported the workplace learning process considerably.

Relevance of the learning for their work: The learning was considered reasonable and relevant mainly because this was about workplace related issues resulting in concrete actions ("no monologues"). The structure allowed for issues to be repeated by others. The impact will be even greater when the users are more experienced with the teaching and learning method. "Colleagues should be able to feel comfortable using this method".

Time spend: Effective time spending, since meetings took place at the workplace where employees demonstrated and applied their knowledge timewise in line with the microlearning approach.

Learning climate: A positive effect on currently used methods was that the structure and conciseness of microlearning were incorporated to share knowledge in other settings (e.g. in toolbox meetings).

Next step: Microlearning is not yet a 'habit' or 'automatism'. Next step is integration of the learning method in the currently used methods for workplace learning (also as part of performance actions) to support a more process-oriented learning environment.

5 CONCLUSIONS AND DISCUSSION

This paper was about the question if and how microlearning can contribute to the construct of an authentic learning environment in HEE. The case study revealed that microlearning as a way to support informal and self-directed learning in an organisation, motivated both employees and management. Microlearning was applied to cover different demands by different users and showed to be purposeful to involve employees in an activating way, dealing with their learning needs in a timely manner.

The conclusion can be that the short-cyclic microlearning method can be beneficial for employees in organisations to support workplace learning, but also for students in HEE to support authentic learning. The important ingredients for successful microlearning are self-directedness of the participants, the ownership of the learning demand, the incorporation of existing knowledge and experiences. Microlearning is a format that is flexible in focus and can deal with a variety of topics. Once people are familiar with the format, they can use it to work on many different issues. There is a lot of potential for this format in problem-based learning sessions for students of various levels of their programmes. With students who do not have sufficient knowledge the initiator and or coach could be more directive in how to progress or the format could be applied to explore what knowledge is still missing within the team. For student teams, either in PBL or in other kinds of project work, who are more advanced in knowledge this method is fit to work on problems and innovations they need in their projects. They can use microlearning as a way to accelerate their work. They will not only improve their efficiency as a team, but will understand how to support continuous learning in a self-directed way.

6 ACKNOWLEDGMENTS

The authors would like to thank Gerdje Pijper (Van der Wal Transport B.V.) and Heide Lukosch (TU Delft) for their various contributions.

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Creative Heuristics in Engineering Education

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Conference Key Areas: Teaching Creativity & Innovation

Keywords: Creativity, Invention, Heuristics

INTRODUCTION

Creativity is one of the key skills of the 21st century. This importance is reflected in the educational policy documents of many countries from Europe, America, Australia and East Asia [1]. Creativity also plays an important role in engineering, and engineering can be viewed as a special case of a more general process of creative problem solving [2].

However, many current curricula in engineering education do not seem to adequately incorporate creativity. An analysis of module descriptions at three leading German technical universities shows that the skills necessary for generating original ideas are absent from most subjects taught [3]. This seems to be especially so for study programs in engineering. A survey amongst students from the three general academic areas engineering, sciences and humanities at the University of Connecticut shows that there are far more absent creativity criteria in engineering than in the other areas [4]. This could mean that prospective engineers are not well educated in creativity skills and that the students' creative self-concepts even suffer from study programs in engineering. A cross-sectional study at a large mid-Atlantic university shows no change in creative self-efficacy for first-year and senior engineering students. Furthermore, it shows lower creative identity and lower expectations for creative results in senior students with the strongest decline in the group of female students [5].

Apart from the problems of over-specialization and focus on factual knowledge, Cropley [2] sees a main problem in engineering in a lack of knowledge about creativity. There often seems to be no consistent definition of creativity and no clear understanding of the underlying psychological principles enabling creativity in engineering. This coincides with the author's

observation that the focus of creativity in engineering is usually on creativity techniques such as brainstorming or TRIZ/TIPS (Theory of Inventive Problem Solving) without a clear understanding of how these techniques work and why. However, the more intuitive creativity techniques such as brainstorming are often too broad for engineering problems as they mainly rely on association, while the more analytical approaches such as TRIZ are focused on invention, but are very complicated and tend to overwhelm the engineering students.

The paper proposes the use of heuristics containing process rules for engineering education in creativity, as they are useful in highly uncertain environments, easy to learn and provide direction and instruction for novice engineers. A literature analysis of existing concepts in creative problem solving and insight psychology is conducted to find the main heuristic principles of creative problem solving. Moreover, a qualitative meta-analysis of existing collections of heuristics in invention from historical analysis, inventor insights or principles underlying creativity techniques provides useful creative heuristics. As a result, the paper develops a framework for creative heuristics in engineering with four main principles. The framework contains a collection of creative heuristics in engineering allocated to the main principles and can be used in engineering education to support students in inventive projects.

1 CREATIVE PRODUCTS AND PROBLEMS IN ENGINEERING

The standard definition of creativity includes the two components originality and effectiveness [6]. On the one hand, a creative product should have novel attributes, which makes it unusual, unexpected or even inconceivable. On the other hand, a creative product should also fulfil a certain need or solve a given problem and be in some form useful, appropriate or valuable.

This is especially so for the products of engineering. In this regard, Cropley & Cropley [7] use the term “functional creativity” to describe the creativity necessary for industrial products such as engineered items or manufactured consumer goods. The focus of functional creativity is on the useful purpose of novel products, i.e. a novel product must fulfil its intended need. Thus, effectiveness is more important than originality for functional creativity.

Creative problems in engineering are described as either insight problems or inventive problems. Insight problems usually lead to a fixation or impasse blocking the route to a better solution [8]. An inventive problem can be defined as a “problem containing a contradiction in the form of incompatible requirements and/or properties [...] that cannot be solved by adequate methods and means” [9]. Both insight and inventive problems cannot be solved analytically but require new approaches to overcome either the impasse or the contradiction.

According to Perkins [10] problem spaces which require a creative solution have four characteristics: They offer a wide range of possible solutions with only a few fruitful ones (Rarity). Those fruitful solutions usually lie isolated or semi-isolated (Isolation) without any obvious connection or clues for a promising direction (Plateau). This makes it hard to depart from existing solutions, so that inventors are often stuck with solutions offering false promises (Oasis). In this situation, simple rules or principles can help to find promising target gradients to initiate a search direction for a better solution and overcome the fixation on current solutions.

In a study of inventors, Perkins [10] finds that inventors tend to work in the middle of the continuum between sheer chance and safe bet. This means that they usually work on problems where they see at least a systematized chance of success or even a fair to good bet. It does not mean that inventors do not exploit chance occurrences along the way, as in fact they often do. It rather means that inventors seem to make use of “general principles underlying invention” [11], which will be explored in the following sections.

2 CREATIVE HEURISTICS

In the scientific literature, two kinds of definition of the term “heuristics” can be distinguished. One kind of definition is from the field of decision-making, and signifies rules of thumb to distil the most important information of a situation for the given choice. This approach often leads to useful solutions for complex problems under high uncertainty, but not necessarily to the best or optimum solution [12]. In the field of decision-making, there is often a clear rational choice to be favoured, and the discovered heuristics have a descriptive character.

The other kind of definition is from the field of problem solving and creativity. In this field, a heuristic can be described as “a strategy or rule of thumb for generating ideas or for solving problems” [11]. These heuristics can be derived by analysing the work of inventors and need to be of a medium generality, so that they are both meaningful and applicable for different kinds of problems [13]. In the field of problem solving, there is usually an open-ended problem situation, in which the targets are not always clear and there is no obvious rational solution. This means that these heuristics are prescriptive and indicate a promising search direction to the inventor. However, due to their medium generality they do not deliver a ready-made solution. “Heuristic reasoning is reasoning not regarded as final and strict but as provisional and plausible only, whose purpose is to discover the solution of the present problem” [13]. Heuristics for creative problem solving are called creative heuristics in this paper.

3 FRAMEWORK OF CREATIVE HEURISTICS

The qualitative meta-analysis focuses on existing collections of heuristics from the field of technical invention. The main research method is a qualitative content analysis. For this, a category system for the classification of heuristics is developed. The development of the category system is theory-driven and deduced from existing literature in the fields of creativity, insight psychology and heuristic problem solving. An overview of the main concepts distinguishing different heuristic principles is given in table 1. Other concepts – not mentioned in this paper – often focus on one single principle, e.g. association or combination.

One basic concept of creative problem solving is lateral thinking. Lateral thinking is described by de Bono [14] as a deliberate and practical process related to insight, creativity and humour. The target of lateral thinking is to restructure insights or fixed mental patterns. The two basic principles of lateral thinking are the generation of alternatives and the challenging of assumptions. With regard to insight problems, Klein [15] proposes a Triple Path Model for insights characterized by different activities. These activities are not only different, but partly contradictory. While the Contradiction Path builds on a weak assumption against conventional wisdom, the Creative Desperation Path eliminates the weak assumption to generate a new solution, and the Connection Path generates a completely new assumption by using coincidences or curiosity to connect different elements in a new way. A prominent categorization of creativity techniques is the structure proposed by Geschka and colleagues [16]. The structure is based on the main underlying idea-generating principles of the techniques, which enable the user to break out of fixed mental routines. The principles distinguished are free association, structured association, configuration, confrontation and imagination. Another set of heuristics to solve various problems called “Modern Heuristics” is proposed by Polya [13]. Apart from analogy and combination, this set of concept contains many rules to restructure the problem, i.e. to vary the problem, to specialize or generalize the problem or to add auxiliary elements or problems.

Table 1. Concepts of Heuristic Principles

Lateral thinking [14]	Paths to insights [15]	Idea-generating principles of creativity techniques [16]	Modern heuristics [13]
<ul style="list-style-type: none"> • Generation of alternatives • Challenging of assumptions 	<ul style="list-style-type: none"> • Contradiction • Connection, coincidence, curiosity • Creative desperation 	<ul style="list-style-type: none"> • Free association • Structured association • Configuration • Confrontation • Imagination 	<ul style="list-style-type: none"> • Variation of the problem • Decomposing and recombining • Generalization • Specialisation • Analogy • Auxiliary elements • Auxiliary problem

From the existing concepts of heuristic principles a framework is developed which serves as a category system for the content analysis (see figure 1). The basis of the framework is the distinction of generating alternatives and challenging assumption by de Bono [14]. Additionally the elements of reframing the problem and fine-tuning the solution are added.

Reframing the problem is a necessary element in the creative problem solving process and specifically addressed in the approach by Polya [13]. It can be achieved by generalizing or specialising the problem, e.g. moving from the level of raw material to the level of final product in product development. Furthermore, reframing of the problem can be achieved by broadening the scope through auxiliary problems or elements. In the case of product development, this could mean focussing on the configuration of the business model or the customer experience instead of on the product offering or it could mean to include further elements such as packaging design or the design of complementary products.

The generation of alternatives can be achieved by “Variabilization & Configuration” and by “Combination & Separation”. Confrontation is incorporated in the connection path of Klein [15] and is an idea-generating principle of creativity techniques [16]. Furthermore the principle of variabilization is a central feature of many inventive heuristics such as those found in [11]. The principle of combination is mentioned in all of the described concepts of principles. Although it is not directly mentioned as an idea-generating principle of creativity techniques, it is implicitly included in the principle of configuration as the examples of creativity techniques in this category mentioned in [16] also use combinatorial principles, e.g. Morphological Box.

Challenging assumptions can be achieved by “Contradiction & Confrontation” and by “Imagination & Visualization”. Contradiction is a central feature of an inventive problem as defined in the inventive approach of TRIZ/TIPS and is an idea-generating principle of creativity techniques. The principle includes both the contradiction path and the creative desperation path of Klein [15] where either a weak assumption is discarded or a weak assumption is used to build a new insight and usually a conventional assumption is discarded. So both of these paths are about discarding unnecessary or inadequate assumptions. Imagination is mentioned as one of the idea-generating principles by Geschka and Zirm [16] and is reported by many

inventors as a central approach, amongst them famous and often-cited accounts of August Kekulé, Albert Einstein and Nikola Tesla.

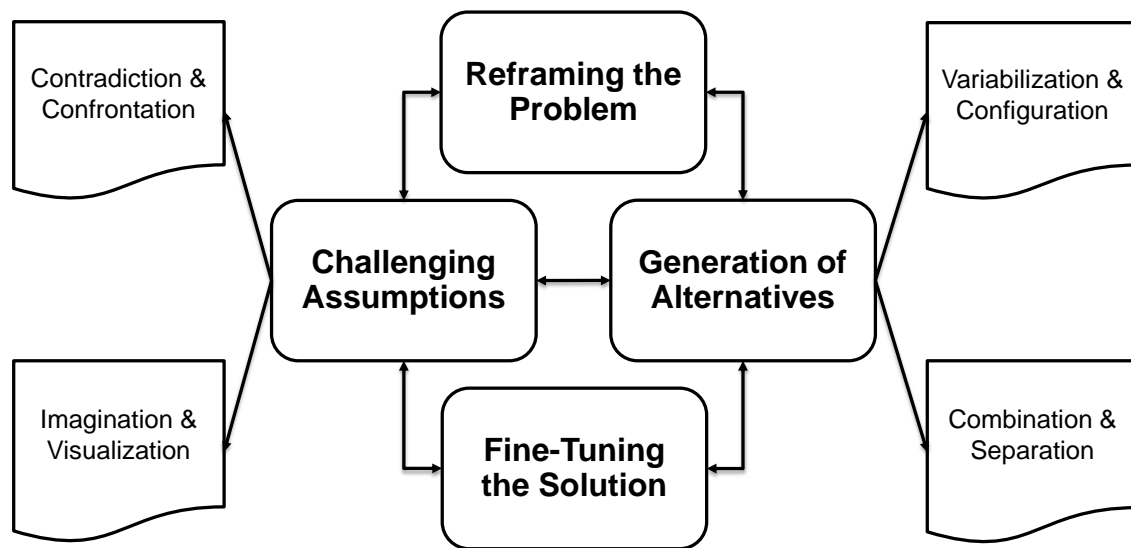


Fig. 1. Framework of Creative Heuristics [17]

The framework can be used as a toolbox with different phases. Usually the creative process starts with the definition of the problem, i.e. the first problem frame. Then ideas are generated via generating alternatives and challenging assumptions. If this approach is successful, the solution can then be fine-tuned. If the current solution is impractical, the problem solver can try to generate more ideas or to reframe the problem to find a better point of departure for a solution. In idea generation, the problem solver can switch between generating alternatives and challenging assumptions.

4 CREATIVE HEURISTICS IN INVENTION

Since heuristics are open to interpretation, a quantitative meta-analysis using statistics is not possible. For this reason, a qualitative content analysis is performed with the help of the developed category system. The content analysis proceeds as follows: Firstly, the determined heuristics are checked for medium generality. This means that each rule has to be specific enough to facilitate a concrete search direction, while simultaneously being broad enough to cover problems in several engineering subject matters. After that, the heuristic rule has to be allocated to a heuristic principle in the developed framework and compared with already allocated heuristics. If an overlap exists, the new rule has to be either integrated into the existing rule or discarded as a redundant rule. The rules come from collections of heuristics in literature on invention such as the collections by Weber and colleagues (e.g. [11], [18]). Additionally, idea checklists such as SCAMPER (acronym for Substitute, Combine, Adapt, Modify, Put to another use, Eliminate, Reverse) or the inventive principles by TRIZ/TIPS were analysed. Table 2 gives an overview over the determined heuristics.

Heuristics of invention offer some very specific rules for creative solutions. E.g. the Inverse Heuristic where an invention is joined with its inverse function seems to be a very powerful heuristic often used by inventors. Examples of products incorporating this heuristic are the claw hammer or the pencil with erasure, i.e. products that can both do and undo an operation. However, some inventive heuristics are of a more general type such as "Vary the variable"

which can be used in its broad form or which can be broken down into more specific sub-rules such the Repeated-Element-Heuristic (repeat an interesting component) [11].

Idea checklists often offer only very broad and unspecific rules such as SCAMPER. A notable exception are the 40 inventive principles offered by TRIZ/TIPS. The allocation of the TRIZ principles in the heuristic framework is problematic as these principles include medium generality heuristics (e.g. Universality) as well as very specific heuristics (e.g. Mechanical Vibration). Furthermore, they include considerable overlap to heuristics, which can also be used for generating alternatives (e.g. Segmentation) [9]. However, the TRIZ principles can be condensed to a few main actions, which are included in the collection, and it seems to be a useful approach to try to find the main contradiction of the inventive problem.

Table 2. Creative Heuristics [17]

Generation of alternatives		Challenging assumptions	
Variabilization & Configuration	Combination & Separation	Contradiction & Confrontation	Imagination & Visualization
<ul style="list-style-type: none"> • Vary the variables • Find a trajectory of evaluation function • Add relevant features • Package relevant features • Improve the human interface • Delete irrelevant features • Abstract and transform (scale, dimensionality, matching) 	<ul style="list-style-type: none"> • Consider the negative or inverse • Combine inventions with complementary or emergent qualities • Combine to eliminate redundancy • Interpolate and extrapolate • Find a new purpose • Separate and recombine 	<ul style="list-style-type: none"> • Kill the product • Reverse the assumption • Force a connection (visual or verbal) • Describe the ideal solution • Find the main contradiction 	<ul style="list-style-type: none"> • Take a picture of the problem • Try to become the problem • Visualize or sketch the ideal solution • Change the perspective • Prototype the (ideal) solution

The creative heuristics collected from the literature are displayed in table 2. For a full description of the heuristics and the analysed sources, see [17]. As the framework is open-ended, further heuristics can be added to complement the framework.

5 SUMMARY AND FURTHER APPLICATION

The paper at hand developed a framework of creative heuristics for engineering with four main principles. The framework contains a collection of creative heuristics for the generation of alternatives and challenging assumptions in the process of invention. The heuristics are suitable for the use in engineering education. Advantages of creative heuristics in comparison to creativity techniques are that they are both easy to understand and easy to apply. It is, however, advisable to explain the heuristics to the students by using examples of products incorporating one or more of the rules.

The framework was already used in a master course on innovation and technology management with a practical part. In the practical part of the course, the students have to re-design an everyday object. That means that they have to find a flaw or dysfunction of an already existing product, which corresponds to mess finding in the creative problem solving process, and translate this mess into a concrete problem. Then they solve the problem using creativity techniques or creative heuristics, thus correcting the flaw – a classical engineering task. This first test elicited positive feedback concerning the heuristics, albeit the approach has not been evaluated on a systematic basis, yet. For this, the students will be randomly assigned to groups who solve their problems with either creative heuristics or creativity techniques in the next course, and the results will be rated with regard to creativity by experienced engineers. Furthermore, the learning outcome will be evaluated by letting the students rate the approaches.

A further measure is to complement the framework and to rank the heuristics according to usefulness or effectiveness. To achieve this, interviews with inventors are going to be conducted in cooperation with two German non-profit organizations dedicated to creativity and invention – the German Inventors Association and the German Association for Creativity.

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Individualized, self-directed learning in a Bachelor's degree course

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Conference Key Areas: Innovative teaching and learning methods; the teacher as a supervisor

Keywords: Individualized learning; goal-oriented learning; learning skills

INTRODUCTION

This paper presents a pilot module carried out within the Lucerne University of Applied Sciences & Arts Bachelor study program Business Engineering / Innovation. The primary objective of developing this 3 ECTS elective was to ascertain to what degree modules can cater to the needs of individual students and how these participants can be actively involved in the development of the module's content.

There are essential differences between the way a person acquires knowledge and skills at university and later on in his/her professional working environment. In particular, university courses hardly involve students in the design of a module's

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orientation and content, which would allow them to co-determine learning objectives and key aspects of the learning process.

The basic concept of the pilot module consisted in having each and every student participant specify his/her thematic orientation at the start with dedicated learning coaches and content experts. This served as the foundation for the continuous planning of the module's contents in line with the students' individual needs. The students themselves were held responsible for acquiring the chosen content, the coaches and experts taking on only a supporting role. In this novel learning scenario lecturers were thus *coaching* learners rather than solely imparting knowledge.

A further objective of the pilot module was to determine whether and how instruction can be individualized for larger groups of students and if individualized instruction has a positive influence on the learning behavior of students at tertiary level.

The learning processes of students in educational (tertiary-level) institutions differ significantly from those in which adults engage in professional (work-place) settings. In a professional setting learning is generally motivated by and closely associated with a concrete assignment, and the learner's compilation of content from various subject areas as he/she tackles this assignment resembles the work of an artist creating a mosaic. The pilot module creates a learning situation which corresponds more closely to the needs and approaches of the working professional. A prospective module, which will be discussed briefly later in this paper, will provide learning guidance to students carrying out industrial projects.

This paper first presents the theoretical background of the pilot module, followed by a description of the underlying methodology. Findings of the module evaluation are then presented. The final sections reflect on and discuss the methodological approach as well as potential improvements and the further development of the module.

1 THEORETICAL BACKGROUND OF THE MODULE CONCEPT

For some years now, educators have been turning from traditional motivational psychology towards theories which focus on the attainment of goals. Early on, motivational theorists such as Deci and Ryan [1] shifted their interest from the effects of external influences on motivation to the subject's self-direction. According to their well-known Self-Determination Theory, motivation is derived from three universal, innate psychological needs: competence, autonomy and social integration. Subjects are more motivated to take action a) if they believe their behavior will afford them greater competence (self-efficacy), b) the more freedom they have in initiating and implementing a certain behavior (autonomy) and c) the more social interaction or connectedness the behavior fosters (gain in interpersonal relatedness).

The pilot module presented here satisfies each of these psychological needs: The module relies not only on the initiative of participants but in particular on their efficacy; greater autonomy is the core concept of the module; and social interaction and connectedness developed among the module participants, who have several extensive group meetings.

The engineer's prospective professional environment is growing ever more complex due to the fast pace of technological change and, especially, digitalization. Consequently, engineers must acquire new strategies to develop their competencies [2]. Traditional tertiary institutions no longer live up to these challenges [3]. They must not only impart knowledge but also competences required for autonomous learning and self-organization.

One acquires the ability to organize oneself primarily through exercising self-organization. Relevant academic literature refers to educational settings designed to foster self-organizational competence as »self-directed learning« [4] or, often synonymously, as »self-organized learning« (»SOL«). Deitering [4] proved empirically that the shift to self-directed learning is challenging for both teachers and learners and entails more than a simple replacement of one methodology with another.

There is no standard definition for SOL or self-directed learning. "Nonetheless, the approaches have a common denominator: Their focus is on the learner, who initiates and organizes his own learning processes. Objectives such as the promotion of self-determination, self-directed activity and responsibility for one's own learning process are to be found in many approaches." [4]

Examples of SOL applied to a specific, common task or mission especially worth mentioning are the Action Learning [5] and Team Academy [6] theories.

The pilot module did not provide a common group assignment, as is the focus in the Action Learning and Team Academy approaches, in order to afford students the greatest possible degree of freedom designing their learning projects. However, this focus on a common group project is to be integrated in a prospective pilot module.

The terms SOL and self-determined learning are not discussed in Hattie und Andermann's definitive guide to tertiary teaching and learning [7]. The module presented here may be regarded as an attempt to fill this gap in that it implements the SOL approach and tests its realization and efficacy at tertiary level.

2 TEACHING METHODOLOGY

This section describes the methodology underlying the design and implementation of the pilot module.

2.1 Selection of student participants

Interested students were invited to attend two orientations prior to registration for the term. In order to participate in these orientations students had to submit a statement in advance, describing in key words the topic which they wished to tackle, conveying their exceptional motivation and declaring their goals.

The objectives of the two orientations were:

- to consolidate students' personal goals
- to group students with similar learning objectives and/or objectives that promised synergetic potential
- to identify unsuitable topics and students with insufficient motivation.

2.2 Establishment of learning objectives

The first assignment of the term was to write a personal success story. The 12 enrolled students were to describe the specific situation which they wished to be able to master after completing the module. This success story also served as the basis for the final module exam. The following is a sample success story.

I have created a new corporate design for an association, a company or an organization, which I have implemented in various marketing instruments such as a homepage, business card and advertising posters. I have utilized my fundamental knowledge to generate a clean, positive image. Monitoring the homepage with analytical tools has allowed me to evaluate the initial reaction of potential target groups. Several possible marketing instruments are presented, from which the client can select the option he prefers.

Fig. 1. Sample success story

Subsequently, the students contemplated which competences they would need to acquire in order to accomplish their success story. This reflection led to the formulation of individual learning objectives. An example is presented in figure 2.

I am structuring my learning objectives according to Bloom's Cognitive Taxonomy. ...
I wish to attain Levels 1 and 2 (knowledge and comprehension) with respect to the development of a corporate design. ...
Regarding logos and the design of homepages I wish to attain Level 6: I want to be able to evaluate logos and homepages and to develop solutions myself. ...

Fig. 2. Extract from sample learning objectives

2.3 The learning process and evaluation of learning progress

Each student was assigned a content expert possessing expertise in the content area chosen. These four content experts had two tasks: a) to assess the success story and individual learning objectives: They determined whether the learning objectives were sufficiently challenging but also manageable within the scope of a 3 ECTS module; b) assessment of their students' achievement in the final module examination.

In addition, the students committed themselves to a minimum of two coaching sessions with the two learning coaches, in which they reflected on their learning process and, if appropriate, adjusted their course of action.

In two steering meetings the students presented the current status of their learning projects to their classmates and obtained peer feedback in open discussions.

2.4 Assessment

Assessment was two-fold, consisting in the assessment of the acquired professional expertise on the one hand and of the acquired learning competencies on the other. Each component carried a weight of 50%.

For the oral examination of their professional expertise each student first presented his/her own success story along with the results they achieved, the strategy they had chosen and the methods employed. An in-depth examination of their expertise followed. The students themselves contemplated and decided in advance what they wanted to present in order to prove their mastery of the content. They simulated a situation which corresponded to their success story.

In the final part of the professional competence examination the student's content expert and the learning coach asked clarification questions. The success story and the learning objectives derived from it served as benchmarks for the assessment of the student's newly acquired expertise.

The assessment of acquired learning competencies also consisted in three parts. First, each student presented and then reflected on their learning process. Subsequently, they estimated the grade they felt they deserved for their performance in the examination of their professional expertise. Discrepancies between their self-assessment and the experts' assessment were discussed.

Thirdly, the coaches presented the student with a new learning situation, which he/she was asked to structure. In this transfer task the student demonstrated his/her overall gain in professional and learning competence.

3 MODULE EVALUATION

Throughout its entire course, students evaluated the pilot module quantitatively with respect to five categories: personal motivation, relevance of the module to their professional future, learning gain (benefit in terms of the amount learned), satisfaction with their own learning progress, and support in the learning process. Furthermore, the module was evaluated qualitatively by the students and the content experts as well as by an external audit team consisting of didactics experts. This section presents the major findings of these evaluations.

In all five categories assessed quantitatively, the pilot module was ranked more favorably compared to all other modules in which the participating students were enrolled. Prominently, motivation was consistently considerably stronger throughout the semester in the pilot module than the average motivation in the other modules. This may be attributed on the one hand to the students' self-determination of their learning objectives and process, which were also emphasized in the qualitative evaluation. On the other hand, one must take into consideration that this module is an elective, deliberately chosen by the participants, as opposed to compulsory modules, which accounted for a certain portion of the other ('control') modules.

The evaluation of the module's relevance to the student's professional future also stood out. From the outset, ranking of the module's relevance was above average, even improving slightly toward the end of the semester. Here, too, there is a distinct difference between the pilot module and the average of the other modules the participants were taking. In their qualitative evaluations, students explained that the pilot module affords the opportunity to cultivate specific competencies which allow them to develop their personal professional profile.

The greatest changes from beginning to end of the semester were observed in the categories 'learning gain' and 'satisfaction with learning progress'. Whereas the pilot module was ascribed an average ranking compared with other modules in both categories at the outset, its ranking rose steadily in the course of the semester and was ultimately above-average for both aspects. The initial 'average' evaluation in these categories was an issue discussed in the final module exam. These discussions revealed that it was difficult for some students initially to actively promote and assess their own learning progress, despite clearly defined learning objectives. This issue also manifests itself in the evaluation of the module's 'support of the learning process': Though ranked slightly higher than the other modules on average, the comparatively wide spread of rankings shows that some students felt better and some less well supported in their learning efforts by the design of the module.

The qualitative evaluation indicates that the students would have appreciated receiving support in their learning processes from an earlier stage of their work, and that the content experts could and would gladly work more closely with the students earlier in the semester. The students, the content experts, the learning coaches and the audit team applauded the opportunity participants have to develop their individual personal profile in the pilot module. Further positive features of the module highlighted by the coaches and the audit team in the qualitative evaluation were the promotion of self-responsibility and the implementation of the self-reflective learning approach.

4 DISCUSSION

The first trial run of the pilot module proved that undergraduate students are capable of formulating and realizing their own individual learning projects. As opposed to traditional course modules, the lecturers here hand over to the students the full responsibility for determining the thematic orientation of their work, defining their learning objectives and organizing their learning process.

In the analysis of the realization of the module, the following were identified as critical success factors for this radical reversal of responsibility for learning:

- **High student motivation:** The students saw the module as an opportunity to develop specific individual personal competencies and extend them according to their personal preferences.
- **Acceptance of professional challenge:** High motivation incites students to set themselves challenging learning objectives. They are thus also willing to accept an expert's pertinent critique of their professional expertise and are motivated to prove their newly acquired competencies on completion of their learning project.
- **Reflection on the learning process:** The students must be given the space in which to reflect on and discuss their own learning process. This may take place within the group of student participants or in a dedicated coaching session with a learning coach.
- **Professional relevance:** In order to be capable of defining their own personal learning objectives, students must first contemplate the purpose of their learning efforts, for example by writing a personal success story in which they describe how the learning project is to advance their professional expertise. It is essential that the learning project be coupled with the individual's professional aspirations early on to ensure the student's motivation and goal-oriented dedication to his/her project.

- **From lecturer to content expert and to learning coach:** In contrast to traditional courses, the student's individual goals and learning objectives form the basis for the relationship between content experts / learning coaches and students. Reflection on the learning process, the generation and implementation of a learning evaluation scheme, and guidance in evaluating goal achievement take the place of imparting knowledge. There is only selective content support through appropriate content experts.

These positive conclusions are complemented by the issues listed below, which could not or only partially be addressed or resolved:

- **Selection of student participants:** Interested students were able to inform themselves about the module and generate initial ideas for their learning project in the two orientations. What ultimately motivated students to opt for or out of the module was not investigated.
- **Integration of the pilot module in the study program:** To which degree the competencies acquired in the pilot module might be transferred to further courses or project modules has not been clarified. This is a subject of the study program's continuous curricular development process.
- **Qualification of the content experts and learning coaches:** Prerequisites for commitment as a content expert or learning coach have not been specified. For the pilot module to be anchored in the curriculum the prerequisite competencies would need to be described systematically and a program would need to be designed and initiated to develop these competencies in lecturers.
- **Transfer of self-direction and self-organization to industrial projects**
As argued in the introduction, learning in a professional setting is normally induced by the challenge of a specific assignment. A prospective pilot module should investigate how students can develop self-regulatory competencies in the context of an industrial project. The students are to autonomously acquire an industrial project assignment requiring team work. Task resolution is driven by the individuals' self-defined learning objectives on the one hand and, of overriding importance, the personal goals formulated in their success stories.

The form of individualized instruction presented here allows students to develop their personal professional profile to enhance their career prospects or simply to study a topic in-depth. In this setting the students reflect on their learning strategies and consciously expand their capability to learn autonomously. The content experts and learning coaches take on an unfamiliar role in which they concern themselves with the personal needs of the individual student and are called on to support and facilitate the student's learning process. Various features of traditional educational settings that have heretofore been taken for granted are overthrown. It is, for instance, a novel experience to see students participate in the design of their own final exam in which they must prove their mastery of the self-defined module content.

The pilot module demonstrates for the study program, for the entire university and for undergraduate studies in general that teaching and learning can be effective beyond the conventions of knowledge transfer. The module prepares students for their prospective learning in professional settings by exacting a high degree of self-

directed learning competency. The module provides a sheltered setting in which the unique learning process of each and every student is facilitated through the pertinent guidance of content experts and learning coaches. Innovative learning scenarios such as this can distinguish a study program as well as an entire university.

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Grit in engineering education

A systematic review

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Conference Key Areas: Engineering skills, Gender and Diversity

Keywords: grit; engineering education research; systematic review

1 INTRODUCTION

With the rapid pace of technological changes, future engineers are not only expected to be 't-shaped' professionals – with a broad and deep technical set of skills – but also to be able to adapt to a continuously evolving environment in solving complex and challenging problems. The traditional approach of engineering knowledge of maths and physics is no longer appropriate to today's challenges. Thus, the ability to be passionate about engineering and a persistent problem-solver, particularly when facing setbacks, is now considered to be as important as the ability to apply maths and physics.

At the same time, there is an urgent need to attract more people to engineering degrees. A few engineering faculties in the UK – such as UCL Department of Civil, Environmental and Geomatic Engineering – have already drop maths and physics A-levels as an entry requirement, and reported an increase in the diversity of their student cohorts. One of the main challenges of engineering education providers is now how to attract students who are passionate about engineering, who are flexible and have a

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broad spectrum of knowledge and abilities. This raises the interest for non-cognitive skills and, more recently, engineering educators and researchers have been focusing on the psychological demands of engineering, and the importance of personal attributes such as grit.

1.1 Grit

Research on grit has gained momentum in the past decade. It is defined as “perseverance and passion for long-term goals” [1], and has been related to both academic and personal achievements. It was initially studied by Angela Duckworth, who found that grit was a stronger predictor of students’ retention in military schools and higher positions in spelling contests than academic measures such as grade point average (GPA). The Grit Scale [1] was developed as a self-report instrument to measure the traits of passion (consistency of interest) and perseverance (perseverance of effort) for long-term goals. The original version of the scale, commonly referred as Grit-O, comprised 12-item using a 5-point Likert scale (1 ‘not at all like me’, and 5 ‘very much like me’). Two years later, Duckworth and Quinn [2] developed and validated a shorter version, Grit-S, comprising 8 items. The instrument retained the 2-factor structure of the original scale and improved psychometric properties.

Grit is particularly relevant when studying the academic success of students from non-traditional backgrounds. Recent studies have reported that grit levels were positively related to Black male’s grades in predominantly White institutions [3]. Other studies have found that at the beginning of their engineering studies, female students viewed themselves as more hard working and diligent, and more likely to say they had overcome setbacks to conquer a challenge than their male counterparts [4].

1.2 Grit in Engineering

The world of engineering is constantly evolving, requiring engineers to be able to adapt and keep the focus in long-term complex problems. Education and training have been focusing mainly on academic and transferable skills, but initiatives designed to address the psychological demands of engineering are rare. Being an engineering student requires a great amount of grit [5]. Engineering programs are often harder, demanding a high self-discipline and commitment towards a variety of different academic challenges.

Research studies of grit in engineering education are still scarce, but suggest that persistence and achievement in engineering are related to non-cognitive factors [6]. Thus, a systematic review is fundamental to situate the context, as well as prior and current work on grit in engineering education.

2 METHOD

This paper presents a systematic review of purposely selected publications, with the aim of providing an overview of the studies conducted on grit within the context of engineering higher education [7].

The research question that guided this review was: *‘What type of studies have been conducted and what methods have been used to study grit in engineering higher education?’* Complementary questions were added to better understand the target population (academic year, engineering discipline, gender, ethnicity, and generational status), the instruments used, and the main findings: *“What populations have been studied?”*, *“What measures/instruments have been used to assess grit?”* and *“What were the main findings?”*

Three types of databases were searched for publications:

- Subject specific databases – Engineering Village
- Journal databases – Journal of Engineering Education; European Journal of Engineering Education; International Journal of Engineering Education
- Gray literature databases – Conference papers and proceedings: ASEE Peer; IEEE Xplore

Figure 1 summarizes the literature review process (concluded in March 2018, meaning that more recently published records were not captured). The word 'grit' was searched in all fields, with the exception of Engineering Village database, where the search was limited to 'grit AND education' in addition to specific vocabulary (students; engineering education; education; teaching; surveys), to filter the relevant publications out of a total of 8466 records. Following the search phase, duplicate records were removed and exclusion criteria were applied to select the final eligible records. All the records that reported studies in engineering higher education and explored 'grit' were considered eligible. A final set of 31 records were initially analysed by abstract and then by full-text, including 29 conference proceedings and 2 journal papers.

SEARCH	Records identified through databases (n = 399) <ul style="list-style-type: none"> ▪ Engineering Village = 54 ▪ ASEE Peer = 123 ▪ IEEE Xplore = 217 ▪ JEE = 2 ▪ IJEE = 3 ▪ EJEE = 0
ELIGIBILITY	Total retrieved records (duplicates removed) (n = 376) Records excluded for not meeting inclusion criteria <ul style="list-style-type: none"> ▪ Reason 1: Grit as a physical construct or adjective 'nitty-gritty' (n = 286) ▪ Reason 2: K-12 or pre-college (n = 9) ▪ Reason 3: Grit as a non-cognitive construct AND mentioned (not studied) in engineering higher education (n = 50)
SYNTHESIS	Records included in synthesis (n = 31) <ul style="list-style-type: none"> ▪ Journal papers (n = 2) ▪ Conference proceedings (n = 29)

Fig. 1. Flow diagram of the literature review process

3 RESULTS

The selected 31 records were analysed by research topics and population, methods and main results. A summary of the analysis is presented in Table 1. Although not presented in the table, most of the studies have been conducted by institutions in the United States (28 out of 31), and 11 were inter-institutional collaborations.

Table 1. Systematic review of the records included in synthesis

Paper	Research topic and population	Methods and instruments	Results
Jaeger, B., Freeman, S., Whalen, R., & Payne, R. (2010). Successful students: Smart or tough?	Academic success. First year students. N = 370	Quantitative Longitudinal Not clear what version of Duckworth's grit scale was used	Significant gender differences in Brief and Total Grit, and Consistency of Interest) - female higher than male.
Bennett, R. M., Schleter, W., & Raman, D. R. (2012). A success enhancement program after the first test in Freshman engineering.	Assessment of programmes. First year students. N = 375	Quantitative Grit-S	Average grit scores of students who passed the class was higher, although non-significant, than the ones who did not.
Bennett, R. M., Schleter, W., Olsen, T., Guffey, S., & Li, W. (2013). Characteristics of students who do not do homework.	Academic success. First year students. N = 409 (N = 20 interviewees)	Mixed methods (survey and interviews) Grit-S	Students completing more of their homework had a higher grit than students completing less, and higher school background on physics and maths
Lerner, A.-M. (2013). Gritty students: The effect of perseverance on retention for traditional and non-traditional students.	Retention. Non-traditional students. N = 129	Quantitative. Longitudinal Grit-S	(preliminary results reported) Junior and Senior students were grittier than Freshmen.
Montoya, L., Sandekian, R., & Knight, D. (2013). Integrating Engineering for Developing Communities into Engineering Education: A Case Study.	Assessment of programmes. First year students. N = 28	Mixed methods (survey and interviews) Grit 'scenario' was introduced as research proposal not being well succeeded.	Students' grit observed by the teacher assistant. Subjective assessment of students involved in a voluntary project abroad.
Holmes, A. L. (2014). The Effects of Test-Enhanced Learning on Student Learning in an Electric Circuits Course.	Academic success. N = 108	Quantitative Grit-S	No differences on grit and self-efficacy of students with different levels of performance
Bottomley, L. (2015). Assessing the GRIT of Incoming Engineering Students.	First year students. Gender. Ethnicity. N = 475	Quantitative Longitudinal (ongoing) Grit-O	Female students viewed themselves as more hard working and diligent, and more likely to say they had overcome setbacks
Chen, J. C., Mcgaughey, K. J., Janzen, D. S., Pedrotti, J. T., & Widmann, J. M. (2015). Grit and its role in achievement among engineering students.	Academic success. N = 420	Quantitative Grit-S	Grit significantly higher in Y1 students (Y2-Y4 equivalent). Students in the highest GPA category showed significantly higher grit than all the lower GPA categories
Choi, D. S., & Loui, M. C. (2015). Grit for engineering students.	Retention. First year students.	Mixed methods (survey and interviews)	(preliminary findings)

	N = 310 (N = 26 interviewees who have earned D/F)	Grit-S	Female students were, on average, grittier than male.
Guilford, W. H., & Blazier, A. B. (2015). Integration of academic advising into a first-year engineering design course and its impact on psychological constructs.	Academic success. First year students. N = 75	Quantitative (N = 33 experimental; N = 42 control group) Grit-O	No significant differences in grit of students in different groups. Curiosity and creativity both negatively correlated with grit.
McDermott, R., Daniels, M., & Cajander, Å. (2015). Perseverance Measures and Attainment in First Year Computing Science Students.	Academic success. First year students. N = 60	Quantitative. Grit-O	Weak significant correlation between conscientiousness, grit and achievement in course
Berger, E. J., Senkpeil, R. R., Briody, E. K., & Morrison, E. F. (2016). A pedagogical borderland? Comparing student and faculty attitudes and actions about teaching and learning.	Learning and teaching. N = 317 students N = 33 staff	Quantitative Grit-S (students only)	Misalignment between students' and lecturers' learning styles. No data on students' grit.
Bracey, J., Jones, G. D., Bracey, N., & Sadeghipour, K. (2016). Chasing the Holy Grail: Pushing the Academic Persistence of Highly Motivated, Underprepared URM Students Pursuing Engineering.	Persistence. First year students. Ethnicity. N = 507	Quantitative. Grit-O	Minority students' personal motivations (self and family), related to grit, are high. 2014 = 3.68 2015 = 3.64
Bracey, J., Sadeghipour, K., Baugh, C., & Fagan, S. (2016). Chasing the Holy Grail: Successful Academic Persistence and Retention of Highly Motivated First-Year Engineering Students.	Persistence. Retention. First year students. N = 509	Mixed methods. Cross-sectional. Grit-O	Decrease in attrition of gritty students.
Choi, D. S. (2016). Engineering survivors: Students who persist in engineering through an academic setback.	Persistence. N = 29	Mixed methods (qualitative: phenomenography) Grit-O	(preliminary results, based on N = 5) 4 categories (based on attitudes toward academic setback and the consequent behaviour towards academics: Avoider; Ignorer; Boxer; Sleeper
Choi, D. S., Myers, B. A., & Loui, M. C. (2016). Grit and first-year retention in engineering.	Retention. First year students. N = 475	Quantitative. Grit-S	(preliminary results reported) Grit not a significant predictor of retention.
Desai, A. (2016). Student Profiling to improve teaching and learning: A Data Mining Approach.	Academic success. N = 60	Quantitative. 12-item instrument to assess grit (Grit-O?)	Method for clustering students according to their IQ and grit.
Groh, J. L. (2016). Gender in the workplace: Peer coaching to empower women engineering students in the classroom and as professionals	Gender. N = 12	Mixed methods (reflective journals; Pre- and –post surveys; Weekly post-class surveys)	(preliminary results reported) No specific mention to findings on grit.

Harkins, M. (2016). Engineering Boot Camp: A Broadly Based Online Summer Bridge Program for Engineering Freshmen	Retention. First year students. N 2014 cohort = 384 N 2015 cohort = 435	Quantitative. Students completed a version of Duckworth's grit scale.	Students who completed more content had an average higher GPA and higher retention rate than students who completed less.
Kirn, A., Godwin, A., Benson, L., Potvin, G., Doyle, J., Boone, H., & Verdin, D. (2016). Intersectionality of Non-normative Identities in the Cultures of Engineering	Engineering identities. N = 371	Mixed methods. Interviews. Topological data analysis. Grit measure.	Five groups differed by affective measures. No quantitative distinction based on grit measures.
Romanella, S. M., & Novoa, C. (2016). Keeping the "SPARK" alive - Investigating effective practices in the retention of female undergraduates in engineering and computer science.	Recruitment. Retention. First year students. Gender. N = 18	Mixed methods (qualitative: focus groups)	No specific data reported on grit. Students wrote application essays in response to a "grit" related prompt.
Senkpeil, R., & Berger, E. J. (2016). Impact of non-cognitive factors on first-year performance.	Performance. First year students. N = 500	Quantitative. Cross-sectional. Grit-S	Non-cognitive factors and previous academic performance increased predictability of GPA by 7%. Grit excluded due to a significant correlation with conscientiousness.
Benson, L., Potvin, G., Kirn, A., Godwin, A. F., Doyle, J., Rohde, J. A., Verdín, D., & Boone, H. (2017). Characterizing Student Identities in Engineering: Attitudinal Profiles of Engineering Majors.	First year students. Engineering identities. N = 2916	Quantitative. Multi-institution survey data. Topological data analysis Grit instrument	Grit (consistency of interest) Non-normative group levels of grit differ (higher or lower than normative)
Berger, E. J., Guruprasad, G., & Senkpeil, R. R. (2017). Characterizing the alignment in faculty and student beliefs.	Learning and teaching. N = 296 students N = 21 lecturers	Quantitative. Grit-S (students only)	No grit data reported.
Call, B. J., Goodridge, W. H., Scheaffer, M. H., & Milliken, T. R. (2017). Entrepreneurial Motivations for High-Interest Students.	Persistence. N = 11	Qualitative (grounded theory)	Grit/persistence was mentioned by participants as a required attribute for success in entrepreneurship (perceived behavioural control).
Choi, D. S., Myers, B., & Loui, M. C. (2017). Grit and Two-Year Engineering Retention.	Retention. N = 465	Quantitative Grit-S	Perseverance of effort was significant for both Y1 and Y2 retention.
Pierrakos, O. (2017). Changing the culture in a senior design course to focus on grit, mastery, orientation, belonging, and self-efficacy: building strong academic mindsets and psychological preparedness	Senior students. N = 61	Quantitative (N = 31 experimental; N = 30 control group) (pre- and post-survey) Grit-S (perseverance)	Students grittier in the experimental group: moderate effect size

Rohde, J. A., Kirn, A., & Godwin, A. (2017). Engineering Allies: The Personalities of Cisgender Engineering Students.	First year students. Gender. N = 2916 (N = 55 cisgender)	Quantitative. Measure of grit	No specific data on grit. Cis-identifying students are more likely to persist in engineering and attempt to change themselves or the world around them through the use of engineering, than non-cis-identifying students.
Sheridan, D. & Carr, M. (2017). La confluence: A study of the interplay of noncognitive and cognitive factors in determining the success of students on undergraduate engineering programmes	First year students. Academic success. N = 60	Quantitative. Duckworth's 10 item scale	First year students were grittier than Y3. For Y3, small effect between grit and achievement.
Turgut, D., Massi, L., Bacanlı, S. S., & Bidoki, N. H. (2017). Multidisciplinary undergraduate research experience in the internet of things: Student outcomes, faculty perceptions, and lessons learned.	Assessment of programmes. N = 10	Quantitative (pre- and post-surveys) Not clear if Grit-S was used	No significant differences on grit were reported.
Kirn, A., & Benson, L. (2018). Engineering Students' Perceptions of Problem Solving and Their Future.	Perceptions.	Qualitative. Interpretative phenomenological analysis.	Grit was conceptualized as short-term motivation. Grit (persistence) moderated by student's perceived instrumentality of a problem-solving task. Grit as domain and task specific, instead of a wider attribute.

4 DISCUSSION AND FUTURE WORK

The reviewed publications focused on the following research topics: first year students, retention, academic success, gender, ethnicity and engineering identities. With a few exceptions, most studies implemented quantitative methodologies and used one of the versions of Duckworth's Grit scale (Grit-O or Grit-S).

As most studies were published in conference proceedings, findings were usually presented as being preliminary or as part of larger research projects, making comparisons between studies difficult. Nonetheless, the majority of studies on academic success found a positive correlation between achievement and persistence with grit. On the other hand, no clear data patterns were found in the studies that compared grit's measures of students in different academic years (freshmen, junior and senior), and in studies that explored grit as a predictor of retention.

However, findings were more consistent in studies that addressed gender differences and underrepresentation. Overall, female students were generally grittier than their male counterparts. Recent studies on gender identities, and on more broad and latent forms of diversity, are extremely valuable contributions to understanding the culture of engineering. Studies were also consistent in reporting significant positive correlations between grit and conscientiousness.

This literature review exercise suggested that the trait of perseverance alone (persistence of effort), may be a better predictor than grit. Further research on the measure of passion (consistency of interest) would be important to fully explore the importance of grit in engineering education. In addition, the results reported in the broader literature are not clear enough about the relationship between grit and creativity. Future research on these issues is important to engineering education, and might be particularly relevant to initiatives that aim to narrow the talent gap and bring more diversity into engineering.

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Denmark-US students' collaboration as a part of ambiguous interdisciplinary engineering design courses

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Conference Key Areas: Engineering Skills, Innovation as the context for Engineering Education, Teaching Creativity & Innovation

Keywords: Interdisciplinary, international, teamwork, real-world engineering projects, communication

INTRODUCTION

The paper describes experiences from the first two successful international projects. The work is focused on project management, project planning, communication, and cultural and language differences during the endeavors. The project relevant phases are presented from the instructors' perspectives and from students' points of view. Developing and planning of common projects in engineering education often give more practical challenges, such as how to deal with engineering programs' differences on the international level, in addition to well-expected differences in engineering fields. Other major challenges are the variations in academic calendar and the amount of credits given for courses in different universities, programs, and countries. There is also a difference in time zones that needed to be considered for this scenario. A special part of the paper is focused on the experience in arranging face-to-face

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meetings and common activities in order to facilitate and enhance students' communication, engagement, and understanding of different cultures. Analysis of students' own opinions of these projects concludes the paper.

In 2017, cooperation between the Section for Electrical Technology at the Technical University of Denmark, Center for Bachelor of Engineering Studies (DTU Diplom) and the Aeronautical Engineering Technology (AET) program of the School of Aviation and Transportation Technology (SATT), Purdue University in the USA was established. The main purpose of the collaboration was to bring together students from different academic programs and cultures [1,2,3] to perform interdisciplinary work [4,5], which is highly relevant for all engineers, and to gain experience with international teamwork. Both competencies are highly required in high technology companies around the world [6,7].

Purdue University focuses on aviation and educates engineers and engineering technology graduates for the aeronautical industry. Purdue uses its own airport (which includes a collection of airplanes and aircraft engines and other components) for teaching and research. The SATT also prepares managers specializing in aviation and educates commercial pilots. The cooperative projects for students from DTU Diplom (Technical University of Denmark, Campus Ballerup) are based on an actual need of the school to modernize and possibly digitize test equipment when running tests on their PT-6 engine. The first project ran in fall 2017 and the second project in spring 2018. There were two tasks for the projects:

1. to digitize a checklist carried out when running tests via a mobile app
2. to collect sensors' data to continuous output to LabView.

The overall foci for the cooperation and the projects were project definition, project management, planning, process improvement, and communication between two teams from different backgrounds, both in an academic and in international perspective. This project work gives DTU students ten ECTS credits and is considered a project similar to the course called "Innovation Pilot" [8], which is a special DTU Diplom course focusing on innovation in engineering and technology. For Purdue students, their project counts as a second part (second semester) of their senior capstone project and students get up to six credit hours. The credit systems are different in USA and in Europe, but it was found that the workload for both courses was comparable.

1 TECHNICAL PROBLEM STATEMENT

The overall foci for the cooperation and the projects were project definition, project management, planning, process improvement, and communication between two teams from different backgrounds, both in an academic and in international perspective. This project work gives DTU students ten ECTS credits and is considered a project similar to the course called "Innovation Pilot"[8], which is a special DTU Diplom course focusing on innovation in engineering and technology. For Purdue

students, their project counts as a second part (second semester) of their senior capstone project and students get up to six credit hours. The credit systems are different in USA and in Europe, but it was found that the workload for both courses was comparable.

2 COMMUNICATION IN INTERDISCIPLINARY TEAMS

Efficient communication in an organization, which in the projects was a combination of the students from Denmark and USA, is a decisive factor on how well an organization will function. The need for information and knowledge exchange grows as a project progresses, and this in turn increases the demand for frequent and systematic communication coordination. Teams of engineers from different branches of the engineering fields work together to develop solutions to complex technical problems [9,10]. This requires communication/language including professional terminology from different areas, such as electronics, mechanics, and computer engineering. Therefore, it is essential for us to train students to communicate and convey academic knowledge in a meaningful way to engineers from different technical fields. The projects put a large focus on communication and the common challenges of communication between interdisciplinary and international teams. Additional obstacles in communication are physical distance and time difference. Specifically, certain challenges arise in what are called virtual organizations: organizations which conduct business and communicate entirely via digital means. In the following, we will discuss the challenges that arise when using certain lines of communication.

2.1 Lines of communication

Establishing the lines of communication between two parties and deciding who was responsible for them were essential in how well the development of the project would go. In the international projects between teams separated by an ocean, the choice of lines of communication was critical for the project results.

2.2 E-mail communication

The obvious choice was to use e-mail as the main form of communication. At the start of the project, especially, this was the best way to communicate. However, this soon led to various complications:

- Communicating via e-mail was slow: Communication via e-mail slowed the process of exchanging information. It took an average of five to six days for each team to respond to a request. This had adverse effects for both teams: it inhibited the efficiency of the development process and it served as a source of frustration for both teams, leading to conflicts.
- Communication via e-mail was signal-poor: E-mail as a communication medium lacks details. Face-to-face communication, which is signal-rich, enables faster feedback, utilization of natural (spoken) language, and allows the sender and the recipient to communicate in a personal manner. These are all elements which e-mail clearly lacks.

However, communicating via e-mail did have some positive effects:

- Communication via e-mail enabled parallel communication: Communicating via e-mail enabled a sender to communicate with many at the same time. It is a parallel form of communication, which the teams utilized to their advantage. One sender could inform all parties (also external interest groups, like professors and advisors) of what was going on.
- Communication via e-mail served as an implicit way of documenting the process: Writing e-mails to one another served as a way of documenting the process from beginning to end. In the beginning of the project, both teams used this feature of communicating and documenting.

3 VISIT TO THE USA

During the first project (fall 2017) the DTU team came to visit the Purdue team about 1.5 months after the project started. This meeting was significant because it elevated the efficiency of the project development and spoke to all the aforementioned theories about the importance of creating a feeling of togetherness between two groups with no prior knowledge or relationship with one another. Within one day after arrival, the Purdue team invited the DTU team to lunch and to watch football in their homes. This had a huge effect on the way both groups started to interact with one another. Having learned from this experience, a similar visit was arranged just two weeks after the second project (spring 2018) started.

The effects of the visits to Purdue where both teams met in person are many. They showed that it is extremely important to establish personal connections with the people you work with through socialization. Meeting each other and creating a common background through shared experiences make it easier to develop the technical solutions and common desire for mutual success in the project work. Furthermore, because the team members met and socialized with each other, the way they communicated after the visits became more efficient.

4 CHALLENGES IN TEAMS WORKING PHYSICALLY SEPARATED

A virtual organization is an organization which is physically separated and therefore will communicate and problem solve via digital means [11]. The team members in our projects were all members of a virtual organization because they never met in person and they only communicated via digital means.

Studies show that virtual groups sometimes work more efficiently than normal groups, but in certain situations virtual groups do not work well. This is especially true under the following conditions:

- The group members have no prior relationship to each other
- The project involves certain risk
- There is no fundamental trust between the group members

When these factors are present in virtual groups, the exchanged information will frequently be misinterpreted and the members of their respective groups will be selective with what information is shared with the other group. This basically translates to a less efficient group as a whole, where the suboptimal lines of communication hinder the project development.

In the projects described, all of the named factors were present. The group members had no prior knowledge or relationship with one another and the projects involved a certain amount of risk for both groups, translating to both teams having a personal interest in succeeding and wanting to affect the trajectory of the project development. Both teams therefore experienced the more adverse effects that virtual groups carry with it, like slow e-mail communication and communication prone to misinterpretation (misunderstandings happened frequently) and both parties had a tendency to withhold information that, if had they known each other, would have been shared. However, the students did try to compensate for this after their visits to Purdue. Both student teams, independently of each other, wanted to switch to a more dynamic way of communicating by combining e-mail, video conferencing, and instant messaging.

5 PROJECT MANAGEMENT

The Lean Six Sigma methodology could be viewed as a combination of the data-driven Tollgate Project approach and variation reduction of Six Sigma and the reduction of waste by using Lean principles [12]. This blending of Lean and Six Sigma is considerable because they both strive to improve performance and pursue perfection [13]. Lean Six Sigma is widely used in the aerospace industry, as well in a widespread range of other types of companies and government agencies [14,15]. Lean Six Sigma is being used in every aspect of business, starting from design and manufacturing and finishing with supply chain processes. As an example, Lockheed Martin developed a method called LM21 (Lockheed Martin in the 21st Century) in 1999. The idea was to deliver excellence to employees, customers, and shareholders through the best approach. Lean Six Sigma became a management philosophy, affecting the whole company: operations, finance, and cash management [16]. Another example is a problem that Boeing had with recirculating air fans rejected during testing for its 777 program. The solution was to eliminate possibilities of foreign object debris entering during assembly [17]. It showed that Lean Six Sigma can't be ignored in the preparation of future engineers. This is why it was chosen as a one of the major components of the projects described [18,19].

6 CONCLUSION

Cooperation between DTU Diplom and Purdue University resulted in joint student projects, where engineering students from Denmark and USA worked together to find solutions for technical interdisciplinary problems. During the projects students had the possibility not only to train their technical skills, but also to develop their understanding of other fields of engineering, enhance their communication and language skills,

broaden their cultural understanding, and grow in their ability to work in team with other team members who were physically away and in another time zone.

Meeting and working with students from another country was quite a new experience for both Danish and US students, even though there are not big cultural differences between the USA and Denmark. Especially for American students, it was an eye opener to learn about other nations, languages, and cultures. Many American students had not visited Europe before. Many Danish students had usually travel to other European countries before and some of them had been in countries all over the world, but they had not experienced the personal contact, socialization, and living in each other homes like they did during the project. This gave them quite a unique experience and the opportunity to better understand the way other cultures think and work.

The technical scope of both projects has been accomplished with very promising results. A mobile application was developed to run on an Android device and the reading of sensors has been implemented with Arduino and software applications to make it possible to visualize the results on computer or tablet. The cooperation and projects prepared both Danish and US students for their future work in international companies with international and interdisciplinary teams.

7 ACKNOWLEDGMENT

Thanks to all the students for their great effort during the project work and for the valuable discussions on future development of international projects and cooperation. A special thanks to Dr. John Michael Davis and Dr. Manoj Patankar for their support and comments concerning the cooperation.

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Right way, wrong way, better way

A global model for engineers working with Indigenous communities

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Conference Key Areas: Ethics in Engineering Education, Gender and Diversity

Keywords: Indigenous peoples, cultural competence, ethical practice

INTRODUCTION

For eight years, a team of Aboriginal and non-Aboriginal staff at the University of South Australia (UniSA) have embedded Aboriginal content across a STEM-based Division. In 2016, a group of Aboriginal and non-Aboriginal women developed, and then piloted, a 'digital extension' of this approach with the *'Blue Wren' STEM, Cultural Understanding and Aboriginal Communities* [1] portal. The centrepiece of this portal is the *Blue Wren Sports Association* problem-based learning collection of vignettes.

The profession of engineering intersects with Aboriginal Australians in many ways. Engineering in remote areas often imposes 'whitefella' (non-Aboriginal) solutions which can mean the difference between improving quality of life (where consultation is done well) or imposing irrelevant, costly and unsustainable solutions (where consultation may have been done poorly) [For example 2].

In Adelaide, South Australia, engineering works proliferate along the banks of its River Torrens (Karrawirra Pari). They include a weir; a hospital; an entertainment precinct; sewers; storm water run-off; a sports oval; a railway; floating barrages; pathways and footbridges. Until recently, most have been developed *without* consultation with the local Kaurna custodians, despite the river's historical, cultural and life-giving role as a food source and gathering place.

This lack of due regard is unsurprising, given historical attempts by Governments to marginalise Aboriginal voices through 'White Australia' policies – displacement from land and stolen generations. A 'cult of forgetfulness practised on a national scale' has denied past wrongs and custodianship of country [3].

By the time an engineering student arrives at university, they have received relatively little by way of education about Australia's First Nations people [4]. This omission in formal learning is mirrored in other countries. For example, where 87% of textbook references to Native Americans pre-date the 1900s [5].

At UniSA a recent survey of engineering students (n26) associated with the study presented, found 73% cited most of their learning was derived from sources other than high school. They demonstrated a superficial or inaccurate understanding such as 'They [Aboriginal people] are not interested in making friends with non-Aboriginal people' to 'They have brown skin' to 'They play diggeridoos'.

As engineering educators, it behoves us to develop graduates who can implement solutions with full and informed community consultation and 'work *with* communities instead of *unto*' [6]. This obligation is globally linked to the United Nations Declaration on the Rights of Indigenous Peoples [7], and mirrored by the Australian professional accrediting body, Engineers Australia [8] and the Reconciliation Action Plans of Engineering firms [for example 9].

This paper presents an evaluation of the first implementation of the *Blue Wren* resource. The pilot took place in a core undergraduate course, *Sustainable Engineering Practice* and examines qualitative changes in student perceptions of working with Aboriginal Australians through looking at student writing.

1 ABORIGINAL CONTENT IN UNDERGRADUATE PROGRAMS (ACUP)

The *Blue Wren* portal is an extension of the Aboriginal Content in Undergraduate Programs (ACUP) project in the Division of Information Technology Engineering and the Environment (ITEE). Most programs in ITEE (including Engineering) are taught at its Mawson Lakes campus. The student population comprises mostly young, predominantly non-Aboriginal, school-leaving males, as well as many international students. Aboriginal lecturers and tutors work with students and staff to develop cultural sensitivity; consultation skills and social responsibility when working with Aboriginal communities. The approach taps into the preferred practical learning styles of STEM students often through case studies [10]. Content is embedded within an existing course and links closely to course objectives and assessment.

In 2017 the *Blue Wren* portal was created by the working group in response to UniSA's Digital Learning Strategy. The resource was developed not so much to fill a gap, but expand on an approach which had already gained national recognition.

2 THE BLUE WREN PORTAL

The working group which developed the *Blue Wren* portal comprises seven women – three Aboriginal and four who are non-Aboriginal. Consulting to the group were Aboriginal Elders; engineering students past and present and a former student and practising senior engineer from large engineering firm, WSP.

The portal provides an array of discipline specific resources including piece-to-camera testimonials from Aboriginal Elders and Faculty, research e-readers, and the centrepiece *Blue Wren Aboriginal Sporting Association* vignettes (see Figure 1).



Fig. 1. Screenshot Blue Wren Online Resource

2.1 Blue Wren Aboriginal Sporting Association case study vignettes

The four sequential vignettes (written primarily by the Aboriginal members of the working group) encourage students to identify interactions between the consulting engineer (James) and the Sports Association Committee (chaired by Eddie):

When Uncle George comes to visit the Blue Wren Sporting Association he finds it difficult to get down the ramp or access any part of the facility. He instructs the Chairperson, Eddie, to sort out the problem. Eddie invites senior engineer, James, to work with the Association to fix the facilities. However, James (who thinks he has all the answers) soon finds out he has a LOT of learning to do.

Prior to each vignette students are given guided questions to consider while watching the video. Such as 'What are the hallmarks of a good engineer?', 'How can James be more inclusive?', 'Where does technical jargon belong?'.

3 METHODOLOGY

The *Blue Wren* portal was piloted in the first year engineering course *Sustainable Engineering Practice (SEP)* in Semester 2 2017 and Semester 1 2018. This course introduces students to the engineering profession and how it is practised within a 'sustainable' context. Students learn about their possible future roles, the work environment, professional attributes of engineers, engineering ethics and sustainability.

SEP includes two lectures – both delivered by Aboriginal staff - focused on cultural and community consultation. One is about Aboriginal history and culture and the second guides the students through the *Blue Wren* vignettes. The students then participate in a culture forum with Aboriginal tutors to explore their own perceptions

about culture and how these link to the profession of engineering. They apply this learning to write a report with assistance from a selection of case studies and other resources via the *Blue Wren* portal. Finally, students apply their learning to develop culturally appropriate solutions to the Engineers Without Borders Humanitarian Challenge – their capstone assignment.

In order to investigate improvements in the quality of student understanding we looked at the depth of student response in their ‘culture forum’. We also examined the quality of their references to Aboriginal Australians in their reports prior to and following the implementation of the *Blue Wren*.

4 RESULTS

The samples of student work chosen are indicative of our observations overall.

4.1 The culture forum

In order to investigate improvements in the quality of student understanding we looked at the depth of student response in their ‘culture forum’. Here, the students explored definitions of culture; engineering and Aboriginal Australians in contemporary society; linkages to their Engineers Without Borders task and what they would take into professional life following their interaction with the *Blue Wren* vignettes.

Prior to the introduction of the *Blue Wren* portal and vignettes (*SEP*, Semester 1 2017) students showed good general understanding of cultural diversity and its importance. However, when asked ‘What would you take into your professional life with regard to culture, Aboriginal Australians and professional practice’ they often used language of an ‘othering’ nature including ‘us’ and ‘them’.

Following the introduction of the *Blue Wren* vignettes (*SEP*, Semester 1 2018), students made clear references to how their knowledge of community engagement and consultation impacted on their professional conduct. They translated abstract concepts into well-articulated changes in their thinking:

...[Being new to Australia] I thought this course was totally irrelevant for a future engineer like me...But...I learned more about Indigenous people, how they were oppressed and deprived of basic human rights...That knowledge has helped me respect and empathise not only with Aboriginal culture, but with all the different cultures that I will have to encounter... Student A

Student A continues to reflect on the impact the *Blue Wren* vignettes:

The previous me was more like the ignorant "James" in the first 2 videos of the Blue Wren Series, who would force opinions and beliefs on people without considering their thoughts, but this course: the lectures, the videos, made me reflect and question myself - would I really be able to become a good engineer or a good person in general and help people if I be like this? Student A

Student A then applies learning to professional conduct in a diverse setting:

This really helped me to see the world in a different angle. I know now that in order to give a good suggestion or develop a solution that actually works, I need to know about the cultural views, beliefs and opinions of the people that I am working with, because no two cultures are the same and what I think is appropriate might not be appropriate for others. Student A

Student B (SEP, Semester 1 2018) refers specifically to the inappropriate actions of “James” the engineer and reflects on how these should be avoided in professional conduct.

Engineers should always put people first and that is through listening. Listening indicates concentration, respect and moreover humility. ...Professional jargon should be eliminated or made clear to the community. In the Blue Wren Aboriginal Sports Association series 'James' uses professional terminologies to interact with the Indigenous community, which of course did not make sense to them. Student B

The *Blue Wren* vignettes focus on the importance of acknowledgement of traditional owners and sensitivity when working on Aboriginal land. Students' depth of understanding of Australian culture and connection to land is a recurrent theme in forum responses and a notable development in student insight since the introduction of the *Blue Wren* portal. Student C (SEP, Semester 1 2018) makes reference to respecting the fact that all of Australia is Aboriginal Australia.

Australian engineering is bound to intersect with Aboriginal Australians Aboriginal people are the original custodians of the Australian land. ...Every region across Australia has its rightful heritage owners, all with varying cultural behaviours and beliefs. It is compulsory to seek permission from the original custodians of the region before any structural, environmental or physical changes are made...it is the respectful and humane thing to do. Student C

Student D (SEP, Semester 1 2018) similarly reflects on the notion of Aboriginal land ownership across Australia.

I think it is important to always be aware that the Aboriginal Australians are the traditional owners of the land. This ownership extends to the entire country, so any projects will be on Aboriginal owned land. Student D

The above examples link to the impact the *Blue Wren* portal and vignettes have had on student recognition of Aboriginal culture, connection to land and history. Students demonstrated their ability to translate best practice principles such as consultation, communication and professional conduct into tangible behaviours and actions that will transform their ability personally and professionally to engage meaningfully with Aboriginal people and communities in their professional lives as engineers.

4.2 Quality of report assignment

In comparing assignments which achieved the highest mark (High Distinction 85 – 100%), we can see a discernible difference in the depth and quality of the work and clear evidence of how the *Blue Wren* resource has informed this work.

For example, prior to the implementation of the *Blue Wren* resource, assignments made generic comments about areas such as understanding the importance of cultural values; stakeholder needs and the consequences of miscommunication. Following the implementation of *Blue Wren* resource, students drew on the practical examples provided where James showed disrespect through stereotyping (making assumptions the Sports Association was ‘Government funded’) or ignored the opinions of the Aboriginal members of the Sports Association deferring, instead, to the one person he did not view as Aboriginal. Students observed how the client felt neglected and how solutions would be less appropriate as a result.

Even the lower assessed assignments, when compared, showed more depth of insight. For example, assignments achieving between 50 and 55% mentioned how the resource exemplified disrespect toward a junior employee of the engineering firm of Brazilian origin (Pablo) who tended to be ignored and cut off during conversations.

Thus, there was clear integration of the many principals presented in the resource and the teaching team felt confident students demonstrated an understanding of the interactions between engineering and people in the social, cultural, environmental contexts in which they operate.

5 DISCUSSION AND CONCLUSION

In a world where the voices of First Nations people are often silenced, the *Blue Wren* approach signifies how we can work together to change the next generation of engineers.

A collaborative teaching innovation led by Aboriginal staff with faculty, students and practising engineers provides a holistic and inclusive approach. As the examples demonstrate, not only has due respect been demonstrated for our First Australians, the pedagogical and professional requirements have also been met.

Despite the paucity of student prior learning and understanding about Aboriginal Australians, the *Blue Wren* vignettes have appeared meaningfully and thoughtfully throughout student work. The open-source resource will remain accessible to students throughout their studies and into their careers as engineers.

Reconciliation work remains difficult – political views; values and lived experiences are often strongly skewed towards ‘righteousness’ and ‘wrongfulness’. A better way is to work collaboratively towards an end point which acknowledges differences but celebrates our common aspirations as colleagues and teachers. The approach must incorporate the cultural leadership of Aboriginal people, while integrating pedagogical relevance and effectiveness from engineering staff. The work presented here provides

a model of Reconciliation-in-action – Aboriginal and non-Aboriginal staff working together to create strong links to ethical practice for our burgeoning engineers.

‘Remember - We are all learning.’ (Uncle George, Aboriginal Elder, Blue Wren Sporting Association).

ACKNOWLEDGEMENTS

We acknowledge the Kurna people as the traditional custodians of the land on which this work took place. We respect their traditions, culture and spirituality which is as relevant in 2018, as it was more than 60,000 years ago.

Thank you also to the early work of Diana Quinn; Patricia Kelly and Mike Carmody.

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Researching Undergraduate Women Who Thrive in Engineering Student Project Teams

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Conference Key Areas: Innovative Teaching and Learning, Gender and Diversity in Engineering Education, Curriculum Development

Keywords: Gender, Inclusion, Engineering Education

Introduction

In “Women in Engineering: A Review of the 2014 Literature,” Peter Meiksins et al., echo the “familiar explanations for why there are relatively few women in US engineering” [1]. Those explanations fall into three categories: 1) childhood socialization, arguing that engineering is generally perceived by children as a “male field;” 2) the lack of support for female students in engineering programs, leading young women to “opt for majors other than engineering;” and 3) the recognition that often women engineers “do not always thrive or remain in the field after they enter the workplace.” These are fairly common explanations. No one offers a satisfactory explanation and all are related to the “pipeline metaphor,” still the dominant frame for policy and research [2]. More telling is that the current literature has focused almost exclusively on the negative – why are female children *not* interested in engineering, why do young women *not* enroll or stay in engineering majors, and why do professional women engineers *not* thrive? What if, in addition to focusing on the negative, certainly important, we also focused on the positive – why are female children attracted to engineering, why do young women stay in engineering, and why do professional women engineers thrive?

In a college of engineering at a university located in the northeastern region of the US, participation in extra-curricular undergraduate engineering student project teams (ESPTs) has grown steadily. Students from that university’s seven undergraduate colleges/schools are represented, as are all fourteen engineering majors in the college. In the academic year 2016-2017, there were twenty-four ESPTs totaling

slightly more than one thousand students. And, at the same time that aggregate student participation has been increasing, the number of women students participating has also increased. In the academic year 2008-2009, only 15.5% of those participating in ESPTs were women. Compare that to 42.7% in 2016-2017. In addition, the number of women in positions of leadership has increased dramatically across the teams.

There are generally three types of ESPTs: 1) those associated with competitions, e.g., Baja (Society of Automotive Engineers), Steel Bridge Team, Violet Satellite Project; 2) those associated with service, e.g., Engineering World Health (EWH), Engineers without Borders (EWB), Engineers for a Sustainable World (ESW), and 3) those teams who are performing for a particular “client” e.g., App Development and Data Science. For participating students, ESPTs provide them with an opportunity to engage in real engineering work that is similar to professional practice and supplementary to their regular academic courses [3].

Investigating the positive for women in this context will allow us to explore the qualities/features that facilitate the positive, as well as how those qualities/features get realized through the specific practices. This leads us to our two research questions: What can we learn from these women’s experiences relevant to and in ESPTs? and How that might help us to better understand the positive and how might that better understanding help us to design more rewarding and enduring engineering educational experiences, curricula and identities for women (and men)? We follow with a description a description of our research methodology and then present a single case study in order to highlight the common themes and offer a predominant narrative story.

Method

Using a feminist, activist interpretive lens, we are interested in “a particular view that builds on and from women’s experiences,” giving voice to those “hidden women” and encouraging an “emancipatory praxis” [4]. Such a perspective is often referred to as standpoint epistemology. This research is a collection of case studies, involving “a number of cases jointly in order to inquire into a phenomenon, population or general condition” [5]. The data collection methods include interviews and photovoice, photographs and videos, which not only encourage participants to share their experience, but also provide researchers the opportunity to make sense of that experience as if they were present.

1.1 A Feminist, Activist Interpretive Lens and Standpoint Epistemology

Standpoint epistemology “argues that all knowledge is constructed from a particular position” [6]. As this epistemology frames this study, we are interested in the positive experiences in the everyday lives of these women as those experiences are related to their participation in ESPTs. We understand that the meaning of positive is always particular and partial and that what is particular and partial about that meaning is solely determined by those women participants. We also understand that while we may expect commonalities, these positive experiences will not only differ among the participants, but that in our role as researchers we need to account for our own standpoints. We need to build and maintain “dialogues across these differences” in order to “stay connected” and perhaps, more importantly, to acknowledge our own biases in our attempts to re-present those experiences [6]. Finally, we understand that also in our role as researchers (and as activists) we should support these women naming and claiming their positive experiences.

1.2 A Multiple Case Study

Case study methodology focuses on a specific and distinct “phenomenon of scientific interest” [7]. Our focus on a group of individuals has led to a multiple case study of which a “critical case” sampling strategy was used [8]. The selection criteria include: 1) undergraduate women who participate in ESPTs for at least 2-3 years; 2) participants who consider themselves to have positive experiences; and 3) participants who are willing to share those experiences. Further, we intentionally attempted to include women from all three types of ESPTs and, if possible, in leadership positions – an indicator of thriving beyond just surviving.

1.3 Interviews and Photovoice

For recruitment, we sent an email describing the study to all the women participating in ESPTs. Meetings were arranged with 10 volunteers that were forthcoming and, during those meetings; the study was explained in more detail. Also, prior to actually contacting possible volunteers, we consulted with the Institutional Review Board (IRB) to make sure that we were adhering to all Institutional Review Board (IRB) protocols.

We conducted three semi-structured interviews: life history [9], learning journey [10] and photovoice [11]. The life history interviews allowed us to attend to the ways these undergraduate women in engineering narrated their lives. Learning journey interviews encourage the interviewee to “reflect on events and be able to relate to learning aspects” [10]. Finally, we employed a “form of participatory action research,” photovoice, which “places participants behind camera lenses,” encouraging them “to document elements of their lives [in project teams] within their own terms” [11]. Participants were then asked to assign meaning to those photographs and videos.

All the interviews were transcribed and coded [8]. We employed, variously named, open or topical or descriptive coding. We made a list of all emerging themes, then grouped the themes to eliminate redundancy, and discussed any differences or disagreements among the coders. A theme passage was used to create a conceptual map – a visual representation of our findings. The last step in the coding process was to write a single narrative story that captures the experience of these women.

Results

The thematic passage of this research is shown below.

Agency is the originating and continuing motivation for these young women to participate in ESPTs. They understand that agency is only realized when they are confronted with **challenging** problems, participate in “hands-on” **doing** in response, and produce “tangible” **outcomes**. Through ESPTs and **engineering praxis**, then, they discover new ways to experience, indeed, to express agency - to solve problems, do hands-on things, and produce important outcomes. Through their continuing involvement, they experience **community** or the shared sense of responsibility to self, others, project and team emergent from their engineering praxis. They understand both **failure** and **commitment** as opportunity and necessity, respectively, and that both are critical to realizing agency. Finally, as they engage with ESPTs and in engineering praxis, they experience a powerfully rich and authentic identity, they experience **becoming an engineer**.

Nickie (a pseudonym) is a member of an upper middleclass family with two parents (neither of whom are engineers), one sister and two brothers. She was born in the northeastern part of the US. She differentiated herself from the other members of her family, "I was probably the least athletic person ever, so I had to find other things...." She enjoyed reading, writing and drawing. "I became very artistic ... and "was super curious" about space, ancient Egypt. She characterized her childhood by saying, "I grew up with Barbie dolls and ballet."

According to Nickie, high "school became part of my identity." And perhaps because she was attending an all-girl Catholic school – "very antiquated ... very traditional ... a lot of history" – where the arts, writing and philosophy were very important; she felt that she was on a "liberal arts track ... [with] every single intention of becoming an English major." Still when she took a physics course as a freshman, "it kind of blew my mind how much you could do with it." She also "did really enjoy science." Nickie recalled two experiences that show the importance of the experience of agency as that experience was related to science. The first experience happened in middle school in a "tech class."

I had this solar car. It was a piece of plastic PVC with two wheels and a little solar servo. But, I made sure that I had the cleanest axle and I want[ed] zero friction as I'm going down. No one else in this class cared at all. But they tested all the times for the whole eighth grade, and my group got the fastest time, and I was like "Oh, Wow."

The second experience happened in that first freshman physics course.

I remember we had this one lab ... where you had to do calculations and use kinematics and roll a marble and hit another marble that was on the floor. I took this really seriously. And, I was the only one in the class to get my marble to exactly hit that [other] marble I was so happy. I was like "Wow, this is so cool."

For Nickie, "just doing something precise and getting something from it was great." The importance of the experience of agency appeared in all of the initial life story interviews, though there were clearly differences in the particular circumstances, agency always seemed to involve three components: challenge, doing and outcomes.

Challenge involved solving problems, problems not unlike realizing near zero friction or rolling a marble in just such a way to hit another. Nickie described an early experience on her high school debate team that was a "total embarrassment." Instead of doing what freshmen usually do, presenting the oratory of others, Nickie decided to do what seniors do – original oratory. Her description of the results were "It was awful." Her response was to scale back and practice. In her junior year, she attempted original oratory again and this time found success, "When I finally was better ... I felt like "I can public speak ... that's awesome." For these women, their early challenges were "hard." The challenges very often required going "very against the grain" or involved defying general societal and peer expectations.

Doing or participating in something "hands-on," "making something," "tinkering" was also important. Throughout her high school, Nickie had been thinking of her future. She asked herself, "What do I want to spend the rest of my life doing?" and her answer was "I want to invent, I want to make." She recalled her first visit to the campus of the university she would eventually choose:

... I'm doing a tour, and one of the big things they were pushing is project teams ... that was the deciding factor for me. I kind of saw how much hands-on experience these kids were getting, and it blew my mind that an undergraduate – someone that would be me in a year or three years from now – was building a plane that flew by itself. I couldn't fathom that.

Apart from the solar car and the marble roll, Nickie did not have many "hands-on experiences" before university. Still, she along with others recalled that, "I kind of had this idea that I wanted to do something ... really, really technically difficult." However, among these women, there was recurring and personal component to this doing. Nickie said, for example, "I feel that I'm always trying to prove myself ... trying to prove myself to myself, that I can do it." For all of these women proving to themselves and others that they could do something difficult was "validation."

Agency also involves outcomes. When Nickie was considering possible career paths, she asked herself "What's going to have the most impact?" Her answer was STEM. She says, "I was just so incredibly attracted to the idea of making something ... of having a final product." Her rationale was "... what is what I am doing, at the end of the day, going to give back ... otherwise what is the point of doing it?" For Nickie, as for the other young women, outcomes that are tangible and yield a final product were important. Whether it was the fastest time with a solar car or hitting a marble or proving to yourself and others that you could "public speak," the result mattered. Nickie spoke about her interest in space, "I want us to go to Mars." She continues, "I think of the last docking with the ISS, they sent up so many medicines, and they had these cool crystalized vaccines that can only grow in microgravity. That's cool." Give back, real impact – otherwise what's the point.

Nickie is someone who valued agency long before she knew anything about engineering. For her, the components of the experience of agency found (and continue to find) an opportunity for expression in ESPTs. She says,

I started on ... Mars Rover the second week of my freshmen year. So really my whole entire college experience had been defined by the team ... if I think back to a specific time, I think back about what was going on in the team, that defines that time period, which kind of says how much of [an] influence the team has had.

When Nickie recounted her ESPT learning experience, there were many stories of agency. Those stories showed her addressing challenging problems:

So my junior year ... we actually did a redesign, we changed the whole suspension system ... we changed all of our system geometries, cut all the masses ... and a big mass to cut had to come out of the wheels ... we went from about 4 pounds per [wheel] to about 1.7 pounds per.

Those stories showed her doing hands-on work:

So we ended up spending the semester doing an iterate analysis of these wheels ... which was really exciting ... I think there was some nights that I just pulled all-nighters just plugging little numbers into the ANSYS program and running it.

And, those stories showed her realizing tangible results:

So we had this whole design [for wheels that could be 3-D printed and] I remember calling every person who printed this material ... and finally we found this [company]

who makes this material ... so they said 'If you give us your design and we can put it on display, then we will give it to you [print the wheels] for free.' Okay Fantastic.

However, ESPTs offered more just a way to express/experience agency. They offered community. Nickie very much respected the other students that she worked with, "the people that I have been able to work with over the years ... just really inspiring, really incredible." She also received respect in return. As part of a routine review, she was told "You know what you are talking about. Talk about it and have some confidence in yourself." This shared respect does not mean that there weren't serious confrontations. Indeed, Nickie recalled one incident during her first year:

The way we had made our parts ... some of our holes were a little bit off on this one square bracket that was ... connecting the whole E-core to the camera mast[So when they went to] "put it on ... my friend and I got this text from our team lead ... I think I still have it Like the subtitle was "THIS IS A DISGRACE." I think that 10 or 11 that night we ran to the lab, I was in my pajamas ... Freaking out, like we need to fix it all."

When I asked her how she responded to that confrontation and others that she has experienced, she said, "I think that I really wanted to be those people ... [in them] I saw what I could be." While there was and is support in ESPTs, some of the recurring qualities associated with community and those relationships were demand and responsibility – the expectation that participants will successfully complete their tasks and respond specifically to team needs.

There were two more qualities/features of these women's experience that recurred during the learning journey interviews: failure and commitment. In the women's descriptions of their ESPT experiences, failure was constant, but (and this is important) never final. Nickie recounted failure in practice, "our holes were a little bit off on this square bracket," an example of technical failure; "our motors weren't working," a situational and unanticipated failure; "we had this whole design ... and we ended up losing ... our funding to make these wheels," a personal failure." Nickie once asked a mentor on the team "What does it take to be a leader? Do you think that I have the potential?" Her mentor's response was "No. You ask too many questions and you don't know the answers." Finally, there was even failure at competitions, "... at competition we ended up not competing in a whole category which is a whole hundred points because we had micro-controller issues. For Nickie and for the other women, these ESPT experiences of failure became opportunities to respond – to get better at "CADing," to "redesign the motors," to find an alternative way, someone else "who makes this material," to realize "Wow, I do need to know the answers" or to raise her own standards. Each year's failure for the Mars Rover team offered an opportunity to "redesign the rover" anew. Failure was an important part of engineering praxis – it defined the challenge, directed the doing and engendered better outcomes.

The other recurring feature/quality was commitment. Over and over again, the women participating in ESPTs told me of the hours and hours and hours that they spent involved in their ESPT. Nickie refers to the Mars Rover team as a "prevalent burden." She along with the other women "didn't have weekends because we just test all weekend long. I also didn't have that much time after school because we would just go back to the lab." However commitment involved more than just time. Before her first competition, Nickie had fallen ill, "I had a 104 fever for four straight

days ... [and] had to postpone my flight ... I should have gone to the hospital." Still, "I ended up going to the competition. I still had a fever, pretty sick. But, I couldn't miss competition ... I wouldn't have missed it for anything." Commitment also involved more than just time and dedication. It also involved making a contribution. Nickie says of her fellow team members, "many were very, very intense, difficult, almost impossible to please. Like you wouldn't get a compliment even if you did something really well ... [but] once you got a compliment, you were like, 'Wow. Okay I actually did something really well.'" ESPTs require time, dedication and contribution.

For participating women students ESPTs offer many important experiences roughly correspondent to those of professional engineering practice. Students learn how to generate a production schedule, to adhere to a budget, to raise funds, to design and test and redesign intricate technological equipment. They also provide students, specifically these women, with the experience of becoming an engineer. Nickie like the other women was not an engineer when she began in her ESPT. Yet, she had models, peers who she could learn from, who were "inspiring, really incredible." These models were so influential that Nickie "wanted to meet them where they were ... wanted them to accept me as someone worthy." She "wanted to be those people ... I saw what I could be." And what could Nickie be? She could be someone who understood and appreciated the intricacies of the design process – identifying "variables," devising ways to "test these variables," learning how "to optimize." She could be someone who understood and appreciated the importance of "decision matrices" and "a plan." Finally she understood and appreciated the importance of "deliverables," determining if she and her team "are going to have a good product." For Nickie, however, becoming an engineer involved more. It involved "learning how to actually confront people ... having a backbone ... being able to standby something." It involved "learning how to trust people ... [and how] trusting them gives them ownership." In a brief summary she says,

"Wow, I can go on for days. I have learned a lot of technical things ... those have really helped me in my internships and probably landed me some jobs. But the interpersonal skills, the leadership skills that I would have never ... there's no reason I would have ever learned them in a classroom setting ... [the] team is ... more ... because I'm never not thinking about it ... it's that project team way of life."

Conclusion

Through our telling of Nickie's story, revealing the results of our research through a single case study, we have tried to answer our research questions: To learn about the qualities/ features of these women's experiences relevant to and in ESPTs and how those positive experiences might help us to design more rewarding and enduring engineering education experiences, curricula and identities for women (and men). We believe that the answers to both questions are contained in our thematic passage. Foremost, we should foster experiences of agency that are realized through challenges, opportunities for hands-on doing, and actual outcomes. All elements should become progressively more demanding and require a deeper and broader understanding of engineering praxis – one that is only possible if we encourage the development of an enduring community or communities. It is through their continued participation in these communities, responding to the demands and fulfilling their responsibilities that they experience a range of models for ways to become and be engineers. We must encourage failure as opportunity, rather than as a somewhat catastrophic and/or final event. We need to require commitment – ask that they give

their time and dedicate themselves to making a contribution. Finally, we need to provide occasions for them to reflect and become aware of their own becoming. This may have been the most powerful experience that Engineering Students Project Teams (ESPTs) offer to students. The data indicated that this was an important reason why these women thrived. A final note: Not one of the ten women interviewed encountered an ESPT environment free of sexist attitudes and/or behaviors. Some of the environments were less overtly sexist. Others were more overtly sexist. However, what **empowered** these women in those environments are the above qualities/features of their experiences in ESPTs. In one way or another, these women were empowered to respond in a way that transformed that environment, despite the pervasiveness of sexism.

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Analogue learning in the digital age

Can we use ‘old-fashioned’ active learning methods to educate engineers in the modern world?

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Conference Key Areas: Engineering Skills, Discipline-specific Teaching and Learning, Teaching Creativity & Innovation

Keywords: active learning, project-based learning, engineering education

INTRODUCTION

“Digitisation” and “digital transformation” are recent buzz words in both industry as well as academia, where we aim to prepare students for success within their future careers. This digital transformation push within the university setting can be seen in simple actions, such as transitions to digital exams and creating of interactive learning spaces¹; in teaching aspects, such as increased focus on topics related to, for example, Big Data and Building Information Modelling (BIM); and even in research, with calls for proposals specifically related to digital transformation². This then raises the question, should all aspects of the learning process strive towards digitisation, or is there still continued benefit to learning concepts the old-fashioned way?

The course examined in this research, Geometric Design of Roads, is a course within the civil engineering curriculum where the students use geometry and physics theory to design road alignments, also considering economics, environment and aesthetics. This design process is iterative: one has to create different alignments to find one that meets design criteria and achieves an acceptable compromise between often conflicting interests. Professionally, this design process is currently aided by specialised computer software, which allows the engineer to calculate, visualise and compare the impact of several alternatives much faster than if it were to be done as in the pre-computer era: by hand, using paper maps, curve rulers, and elbow grease.

¹ <https://www.ntnu.no/laeringsarealer>

² <https://innsida.ntnu.no/wiki/-/wiki/English/Call+for+project+proposals++Digital+transformation/>

In the aforementioned course, the principals of road alignment design are taught, in part, through active, project-based learning methods in which the students are presented with a realistic job task of designing a road alignment for a given location. When the term “active learning” is used here, it is grounded in the definition provided by Prince [1], who states that active learning is “any instructional method that engages students in the learning process”, in contrast to the more passive traditional lecture format. The effectiveness of active learning has been documented by Prince [1] and more recently in a meta-analysis [2]. Project-based learning is one type of active learning method that is characterized by (although not exclusively) tasks that are similar to professional issues, is directed toward application of knowledge, and requires both self-direction on the part of the student and cooperation in teams. Project-based learning activities have been indicated to be effective in teaching design methods in engineering education [3] [4].

The two project-based tasks examined in this study are intended to be authentic and emulate the complexity of an actual professional project, although one is performed not with the use of current software, but in the old-fashioned way with paper maps and rulers. Both drawings and computer models are central to the active learning activities in the course at hand, as in most engineering design processes. These are representations, and are used not only to communicate or document results, but also to individually and collaboratively think about the task, and synthesise ideas [5]. Representations can be sketches, prototypes or computer models, but Henderson [6] has pointed out that the flexibility of more informal, analogue sketches during a design process is at risk of getting lost when designing solely with digital tools, which affects the thought processes that rely on it. An education specific issue of representations is that when new technology is brought into the classroom one tends to ask how it can improve learning, but forgets to ask what the analogue representations that are being replaced did for learning in the first place [7].

It has been anecdotally observed that the activity consisting of designing roads by hand helps the students synthesize theoretical concepts at a perhaps higher level than within the similar activity using current design software. It is hypothesized that a large share of the theoretical learning occurred during this old-fashioned project task, despite its distance from current technological practice. We therefore sought to assess whether the old-fashioned design process is still relevant as an active learning project for students to develop their newfound knowledge in the modern world. This was examined during the length of one semester of the course, through surveys aimed at mapping students’ perceived learning as well as actual learning, and a focus group interview after the conclusion of the course.

1 THE COURSE CONTEXT

The course is divided into three phases. The first phase of the course (5 weeks) consists of traditional lectures and individual assignments. In this phase the students are introduced to the theoretical concepts of road design, in addition to considerations of regulations, and social and environmental requirements. Each weekly lecture (3 hours) covers one topic, and the five main topics are accompanied by a relatively short exercise intended to provide repetition and illustrate use of the concepts and mathematical tools provided in the lecture. The exercises are compulsory but ungraded. It should be noted that one lecture topic was presented in a flipped classroom model over the course of the study. This was experimental in nature and discussed briefly in the results.

The second phase of the course (5 weeks) consists of a project-based task, hereafter referred to as the “old-fashioned project”. Students are divided into groups of four or

five, and given a map of a terrain and curve rulers to construct a road alignment. They are to design an alignment (both horizontal and vertical) between two points on the map. The road alignment has to satisfy current national design requirements, be safe and comfortable to drive on, and fit well to the topography. The resulting alignment is to be documented and discussed in a final report.

During the final phase of the course (3 weeks) students are introduced to the road module of a Building Information Modelling (BIM) tool. This software is frequently used professionally and competence in this tool is a sought-after skill in road engineers. Similarly to the old-fashioned project, students work in groups of two or three on a task (hereafter referred to as the “software project”) of designing a road using this tool. Again, the road alignment has to satisfy current national design requirements, be safe and comfortable to drive on, and fit well to the topography. The software project has a second objective to allow students to familiarize themselves with the sophisticated software. The project task culminates with an informal presentation of the road alignment, evaluating both the design and knowledge of the software.

Both the old-fashioned project and the software project are compulsory and graded exercises within the course. *Fig. 1* shows students working with both projects.

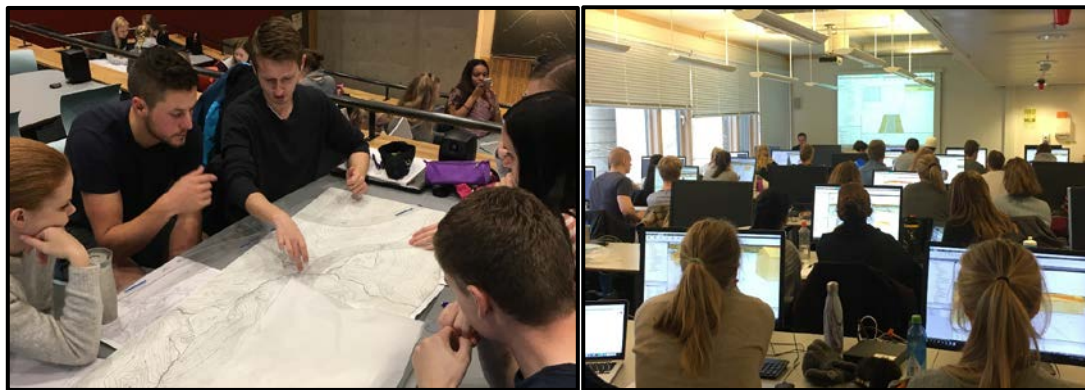


Fig. 1. Students working with the old-fashioned project (left) and software project (right)

2 METHODS

Two methods were employed during the study to understand the efficacy of the various learning methods: student surveys and a focus group.

In order to assess how the different phases of the course contributed to learning, six surveys were scheduled throughout the course, see *Table 1* for an overview. As there was a possibility that within different topics, the different learning methods would yield different learning outcomes, the surveys focused on three specific topics: (1) horizontal alignment, (2) vertical alignment and (3) aesthetics. As stated previously, these were lectured over one week each, and topics 1 and 2 had corresponding individual exercises.

The surveys were similar in setup. Students were asked to rate their learning outcome on a five-step likert scale, and also answer two concept questions to objectively measure actual learning from the lecture and assignment combined. This would reveal any discrepancy between self-assessed and actual learning. See *Fig. 2* for an example of a concept question. Two more surveys were distributed after the deadlines of the projects. In these the students were asked to rate their knowledge gain in the three topics (horizontal alignment, vertical alignment, and aesthetic), to find whether students experienced any additional learning during either of the two projects. Selected concept questions covering all three topics were also asked again.

Table 1. Course and questionnaire schedule

Phase	Week	Content	Survey
Lectures and individual assignments	1	Road planning process	
	2	Horizontal curvature (HC)	1 Horizontal curvature - self-assessed learning gain - concept questions
	3	Sight control	
	4	Vertical curvature (VC) (flipped classroom trial)	2 Vertical curvature - self-assessed learning gain - concept questions
	5	Aesthetics (A)	3 Aesthetics - self-assessed learning gain - concept questions
Old-fashioned project	6	Self-directed project work with guidance	
	7		
	8		
	9		
	10		4 Old-fashioned project - self-assessed learning gain in HC, VC, A - evaluation of learning gain from project in HC, VC, A
Software project	11	Self-directed project work with guidance	
	12		
	13		5 Software project - self-assessed learning gain in HC, VC, A - evaluation of learning gain from project in HC, VC, A
	15		6 End survey - effectiveness rating of all learning resources

As the overhøyde increases, the minimum horizontal curve

☐ A Increases
 ☐ B Decreases
 ☐ C Stays the same

Fig. 2. Example of concept question from the surveys

In the final survey, following the conclusion of in-class activities and project deadlines, the students were asked to rate the effectiveness of each learning resource, such as lecture notes and assignments that had been available to the students throughout the course.

All surveys were anonymous, voluntary, and utilized an online survey platform. The surveys were distributed to a class of approximately 80 students.

The intent of the surveys was to provide an indication of when, and to what degree learning occurred, and would therefore show whether the old-fashioned project in the second phase of the course was successful in improving theoretical understanding. However, the surveys do not provide any insight into why learning was successful in any of the three phases, or give any other understanding of how learning occurred for the students doing the activities. Therefore, the surveys were supplemented by a focus

group interview conducted two months after the final exam of the course. Seven volunteer participants were enlisted. In the focus group, students were asked about their experience in the course in general, and in the old-fashioned project and software project specifically. Emphasis was put on how theoretical understanding was acquired in order to arrive at a finished road alignment in the projects. In addition to evaluating how theoretical concepts were internalised during the phases, the participants were also asked to reflect on whether there were any other outcomes – positive or negative – from the different activities.

The focus group facilitator was not the instructor of the course, but was knowledgeable in the course, having taken it previously. The focus group utilized an interview guide as a base but allowed for flexibility given the participants' engagement and focus. The interview lasted 1 hour and 15 minutes, and was recorded.

3 RESULTS

The following section presents selected results from both the surveys and focus group. The survey response rates varied between 29 and 49%.

3.1 Surveys

The concept questions in the three surveys given during the initial traditional lecture phase resulted in generally high average scores (students answered correctly). Topic (1), horizontal curvature, had the best results compared to the other topics, but the differences were small. The students also considered their learning outcome to be better in horizontal curvature than the other topics. The respondents were least confident about their degree of learning in topic (3) aesthetics, with an average self-assessment of 2.89 on a scale from 1 to 5. The average self-assessment rating for horizontal curvature was 3.34 and for topic (2) vertical curvature it was 3.00.

Fig. 3 shows how students rate their knowledge gain in the different topics during the two active learning projects. The students report to greatly increase their knowledge during the old-fashioned project from what they already knew from lectures. All of the respondents reported to have learned something during the project, as no one gave the lowest score. The results for the same question in the survey regarding the software project were similar, although to a slightly lesser degree. The concept questions in the survey after the old-fashioned project gave scores at approximately the same level as in the surveys during the first phase for all three topics.

Fig. 4 shows how the respondents in the final survey rated the effectiveness of the different learning resources provided throughout the course. The two projects are listed as 'Active learning projects'. Support from teacher, the learning activities and lectures were rated as moderately to very effective, while the video lectures and curriculum literature were rated as less effective.

3.2 Focus group interview

The participants of the focus group expressed generally positive experiences with the course learning methods. One participant said that they "liked having the curriculum presented at the beginning, and then be able to digest it while working on the project for a longer period of time." Another described the relationship between the individual assignments and the project work: "There was a good balance between practicing specific methods in the individual assignments, methods that not necessarily were used by everyone in the group during the project work, and then later work on the larger projects where you got to see the whole picture and understand how all the pieces fit together."

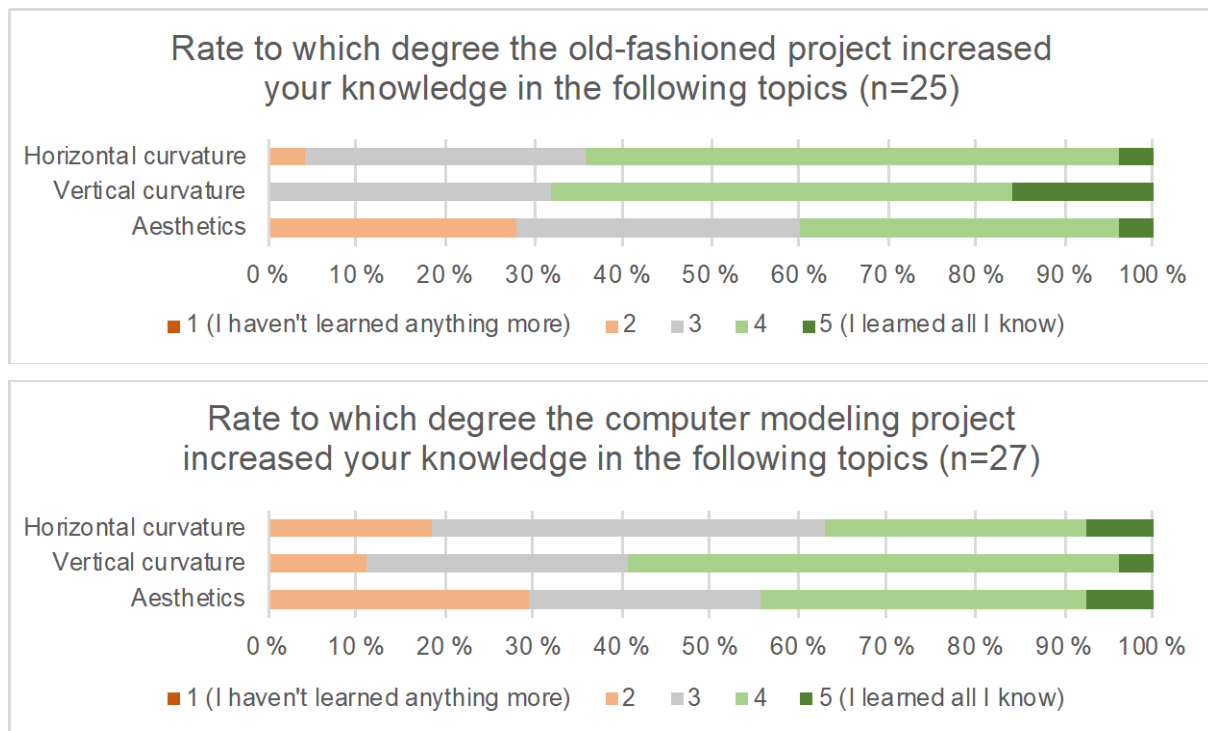


Fig. 3. Added learning from active learning projects

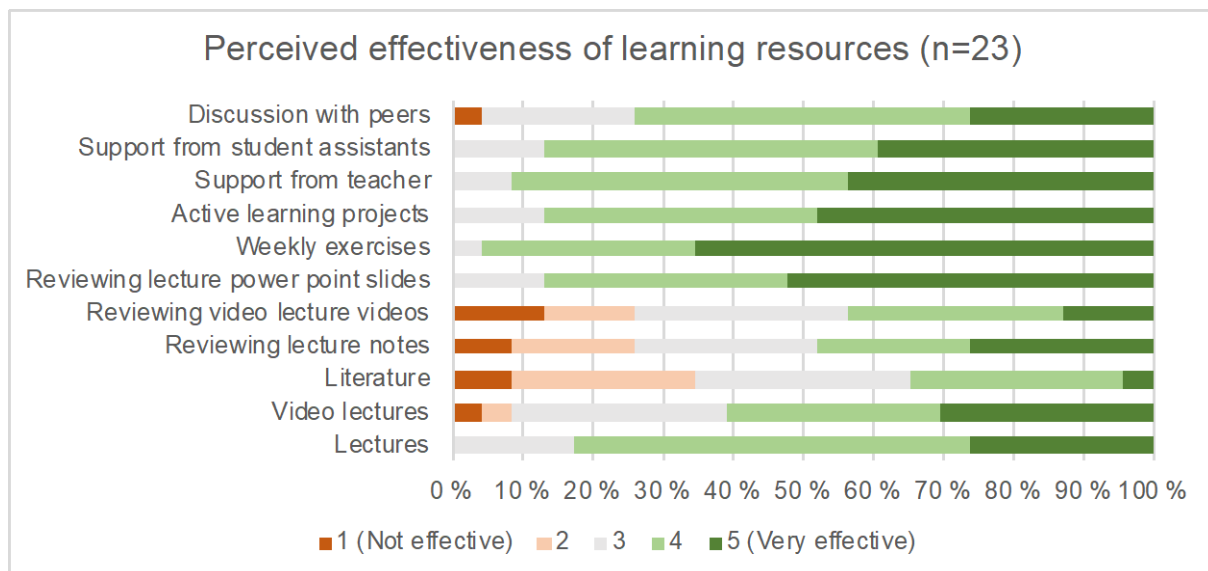


Fig. 4. Effectiveness of learning resources

Although the old-fashioned project was described as cumbersome and at times frustrating, the participants emphasised that if there had been only one software-aided project, this would have yielded less understanding of the underlying theory: “The software does a lot of the work for you, leaving you to try out input values until all the lights are green. It does all the calculations for you, and so you don’t have to think about it as thoroughly.”

However, they also expressed that the software project contributed to understanding of some of the concepts, especially aesthetics: “It’s difficult to visualise the road in the old-fashioned project, it wasn’t until we made the 3D model of a road in the software project that I fully understood how much destruction a road can cause in the terrain. You don’t see that while drawing the line on the flat map.”

The previously mentioned flipped classroom trial used for the vertical curvature topic was also discussed during the focus group. While it was not the main focus of this study, students' reception to the learning method may impact the study results. The participants of the focus group expressed general scepticism towards the flipped classroom method. Some had not seen the videos at home in advance of class and so had skipped the classroom activities because they didn't feel prepared. Others had come to class even though they hadn't seen the videos in advanced, which meant some of the material presented in the videos had to be revisited at the beginning of class – to the dismay of the students who had actually prepared. The students felt that the flipped model required more effort on their behalf, while not adding more value since they already appreciated the traditional lecture model used for the other topics.

4 DISCUSSION

The motivation for this study was to evaluate how the active, project-based learning activities detailed above, with a specific focus on the old-fashioned project, contributed to students' learning of the underlying theoretical concepts in the road alignment design course. The surveys and the focus group interview show that students experienced added learning outcome from the old-fashioned project work. However, as noted in the survey results, the course participants also reported a significant increase in learning within horizontal curvature, vertical curvature and aesthetics during the software project. This is contrary to statements made in the focus group, where participants expressed they had already learned most of the theoretical concepts during the old-fashioned project before encountering more technical challenges in the software project. Therefore it is uncertain whether the students answering the surveys understood that they were to rate increase in knowledge, and not e.g. general understanding. In hindsight, it might have been better to pose these questions in parallel instead of several weeks apart, so that the comparison became clearer. Regardless, the results indicate there is value in both old-fashioned project work, as well as the software project.

Since the respondents scored quite well during the first concept tests in surveys one to three (testing knowledge after traditional lectures and individual exercises), there was not much room for improvement on these questions in the survey following the old-fashioned project and software project, and therefore it was not a surprise that the results were similar on these surveys. One possible reason might be that the concept questions, in form, were much like the questions posed on the individual exercises during phase one. It is also noted that students seemed to have gained understanding on vertical curvature even though the flipped classroom model used to teach this topic received mixed feedback.

Despite inconclusive results from the concept questions on objective knowledge gain during the old-fashioned project, the testimonies from the focus group interview support the hypothesis that the old-fashioned project helps in synthesising concepts. One could imagine that having to learn a design method that no future employer utilizes directly, and that is inarguably workload-heavy, repetitive and at times frustrating compared to modern standards, would bring down students' motivation in the course, but that does not seem to be the case. Overall students appear to understand why the old-fashioned method is taught and even enjoy the process of drawing and plotting on large paper maps, gaining also from sketching by hand as both a way of sorting and synthesising ideas, as well as providing a common ground for students and teachers to discuss ideas and collaborate. This is in addition to the other benefits associated with problem-based learning. Additionally, it is important to note that while the method employed in the old-fashioned activity is no longer utilized in practice, it is not fully

outdated as the digital tools provide an automatization of the old-fashioned methods. Thus understanding the methodology behind the software helps students understand its output.

5 CONCLUSION

In an age of digital transformation, this research considers whether “old-fashioned” methodologies are still relevant within the learning process. A series of surveys and a focus group within an ongoing course were used to better understand the efficacy of the various learning methods, both analog and digital. While there is a risk of bias in the results, due to that the more eager, motivated students might be more willing to take part in surveys and a focus group than their counterparts, the results of this study indicate that old-fashioned methodologies can still be utilized as an effective and enjoyable learning activity in today’s modern and increasingly digital world.

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SMART GERMANY

ENGINEERING EDUCATION FOR THE DIGITAL TRANSFORMATION

Discussion paper for the
VDI Quality Dialogue

VDI theses and
fields of action
March 2018



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Summary

The Digital Transformation is currently permeating all fields of engineering with an intensity hitherto unknown. The following theses describe the current situation as perceived by the authors. The consequences for engineer training have been extrapolated from this and impulses for curriculum development have been derived.

Part 1: Theses regarding Digital Transformation

Society, personal life, professional world, and world of work

Digital Transformation will change the world of work fundamentally.

The key enabler is imparting the necessary skills for accessing digitized areas of life.

Social competences for an interdisciplinary and transdisciplinary collaboration provide a decisive additional benefit for value creation and research. Engineers bear the ethical responsibility for what they create.

Education for the Digital Transformation

Digital Transformation needs to become part of the curriculum.

Sensitizing with regard to social acceptance and change forms a part of an education for the Digital Transformation.

Digital Transformation makes new forms of teaching and learning possible.

Digitized teaching will occupy a growing share of educational processes.

Globalized and lifelong digital learning

Open education – education for all – will be facilitated by the Digital Transformation.

Digital Transformation is leading to a stronger individualization of educational and life planning. All interfaces of education and continuing education are to be mutually coordinated in the process of lifelong learning.

The selection and evaluation of information is becoming more important, while the relevance of easily accessible knowledge is declining.

Part 2: Consequences for engineering education

The natural way digital natives handle digital means of communication does not yet imply any deeper understanding of the Digital Transformation. In addition to the classical content of an engineering study program, skills in this area are essential. This not only includes the technological content but also the understanding of new business models, data security and protection, as well as social implications.

Since Digital Transformation acts at the interfaces of current domains, an extensive competence in collaboration going beyond the ability to work in a team is necessary. Here, regularly scheduled collaborations should take place even during the degree course, not only campus-wide but also reaching out externally as well.

Knowledge globally available on the internet ensures that the importance of self-learning competence is constantly growing.

Part 3: Impulses for curriculum development

Digital Transformation affects the entire course of studies. For each module the questions must be asked as to how and to what extent Digital Transformation requires a change in the skills profile of the participants. Digital Transformation must be incorporated integrally and not simply pasted on.

New content for the engineering course is sorted into various levels of abstraction (model level, system level, technology level and application level). To do so, a third dimension representing the degree of digitization is added to the commonly used T-shape model.

The authors take the view that easily accessible knowledge should give way to new content if it is not fundamentally important. Competence in selecting and assessing information on the internet is increasing in importance.

The social responsibility of engineers is changing with the digitization of engineering products and is receiving new challenges. This must be reflected in the course of studies. Students need the ability to assess the impact of technology and to act according to their judgment.

To support curriculum development, a dialogue process with external partners is presented. Through a dialog between the institutes of higher education and partners from business, a critical light should be thrown on the course content and the expected skills of graduates.

Educational requirements and prospects for engineering in Digital Transformation

The Digital Transformation is currently permeating all fields of engineering with an intensity hitherto unknown. Institutes of higher education should not only respond to this but also contribute to this radical change. In order for the engineers of tomorrow to be well prepared for the digital world of work and research, it is necessary for the Digital Transformation to be fundamentally reflected in the upcoming further developments of the curricula.

Curriculum development is a process that must be carried out regularly. It is imperative that it takes the Digital Transformation into account. This discussion paper is to be understood as a basis for discussion with experts from the institutes of higher education, business and politics. Present needs are here delineated from the current point of view of the authors. It does not represent a positioning of the VDI.

This discussion paper is divided into three sections. First of all, an approach is made to the change in education on an abstract level in the form of theses, which were initiated by the VDI's Interdisciplinary Committee on Digital Transformation. In a second step, the consequences for engineering education are extrapolated. The focus here is on Digital Transformation as a teaching content in contrast to digitized teaching, since the use of digital media for new teaching formats and didactic variants is already very advanced locally and is in development throughout

Germany, whereas revision of the curricula in terms of Digital Transformation is frequently in the early stages in classical engineering courses.

The third part then deals with impulses for the development process for engineering course curricula as part of Digital Transformation. Here, the approach of an integrated incorporation into the study programs is pursued rather than an additive one. This part should in particular be seen as a proposal for a systematic exchange between institutes of higher education and companies.

Since 2007, the VDI Quality Dialogue on higher education has provided a prominent forum that facilitates discussions between representatives from the institutes of higher education, politics and industry, as well as demonstrating good practice examples. The authors welcome the fact that the value of engineering education has increased in recent years and they will also continue to support this.

The 6th VDI Quality Dialogue, which will be held on 1st and 2nd March 2018 at the TU Berlin¹, will focus on the second and third parts of this discussion paper, facilitate an intensive exchange between the institutes of higher education and companies, and provide a platform for good practice examples.

Düsseldorf, February 2018

¹ www.vdi.de/bildung/qualitaetsdialoge

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Part 1: Theses on Digital Transformation

Higher education is always guided by the current state of knowledge and by the present and future challenges that professionals and leaders face. Technological innovations are taken up in the context of the cyclical revision of courses and anchored in the curricula. The ever-accelerating advancement of digital technologies more than ever requires a renewal of qualification goals and educational content.

Digital Transformation stands for the global change in the economy and in society, caused by the systematic penetration of daily life by information and communication technologies (ICT). This change has an impact on all areas of life and encompasses all sectors of industry. It interacts closely with the way we live, operate economically and work.

The obvious progress in key scientific fields such as data science/data engineering, artificial intelligence and digital networking not only stands for a further development and improvement of what already exists but also gives rise to a variety of replacements for existing applications. Physical systems and processes are constantly being digitized. This leads to optimizations of existing as well as to the emergence of entirely new concepts and applications, which are only possible through the use of digital technologies. Data and algorithms are available for the evaluation of any interaction and complex processes. Robots and autonomous systems can solve problems without human intervention. In the internet of things, information is exchanged instantaneously between people, machines and arbitrary things. This goes hand in hand with a great responsibility on the part of the individuals involved – in particular, the engineers. They must get involved creatively in a normative environment, even in social discourse.

Institutes of higher education must prepare their future graduates for Digital Transformation. The following theses are based on the current perception of the authors and list the associated challenges.

1 Society, personal life, the professional world, and the world of work

Digital Transformation permeates all areas of society and affects all developmental, transformational and

application processes even in education. Education has a multivalent task both as an application field as well as a mediator and thus also as a driver of the Digital Transformation. The goal must be a digitally mature and enlightened society.

1.1 Digital Transformation will change the world of work fundamentally

Work will be digitized and automated, which causes a **high qualification pressure** for the general public and, above all, for those working in the STEM sector, who are the drivers and shapers of Digital Transformation. The digitization of jobs creates a clear change in professional requirements and leads to **new job profiles and occupational profiles with different skills shapes** in new work environments.

1.2 The key enabler is imparting the necessary skills for accessing digitized areas of life

The basic requirement for the participation of wider layers of society in future living, learning and working environments is **imparting the necessary skills** for dealing with digitized areas of life. First of all, the access threshold to digital systems and components must be surmountable in order to be able to participate and share in the development and utilization of digital worlds. **Access will be on diversified levels**, where the degree of subjective skill-building will decide on the form and extent of participation and sharing in digital processes.

1.3 Social competences for an interdisciplinary and transdisciplinary collaboration provide a decisive additional benefit for value creation and research

Digital Transformation succeeds through an **interdisciplinary and transdisciplinary collaboration**. In order to work with the perspective of other disciplines, strengthening of the necessary social skills is required. This should be understood as a **decisive added value**.

1.4 Engineers bear the ethical responsibility for what they create

Technologies deeply affect people's lives and work as well as the natural world. **Regardless of digitization**, engineers must even today bear the **ethical responsibility** for what they have created. However, **with digitization new dimensions** are added in the necessary **technology assessment**.

2 Education for the Digital Transformation

From the author's perspective, teaching and learning in the context of Digital Transformation includes two main aspects. For one thing, teaching itself is digitized, being often referred to as e-learning or already as digital education. Digitized teaching is, for example, the use of digital teaching and learning platforms or the use of digital tools in the classical lecture. On the other hand, however, Digital Transformation must itself become a subject of teaching, as has already been shown. Both aspects of digital education need to be implemented in order to educate people for Digital Transformation.

Even if the development of curricula with regard to Digital Transformation stands at the forefront of the VDI Quality Dialogue and this discussion paper, the digitization of teaching and Digital Transformation as a learning content cannot always be sharply separated from each other. In order to impart the new teaching content effectively and sustainably, the use of digitized teaching methods is often necessary, but is at least useful.

2.1 Digital Transformation needs to become part of the curriculum.

Comprehensive teaching of the necessary skills for Digital Transformation requires an **uncomplicated handling of digitized teaching** because without a hands-on approach to digital media and methods, many fundamental systematics of digitization cannot be conceived. More important, however, is the **imparting of skills for the Digital Transformation** as such and its critical examination.

2.2 Sensitizing with regard to social acceptance and change forms a part of an education for the Digital Transformation.

Part of an education for the Digital Transformation is **raising awareness with regard to social acceptance and change**, which itself changes due to intrinsically intelligent autonomous systems as technology and their daily use. The goal should be to **create a sense of responsibility and an interface competence** as a basis for shaping the social transformation processes triggered by technological progress.

2.3 Digital Transformation makes new forms of teaching and learning possible

Digital Transformation makes **new forms of teaching and learning** possible and creates new space for both cooperative and also individualized learning. The didactic and content-related limits of existing forms of teaching can be expanded and new worlds of learning opened up - especially in the context of not only stronger networking but also digital platforms and tools. This is accompanied by **greater efficiency and effectiveness for learners and teachers**. The merging of real and virtual learning environments, the interplay of knowledge acquisition and application, ratiocination, and also many other forms of skills training can be redesigned.

2.4 Digitized teaching will occupy a growing share of educational processes

Digitized teaching will occupy a growing share of educational processes and thereby enter into a symbiosis with existing educational formats. Digitization of education will in particular take place in those areas in which it can significantly contribute to the **improvement of teaching and learning processes** and of knowledge transformations. Part of this development is the spread of digital formats such as massive open online courses or digital learning management in the field of education. Moreover, **digital business models outside of traditional education providers** are pressing into the education market.

3 Globalized and lifelong digitized learning

In all areas of working life, Digital Transformation is creating new requirements for lifelong learning. But even in private everyday life, Digital Transformation has a considerable influence. Aspects such as the barrier-free accessibility of new applications play an important role in participation in social life, which increasingly requires an uncomplicated dealing with new technologies.

Digital Transformation opens up new possibilities in the context of globalization. In the educational context, Digital Transformation can weaken regional differences and create an access to education which is independent of location.

The digitization of knowledge and of teaching enables completely new dimensions for a use by broad strata of society. Both the social dialogue about technology-driven developments and also education and further education can thus be designed sustainably and economically.

3.1 Open education – education for all – is facilitated by the Digital Transformation

Education for all – worldwide access to data, information and knowledge – is only possible on a wide scale through the digitization of education. Open education not only includes changes in the global use of knowledge but must also promote **intergenerational learning, both regionally and globally.**

3.2 Digital Transformation is leading to a stronger individualization of educational and life planning

Digitized education processes promote interlinking of education and further education as well as **individualization of educational and life planning.** Opportunities arise not only for individual ways of acquiring skills together with a higher permeability in the education system but also for individual skills profiles for each person, especially through further education.

3.3 All interfaces of education and continuing education are to be mutually coordinated in the process of lifelong learning

All interfaces of education and continuing education in the digital world of education should be mutually **coordinated in the process of lifelong learning, from the kindergarten up to senior citizens' academies,** in order to support learners with a sustainable social participation and with uninterrupted personal and vocational development.

3.4 The selection and evaluation of information is becoming more important, while the relevance of easily accessible knowledge is declining

Digital Transformation promotes networking in the field of education. The widespread availability of global knowledge enables the easy integration of many sources of information. Connectivistic learning and the selection of important information thus gains a growing significance. The relevance of providing easily accessible knowledge is decreasing.

Part 2: Consequences for engineering education

Engineers play a central role in the Digital Transformation since they are significant drivers of digital change. An engineering course must impart in an appropriate way the skills needed for Digital Transformation so that for research and for business young talent is qualified for the future.

In a disruptive process such as the Digital Transformation all stakeholders involved in engineering education need to rethink their structures and processes. In this part of the discussion paper, the authors will extrapolate the consequences for the content-related design of engineering education on the basis of the theses in the first part. In doing so, the theses relating to course content will be treated more intensively. The other theses in the first part cover the context of the overall situation, as the authors currently perceive it, but here are relegated to the margins. For example, no extra-curricular possibilities, such as in-company training or non-university online courses, are considered. It is further assumed that educational qualifications appropriate to higher education entrance have been obtained before taking up studies.

Digital Transformation is an integral process that affects all areas of the engineering sciences, and each module of a course of study. Even if a specially created (preferably interdisciplinary) module during the course of studies can shed light on the general facets of the Digital Transformation, nevertheless, each individual module should in its own context be examined and further developed in terms of the effects of the Digital Transformation. The intensity should be graduated according to its relevance within the modules. As described in the first part, a fundamental change in society goes hand in hand with Digital Transformation. The technical solutions of today and tomorrow have a much more direct influence than was still the case 20 years ago. Thus, the social responsibility increases. Different aspects of curriculum development are highlighted in what follows.

Skills prior to entry upon studies

Younger generations who have grown up with digital communications technology in their everyday life – so-called digital natives – have already been markedly influenced by the Digital Transformation. Today they **can as a rule use digital formats**

and communication processes in a much more straightforward way than many lecturers. In order to optimize and professionalize their teaching, teachers should be familiar with the methods of **digitally supported teaching and use them purposefully** (↗ Thesis 2.3). In the institutes of higher education there should be central support offices to help lecturers in the **conversion of didactics**.

The fact that today's students are absolutely at home in their dealings with certain digital media **does not mean that they also have an in-depth understanding of the technologies** (↗ Thesis 2.1) nor of the possibilities and limits of Digital Transformation and its **impact on society and the environment** (↗ Thesis 2.2).

Personal and social skills

Existing knowledge is increasing rapidly in both its extent and its depth of detail. To be sure of finding and appraising the necessary information in any situation, **self-learning competence** (↗ Thesis 3.4) must be included as a learning objective in new and existing curricula.

Still important characteristics are decision-making ability and cooperation skills.

The decision-making ability (↗ Theses 3.2 and 3.4) is the ability to focus on what is essential, to set priorities and to assess alternatives in order to act and to rely on one's experience in unpredictable situations. The more possibilities there are, the more important this skill is. Digital Transformation is contributing to a massive increase in opportunities in many areas.

Cooperation competence (↗ Thesis 1.3) is the ability to collaborate in social, technical and business matters, to achieve consensus and mutual acceptance. In addition to team ability it also includes the ability to enter into partnerships outside the organization. This includes the active implementation of a constructive feedback culture. It is important on the one hand to promote mutual acceptance on the part of the students and, on the other hand, to utilize the increased possibilities of individualized feedback and thus provide transparency.²

² Based on Erpenbeck, J.; Heyse V.: Die Kompetenzbiografie. Waxmann 2007

In order to convey **appreciative and goal-oriented cooperation behaviour** to students, corresponding learning objectives should be integrated into the curricula and explicitly promoted in teaching through feedback and the creation of reflection events.

Technical skills and the imparting of knowledge

In the third part of this discussion paper, a portfolio of specific technical skills is listed. The authors will therefore confine themselves at this point to general statements about professional skills and knowledge dissemination.

In the future there will be a **greater need for graduates with hybrid skills**; in other words, domain know-how in an engineering discipline paired with solid basic knowledge in digital disciplines (↗ Thesis 1.1). Conversely, computer scientists are sought who bring a basic understanding into the context of the classic engineering sciences. With the aid of interdisciplinary modules, which operate, for example, **by using problem-based learning methods, students from various disciplines can learn from each other and at the same time strengthen their interdisciplinary skills** (↗ Thesis 1.3).

New educational content for Digital Transformation should not be a pure mediation of information about it, but must rather **strengthen the ability to transfer information by combination into new knowledge and knowledge into new conclusions** (↗ Thesis 3.4).

Therefore, there must be a focus on such teaching content as conveys combination, abstraction, modelling, knowledge about model boundaries, risk assessment and containment, interfacing skills with other disciplines, documentation and communication of data and results, data analysis and quality assurance of the knowledge constantly available on the internet. This will only work under a challenging re-adjustment of the teaching content with a **reduction in the easily accessible knowledge**.

In addition, the **special relevance of the options in the digital world should be communicated – especially through the now widespread connection to the internet**. Digital mappings of real objects and processes have long been part of the simulation methods routinely used by engineers. What is new, however, is the comprehensive networking of real and virtual information so that entire ecosystems can be mapped as digital twins and the communication and development possibilities of the individuals involved

can be raised to a different level. Not only in this way are predictive simulations made possible which then, following activation of the derived, simulated measures, have a direct impact on the real-life models or their modification by computational steering and artificial intelligence. The **digital world is increasingly controlling the real world**; this calls for an appropriate awareness in this way of thinking.

The development of products and entire scenarios in the virtual world requires a deep understanding of the underlying models and their limits, of the **simulation technologies** (↗ Thesis 2.1), their tools and process chains. Furthermore, essential business models are organized in the digital world which are then however implemented in the real world via the acquisition of information using sensors and execution by actuators (such as machines in manufacturing, autonomous vehicles in the context of mobility). The creation of **control loops between the virtual and the real world** is significantly intensifying; for this reason, a broad understanding of the possibilities of these two worlds should be imparted. Here, the simulation of real processes and the intelligent filtering of large amounts of data is also just as much a key skill as is knowledge of agile process methods in software development.

Ethics and society

Engineers should perform their actions with an **ethical and professional responsibility** (↗ Thesis 1.4) towards society and the environment. The prerequisite for this is an ethical discourse in engineering education: not only topics such as data protection and misuse as well as data security and data falsification, but also the decision-making parameters of autonomous systems are part of engineering products. There is a need for competence in **technology assessment**.

Digitization is speeding up global networking, which in particular enables a global exchange of information in which many people participate. In the education of future engineers, **space should be made to allow for reflection about cultural constraints or changes in their effect on technical fields of work** (↗ Thesis 1.2).

Part of digital education is to develop a sense of responsibility and an **interface competence** as the basis for the design of social transformation processes triggered by technological advances (↗ Thesis 2.2).

Engineers must participate actively in critical reflection and in the social impact assessment of new technologies and share a formative role in normative processes. They must bring their expertise to

the forefront of societal discourse so that regulatory frameworks can be adjusted to promote progress and competitiveness and to enable the implementation of innovative solutions. In this way they can contribute to **shaping the discourse objectively on a scientific basis**.

Engineers have also the responsibility of contributing to solutions for the regulation and control of uncontrolled developments resulting from digitization in different areas. **Misuse of digital technologies** is not only harmful to consumers, the environment or the economy, but also to the reputation of engineering as a whole and must be prevented at all costs.

Students must be put into a position of **independently subjecting their actions to ethical examination**, coming to their own judgments, and acting in accordance with ethically-based criteria (↗ Thesis 1.4).

Understanding of quality and safety

Even the **understanding of quality and the quality requirements of engineering products** must take account of Digital Transformation (↗ Thesis 2.1). It is generally known that software solutions can never be a hundred percent safe. This does, however, mean that students need to develop an understanding of the right level of safety measures and the limits of the underlying model approaches. For example, in connection with products in the area of the 'Internet of Things' (IoT), an awareness of the different speeds of the product development cycles of all product components is essential. For instance, while the refrigeration technology of a refrigerator is designed to last 20 to 30 years, the software is already a security risk after a relatively short time. This must already be taken into consideration in development.

Furthermore, **data protection and data security** are unavoidably the responsibility of engineers.

It is well known that products can be made mechanically much simpler and more unstable if they can be electronically stabilized by digital measures such as control technology (for example, ESP in the car). Here, current Digital Transformation is yielding increasingly wide-ranging opportunities for developing **modified quality requirements on a mechanical basis with higher quality on the overall system level**. The focus must always be on the latter.

In principle, an increased importance is given to **weighing up the advantages of quality assurance before and after completion of a product**. In this

regard, it is a matter of determining which areas need to be differentiated right from the start and which can, via updates based on user data, lead to a significant added value during the lifetime of the product. This increased number of degrees of freedom should be reflected in the course of studies.

Forms of organization

The questions to be tackled in the digital world of work and life are steadily becoming more and more complex. New digital tools in turn make it possible to reduce this complexity.

Intelligent solutions require an interplay of different disciplines in the **sense of a transdisciplinarity and an interdisciplinarity**. The necessary skills can be promoted especially through problem-based and project-oriented learning. The institutes of higher education should **check whether the current structure of faculty and departmental boundaries is having an inhibitory effect** on the development of the curricula with regard to the organization of interdisciplinarity, systemic thinking, quality, flexibility and agility (↗ Thesis 1.3).

To be able to drive Digital Transformation forward in the industrial world themselves, engineering students can already at an early stage try out **entrepreneurial thinking and acting**. This is supported by links with start-up centres. Entrepreneurship, creating business plans, working with real 'use cases' as well as understanding and developing business models should be integral components of engineering education (↗ Thesis 2.1). Practical phases in companies can be supportive here. At the institutes of higher education the various **aspects of Digital Transformation can then be exchanged and reflected upon**.

Persons involved

During curriculum development, **opportunities for cooperation throughout the institute of higher education** should be explored (↗ Thesis 1.3). Interdisciplinary exchange is a possibility particularly in the case of problem-based learning projects. Especially between, but also outside of classical engineering departments can emerge forward-looking cooperation.

A **dialogue between institutes of higher education and companies, associations and unions** offers the opportunity of mutually coordinating the skills required by Digital Transformation. Here, the **responsibilities of both sides should be defined**: institutes of

higher education can teach the basic principles, deeper points of focus and learning strategies while companies, associations and unions can meet their specific requirements through training and further education opportunities. Experiences from the **integrated degree program** can be helpful here.

The process is supported by the regular **appointment of scientists from industry** in order for there to be an

adequate number of professors with business experience at the institutes of higher education.

Digital Transformation enables an improved **exchange with other educational institutions** ([🔗 Thesis 3.3](#)), for example, schools, vocational schools, colleges for further education, and so on. This should be used and cared for in the spirit of individual learning pathways.

Part 3: Impulses for curriculum development

As already described in the introduction, the VDI has offered engineering education a prominent platform with its Quality Dialogues since 2007. The authors welcome the fact that the importance of engineering education has increased in recent years. This contributes to the fact that even in the years ahead graduates of German institutes of higher education will be able to enjoy an excellent starting position for their working and research lives.

The institutes of higher education are facing a variety of challenges relating to curriculum development, which have among other things already been discussed in previous Quality Dialogues but which also have been and will be addressed in a variety of other events and publications. These are mostly applicable to a broader landscape of disciplines.³

From the point of view of the authors three groups of actors are crucial to the further development of the courses of study. In addition to the institutes of higher education themselves, companies are involved as employers and politics as a party providing the framework.⁴ The focus of the following impulses is on the institutes of higher education and the economy. The challenges of politics will be tackled by the VDI together with its partners in the follow-up to the Quality Dialogue and processed separately.

Following on from the previous parts of the discussion paper, this part will also deal with the challenges for curriculum development in the engineering sciences which result from Digital Transformation. On the basis of the consequences described in the second part, impulses for reflection, revision and readjustment of the undergraduate programs are identified. This should not be understood in the sense that a large number of new modules are required but rather that the skills for Digital Transformation should be integrated into existing modules.

As already discussed, Digital Transformation succeeds in particular by linking well known technologies together as well as through transdisciplinary and interdisciplinary developments. For this reason, at the end of this discussion paper a dialogue process is proposed, which can be based on various processes, such as an organizational process, a value chain or a development process. Here, one can derive needed and desirable skills for the Digital Transformation together with the own and other departments, business

and other partners in order to introduce those in the study programs. At the same time it is also possible to determine what content has now become obsolete or can be easily updated and what content remains indispensable.

In addition, it is possible to balance with partners from the business sector which knowledge should be available and which skills and competencies should be learned in the study programs and vice versa, what during the company training and further education.

Matrix of technical skills for Digital Transformation

Not only in the incorporation of new course content but also in the evaluation and re-adjustment of current content the question always arises as to what scope, what depth of detail and what degree of abstraction is appropriate and conducive to achieving objectives. For technical skills regarding the Digital Transformation, four levels are proposed.

In the exemplary matrix (Table 1) below, a variety of possible digital techniques and methods are listed and (vertically) sorted by subject area. In addition, there is also (horizontal) sorting by the degree of abstraction. These range from the model level, via the system and technology levels, up to the application level.

In preparing development of a curriculum, a collection of all eligible course content should be made first. The sorting process that follows not only helps preserve the overview but is also supportive in discussion with partners regarding the appropriate adjustment and selection of content. Furthermore, it can provide information about which areas skills could be useful. Of course, the matrix must be customized or even created individually for each course.

The content of the matrix (Table 1) is continuously updated on the website of the 6th VDI Quality Dialogue⁵ so as to provide as many subject areas as possible for further study courses. Examples of curriculum developments are also presented on the website as possible stimuli. Beyond the sorting in the matrix, the intertwining of the teaching content can also be represented in a semantic network (Fig. 1). Here the arrows symbolize the mutual dependence of the topics. This helps when defining modules which are based on each other.

³ For example (in German): www.hrk-nexus.de/fileadmin/redaktion/hrk-nexus/07-Downloads/07-02-Publikationen/Handreichung_Anrechnung_15.12.2017_WEB.pdf

⁴ Compare Henry Etzkowitz, „The Triple Helix“ (2008)

⁵ <https://www.vdi.de/bildung/qualitaetsdialoge/6-qualitaetsdialog-ingenieurausbildung-in-der-digitalen-transformation>

Example of a matrix

	Model	System	Technology	Application
M1	Business/Management	Business/Management	Business/Management	Business/Management
	business models, investment models, value chain	ERP-, PLM-systems	digital transformation cognitive personalization knowledge management	digital eco systems/ digital system management
M2	ICT	ICT	ICT	ICT
	reference model, unifying, web x.y	big data/data analytics, smart systems, human-machine interaction	connectivity/cloud systems, internet of things, usability engineering	wearables, web x.y/ platforms
M3	Production/Logistics	Production/Logistics	Production/Logistics	Production/Logistics
	networked production process, digitized work process/smart factory, decentralization	automation, integrability, interoperability, composability, resilience, CAD/CAM-systems	robotics, working environments, production intelligence (PI)	additive and adaptive methods, maintenance, augmented/virtual reality
M4	Safety/Security	Safety/Security	Safety/Security	Safety/Security
	security/trust/privacy/safety concepts/legal basis	system safety	safe technologies, back-up technology	industrial safety systems, data protection
M5	Engineering	Engineering	Engineering	Engineering
	smart and interoperable modelling in MT	smart and flexible systems	automated mechatronic systems in production and logistics	smart lab/design thinking

Tab. 1 (Author: Prof. Schumann - For the development of the study program "Digitalization" in the context of a German-Chinese cooperation.)

Societal, personal and social skills

Not only in order to meet profound educational requirements of the course of study, in addition to the subject areas specified in the matrix the previously described societal, personal and social skills must also without fail be integrated in engineering education. The importance in connection with Digital Transformation has been described in the second part of this discussion paper and will also be a central theme of the VDI Quality Dialogue.

In addition to an overall concept for these extradisciplinary skills in the study course, for each module there should be a discussion on extradisciplinary issues. A check should be made as to how, for example, cooperation skills can be integrated into existing modules by revising the didactic concept.

Furthermore, docents should retrospectively address the interactions of earlier developments of their own discipline with society and thus regularly bring the subject of the responsibility of engineers into the course of study. On this basis, current developments can be examined with regard to their social impact. In this way, an attitude can be created in the sense of a social responsibility.

The T-shape model for a curriculum in Digital Transformation

In the competence-oriented development of modern curricula, the centre of focus is on the requirements applicable to future engineers. These are subject to a continuous process of change. In the course of Digital Transformation it is particularly important to assess what content in the light of the permanent accessibility and thus can only be addressed in the form of examples and be scaled back in the lectures. This should be done in favour of new content and options arising from digitization and also from the networking of different disciplines, and which open up new possibilities for value-added processes and finally opportunities for progress. Furthermore, content and skills need to be identified which have long-term relevance or which deliver the ability to get along with further radical changes as well as shaping those.

In this discussion paper the classic T-shape model⁶ has been supplemented with a third dimension in which the level of (possible) digitization according to the matrix can be visualized. The width of the horizontal bar symbolizes the broadness of skills including interdisciplinary competences, while the length of the vertical bar represents the depth of several of these skills – for example, through

⁶ Compare David Guest, The hunt is on for the Renaissance Man of computing, The Independent, 17.09.1991

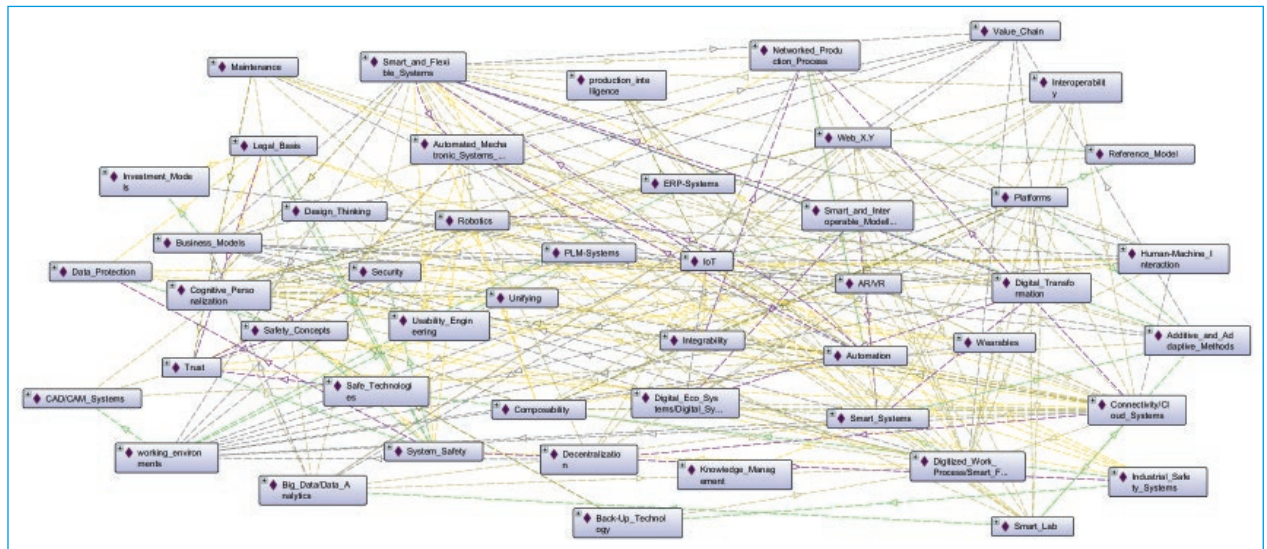


Fig. 1: Symbolic Example of a semantic network (Author: Prof. Schumann)

modules in the advanced course. The height stands for the degree of digitization of the course content as presented above, but not in the sense of a digitized teaching. The three changes shown are

1. The adjustment of the degree of digitization of each skill,
2. The reduction of existing teaching matter (light-blue crosshatched boxes) in order to make room for new content (light-blue boxes), and finally
3. The shifting of content which was previously taught to all students (medium-blue crosshatched boxes) into the in-depth study category (medium-blue boxes).

This also has to be done individually for each course of study. The graphic should also make clear that the study's scope (footprint of the T) is not increased and that the skills for Digital Transformation should primarily be integrated into the existing content.

Dialogue process

The program committee of the VDI Quality Dialogue at the TU Berlin 2018 proposes the following dialogue process using the previous tools in order to support curriculum development. Partners from the academic and business environments should in particular be approached. With which department or level the dialogue is conducted has an effect. A discussion with the development engineers of a company may thus yield quite different insights regarding current needs than a meeting with senior management. Both viewpoints are certainly beneficial and should be internally assessed and incorporated appropriately in the curriculum.

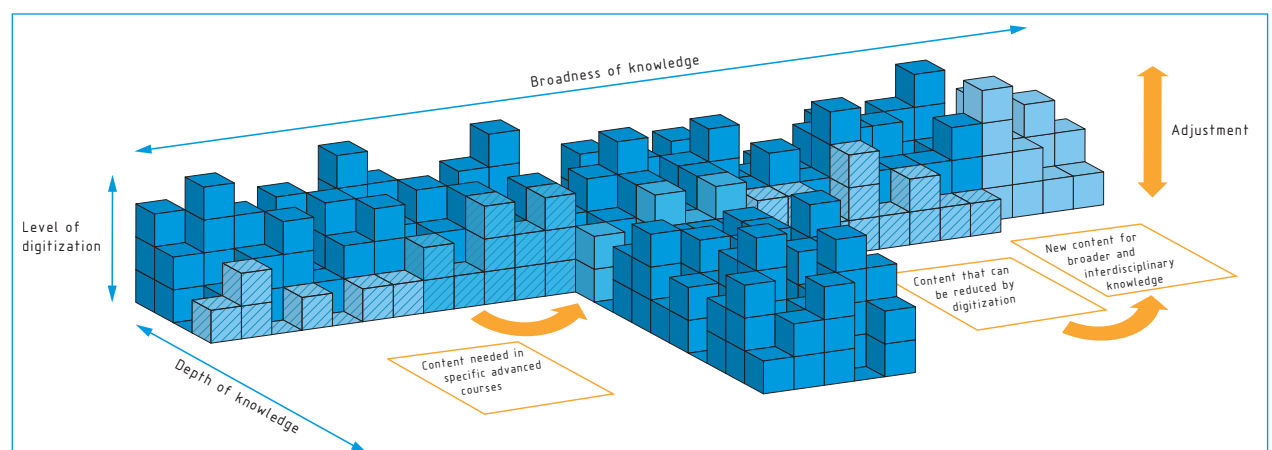


Fig. 2: Processes in the three-dimensional T-shape model (Graphic: VDI/Gallenkaemper)

The following steps are carried out in the subsequent dialogue proposal (Fig. 3):

1. On the basis of a process (such as a project schedule of a typical company in the university environment), a skill is identified. It is further determined to what extent the necessary skill should be present (in the diagram, shown as 75%).
2. In the case of a technical skill for the Digital Transformation, the question of the required level of abstraction is clarified. This can also mean that the desire for a very specific skill is generalized or extended for the course of study. Similarly, other required skills can be identified (see also the semantic network in Fig. 1).
3. Using the information collected from the discussions with external partners, the requirements for internal curriculum development can be determined.
4. The individual components of the study program are here weighed up in relation to each other, and content, depth, scope and – where appropriate – cooperation partners defined.
5. On this basis the skills to be acquired in the course of study together with their scope can be deduced.
6. The possibility arises of discussing realistic study objectives with the external partners. These should meet the academic requirements of teaching at institutes of higher education but should also lead to graduates, which can participate in a vocational adjustment. Basic knowledge, competencies and skills are usually acquired at the institutes of higher education while specializations are taught during in-company training and advanced training.

If necessary, steps 2 to 6 are repeated once more when both sides consider a change of priorities as profitable.

Step 2 constitutes a special challenge for the dialogue. Once a very specific requirement of the graduates has been formulated in step 1, the appropriate classification and generalization is by no means a foregone conclusion. For most external discussion partners this question probably requires a changeover from an operational to a more universal perspective.

Due to the growing number of skills required and therefore increased content of teaching, there will be a stronger intertwining of the mutual dependencies of the modules. The number of these dependencies is boosted in particular by interdisciplinary modules. It is therefore all the more important to devote adequate attention to curriculum development and to intensify the dialogue within the institute. The challenges should here be approached starting from the formats being newly developed; this also means that any conflicting (internal) structures will have to be adapted. This flexibility is necessary for the adjustment of the study courses within the context of Digital Transformation.

The exchange in the last step will certainly also lead to some discussions. But precisely these are necessary not only if the institutes of higher education are to educate employable graduates but also to define appropriate objectives for the course's time framework.

It thus becomes clear as well that education for Digital Transformation does not stop with the course of study. The authors are convinced that firstly, lifelong learning is necessary for graduates to keep up with future developments, and secondly, the academic teaching must be continuously scrutinized and adapted to future developments.

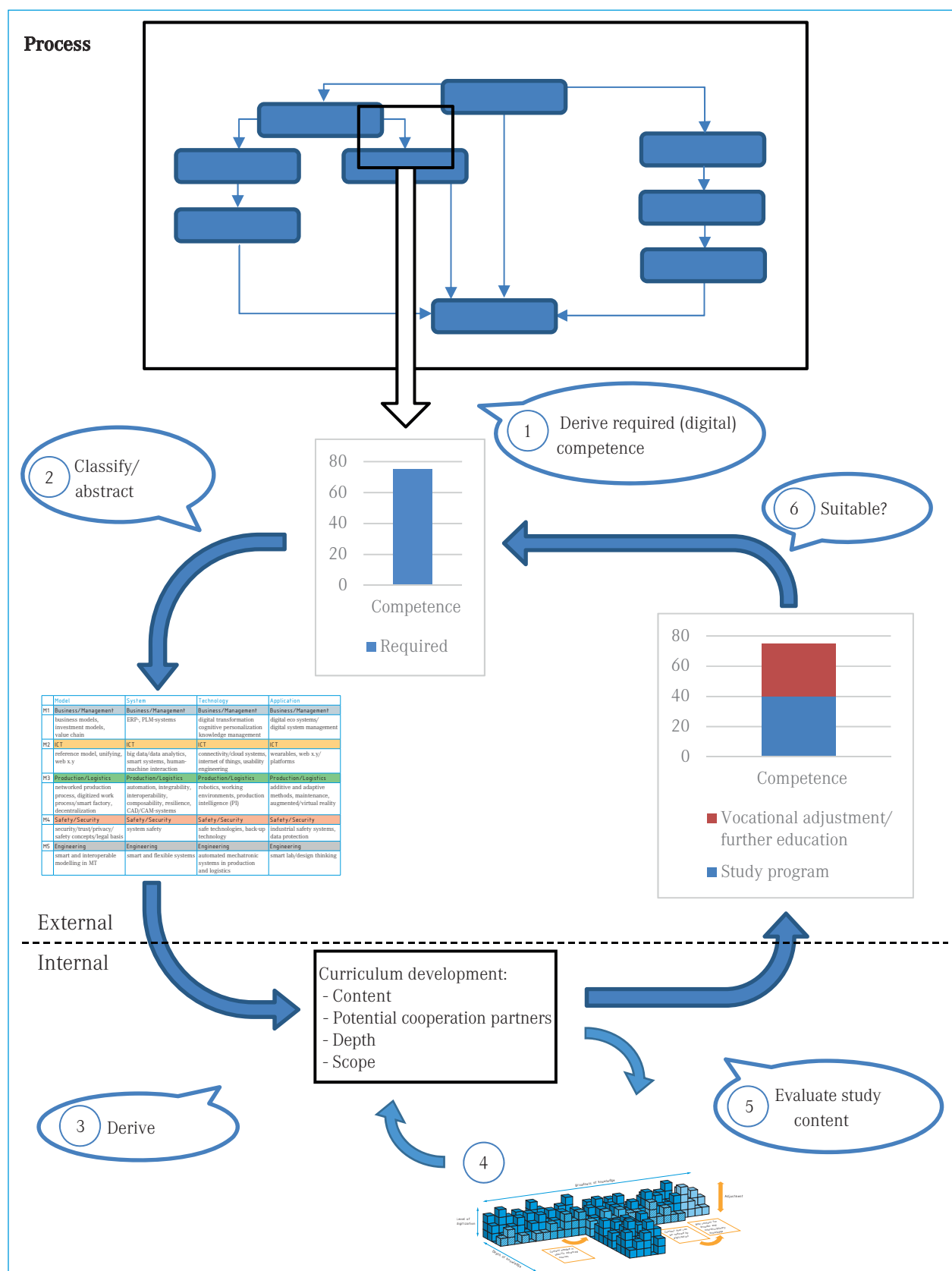


Fig. 3: Dialogue process for curriculum development (Graphic: VDI/Gallenkaemper)

Project families: How to improve learning in thesis works and increase impact on research

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Conference Key Areas: Innovative teaching and learning methods, Engineering skills

Keywords: Active learning, generic skills, peer supervision

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INTRODUCTION

A university has a number of activities, of which teaching and research are the two most important and dominating activities, often in competition for the resources. Thesis work is an important but also resource requiring activity during the education, in which the students demonstrate their true competences, apply what they have learned and solve problems without a textbook solution. In doing that they typically work one or two students together on stand-alone projects, a concept which often stress both students and supervisors and which requires much support, in particular if they have experimental activities. It is, therefore, relevant to improve the concept of the thesis activities and to consider the following questions

- Can we identify the most important key competences for the candidates ?
- Is the level of the candidates competences sufficient ?
- Can we increase the students learning outcome and generic skills in their thesis projects?
- Can we increase the students' contribution to research and innovation?

This paper describes learning outcomes, generic skills developed by the students and the scientific impact with applying the concept, project families, in thesis work.

1. THE KEY COMPETENCES

Identifying the most important key competences is extremely important for a university, in order to focus the teaching and learning correctly. DTU Civil Engineering was in 2009 [1] inspired by an earlier investigation carried out for MIT in 2001 among faculty, young candidates and their employers [2], to identify the most important key competences for MIT graduates. The DTU investigation used questionnaires and interviews of the young candidates and their employers and identified the three most important competences as: 1) Engineering reasoning and problem solving, 2) Communication (oral and written) and 3) Personal skills and attitudes (initiative, thinking, critical, creative and flexible). The MIT investigation and others [3], [4], [5], [6] found similar priorities of the competences in the period 1988 to 2016.

The educations at Danish universities are all under an accreditation system, where each education is reviewed every 3 or 6 years. A part of this accreditation is a review of candidate quality, where the reviews have confirmed that our candidate competence level is very good and even increasing.

2. THE PROJECT FAMILY CONCEPT

The authors decided to develop and test a new concept for the thesis work to support the learning of the key competences more efficient [7], [8] than the traditional thesis project, where a group of 1 or 2 students working on a stand-alone project with a supervisor. The traditional projects are always problem-based and benefits from the advantages, known from problem and project-based learning and includes many CDIO aspects, but have weaknesses due to the very individual work activities, where peer interaction or cooperation rarely occur and many resources are spend on very basic problems.

The new concept aims at both improving the students learning and increasing their contribution to research and innovation by focusing a group of student projects at a common research topic, where a research group form a supervisor team. This concept intend to support an increase in voluntary peer-interactions and collaboration and to create an improved base for a good project flow. The reformed concept is called the **project family** concept.

The project families may deal with different parts of a larger problem or they may deal with the same problem, defined by the supervision team. The students specify their project statement individually, so each project is still unique, which still is a requirement. However, the projects in the family are encouraged to cooperate and they may even use each other's results (with references).

The formative assessment is based on a midterm conference where each project presents their results so far to the project family, the supervisors and often representatives from the industry, as well as the peer interactions at the supervisor meetings. The summative assessment of the projects are the same as for the rest of the departments' students (reference group), which is an oral presentation with an external censor and on a written report.

The authors have over the years 2011-2017 tried the project family concept with 104 Civil Engineering students (26 BEng students, 49 BSc students and 26 MSc students) in 14 project families. The project families have varied in size and have consisted of between 4 and 16. The project families may consist of a mixture of BEng, BSc and MSc projects with different basic knowledge, learning levels and number of ECTS points. The project families have been until now been organised under three different research areas with different supervision teams at the department:

- ZeroWaste: Focus is on utilising waste materials as secondary raw materials.
- Glass structures: Focus is on use of glass as a load-carrying structural material.
- Strengthening of structures: Focus is on strengthening of concrete beams.

Due to the difference in the research topics and their maturity and the personal style of the supervisors, the supervision concept for the project families vary slightly. The supervisions schemes are shown in Table 1.

Action	ZeroWaste	Glass	Strengthening
Start-up meeting	X	X	X
Weekly project family meeting with all students, main supervisor and relevant co-supervisors	X	X	Only first month
Time required for weekly project family meeting	½-1 hour	1 hour	1,5-2 hours
Individual meetings	If required	No	After first month
Project status at every project family meeting	X	X	X
Task groups formed during the period for dealing with different challenges.	No	X	X
Group instruction in experimental procedures	X	X	X
Group instruction in special computer programs	Not required	X	Not required
Sharing experimental facility	X	If experimenting	X
Midterm presentation (poster based) and discussion about further project activities	X	X	No
Sharing a joint room for all students	X	X	X

Table 1. Overview of supervision and sharing of facilities.

3. THE STUDENTS BENEFITS

3.1. Grades of the projects

It is difficult to measure the direct effect on the grouping of projects in project families on each of the three key competences; Engineering reasoning and problem solving, 2) Communication and 3) Personal skills and attitudes, individually. The combined effects, however, can be documented by comparing the grades earned by the project family members with the grades of the students conducting their thesis work in traditional stand-alone projects (reference group).

The reference group consisted of the BEng (338), BSc (159) and MSc (395) Civil Engineering students, who carried out their thesis work at DTU Civil Engineering during 2012-16 and represents the same educations as in the project families. The weights of the three educations are set to their relative numbers in the project families, just as similar weights will be used in all other comparisons (Figures 1 and 2 and Tables 2, 3 and 4) in this paper in order to have as representative a reference group as possible.

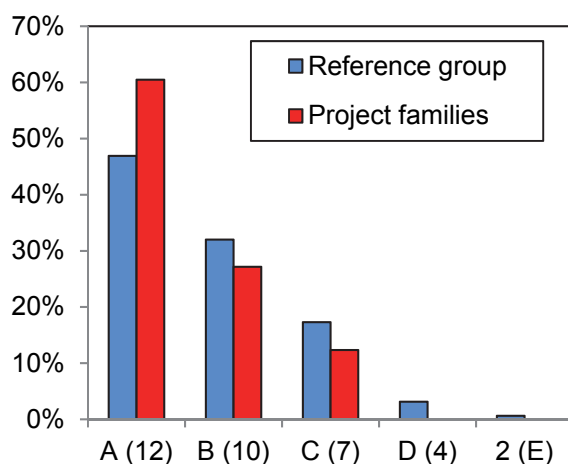


Figure 1. Distribution of thesis grades 2012-2017, Danish grades in brackets.

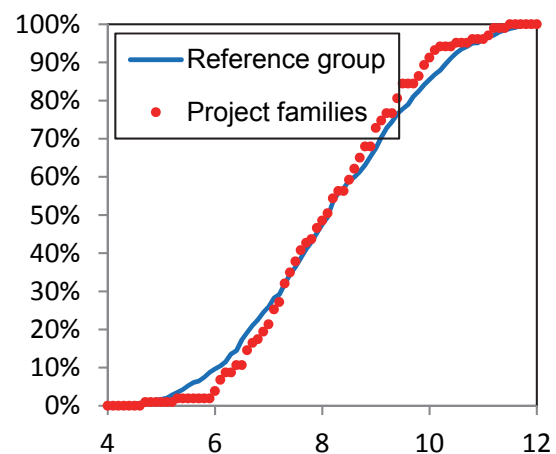


Figure 2. Accumulated distribution of average grades during their education.

Figure 1 show that the grades are better in the project families, than in the corresponding reference group. Figure 2 illustrates that the variations of their average grades during the studies are very similar in the project family group and in the reference group.

The grades for the different Civil Engineering educations are shown in Table 2, where it can be seen that the project families have lead to a statistically significant increase of the thesis grades, regardless of the education (significant defined as a confidence level of 95% and simulated using a Monte Carlo simulation). The statistical significantly results are marked with * in Tables 2 to 4.

It can be seen from Table 3, that it is especially the below average students, who significantly improve, but that the improvements are observed for all groups except the top 25 % performing students.

Table 4 shows that projects within all three research and supervision groups have resulted in improvements of grades, compared with the reference group. The data for

the reference group in Table 4 is a combination of the data for the three educations, weighted corresponding to their numbers of students in the project family.

Type of education	Project families			Reference group		
	Education	Thesis	No	Education	Thesis	No
BEng	7.1	10.9*	26	7.7	9.7	338
BSc	8.1	10.8*	49	8.1	10.2	159
MSc	9.0	11.1*	27	8.7	10.2	395
All	8.1	10.9*	104	8.1	10.1	892

Table 2. Average grades for students in their education and in their thesis, grouped after their education.

Average in education	Project families			Reference group		
	Education	Thesis	No	Education	Thesis	No
Below 7	6.3	10.0*	22	6.1	8.3	227
7 to 8	7.4	10.9	28	7.5	10.0	196
8 to 9	8.5	11.1	26	8.5	10.8	178
Above 9	9.8	11.5	28	10.0	11.5	291

Table 3. Average grades for students during their educations and in their thesis, grouped according to their average grades in their educations.

Project family	Project families			Reference group	
	Education	Thesis	No	Education	Thesis
ZeroWaste	7.8	11.0*	57	8.0	9.9
Glass	8.5	10.7	33	8.4	10.2
Strengthening	8.4	11.1	14	8.3	10.0

Table 4. Average grades for students in their educations and in their thesis, grouped after research area and supervision team.

3.2. The students experiences

A number of questionnaires were issued to the students in 2014 (11 of 14 students answered) and in 2017 (15 of 23 students answered), asking them about their experiences, dealing with supervision, peer-interaction, their work situation and how they rate their own performances. The sums of the responses are shown on Figures 3 and 4.

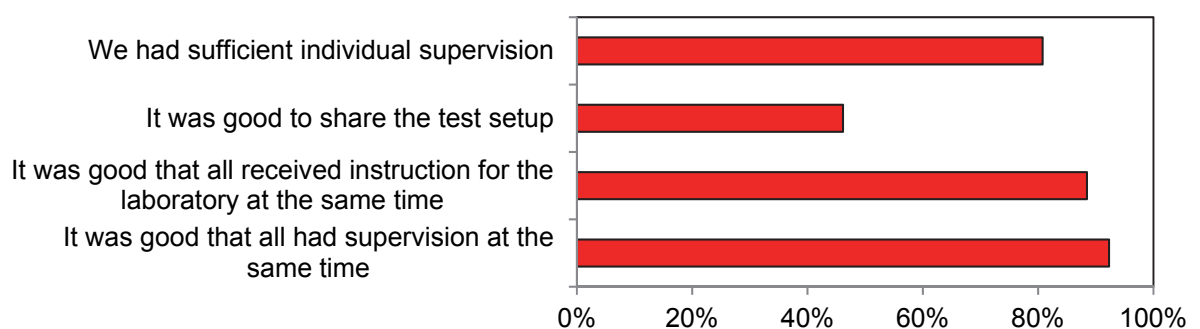


Figure 3. Question to the student: How was the supervision ? (Mark all you agree with).

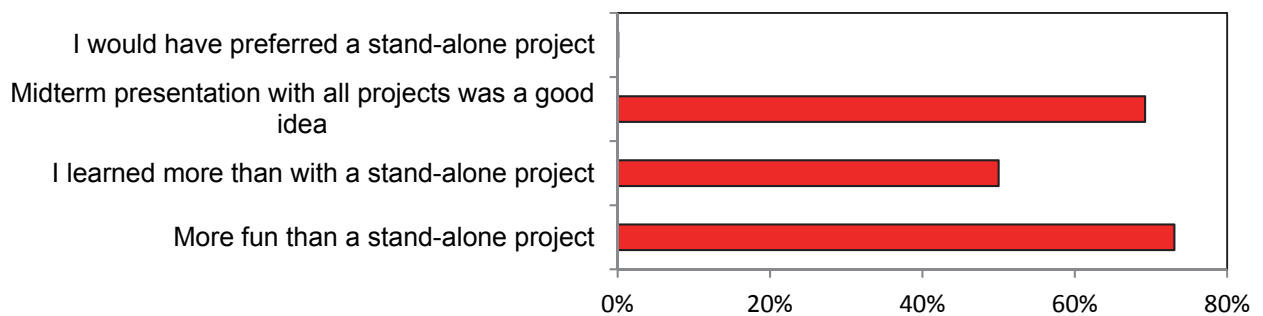


Figure 4. Question: How the students experienced the work in a project family (Mark all you agree with).

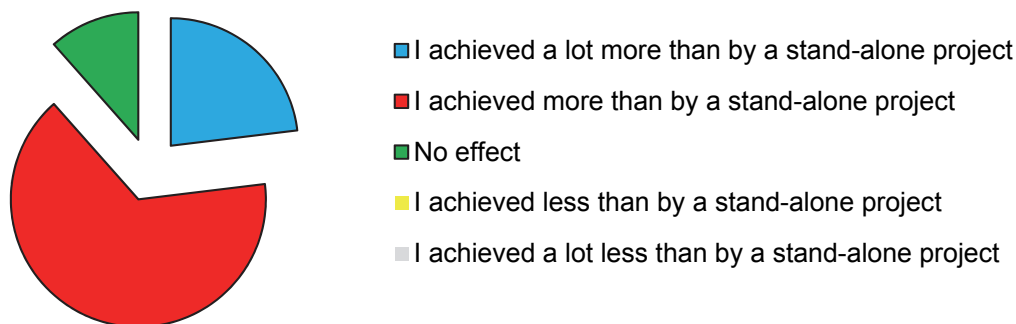


Figure 5. Question: How did the project family concept affect your achievements ? (mark only one).

The Figures 3 to 5 show, that the students appreciated the concept of project families, that they interacted well and had more fun and that they felt that they achieved more than if they had worked on a stand-alone project. Some of the students added qualitative comments to their questionnaires or to a later interview [9], where one student stated:

" When you are in a project family, you have more angles to your work, You achieve more on less time, because you are constantly challenged in your way of thinking. If you work alone, that will be slower"

THE UNIVERSITY'S BENEFITS

3.3. The supervisors experiences

The supervisors found that the supervision required for basic instructions was the same for a project family as for a single, traditional stand-alone project, although individual supervision was still used in addition to this. The students are better prepared for the project family supervision meetings, than for the traditional projects and the supervisors spend less time on basic activities. This allowed the student projects to progress to a deeper level and the learning process and the supervision could deal with deeper and more advanced topics, as both students and supervisor had room for the more advanced experiments and discussions and thus improving their use of engineering reasoning and problem solving.

The quality of the students' planning, their input for supervision and not least their oral and written communication and technical vocabulary have been significantly

improved, just as a much larger number of the thesis reports are useful for the supervisors' research. The larger number of students in a project family has also the benefit, that the supervision group can actually plan for a project family to have a substantial input to their research. The project family concept has also significantly reduced the number of reports, which could not be used in research due to lack of proper reporting. These improvements are difficult to indicate numbers for, but the reported grades illustrate the improvements clearly, as the summative assessment has not changed.

The results from the project families have been used in 14 publications in conference proceedings and scientific journals or as "pilot" or "screening" testing in the research areas. The use of the project results depends much on the type of scientific area and the maturity of the research area in which the students participate.

An additional benefit of the use of project families is a more rational use of the laboratory resources, where a 25-75% reduction of the hours used for instructing and supporting the students has been estimated by the laboratory leaders. They report also that the students are better prepared for and behave more professional in their laboratory work and thus learn more and faster, just as they observe an increased peer-interaction by the project family students compared to the reference group students and that the project family students even instruct and correct each other in the laboratories. The students have in their work and in their interaction with the supervisors and the laboratory staff shown a marked improvement in their personal skills and attitude, which appears much more professional and mature than previously.

4. SUMMARY AND PERSPECTIVES

The use of project families improves learning outcome and grades and increase the quantitative input to the research activities. The improvements on grades are largest for the below average students when making their thesis project in a project family, whose performances were improved to match the performance of the above average students in the reference group. No effect has, however, been observed among the top level students (with grades among the best 25 % performing students), probably because these would normally obtain an A(12) for their thesis work.

The use of project families requires the supervisor and laboratory leaders to plan ahead of the projects initiation, to secure the necessary allocation of staff, equipment and facilities. The concept reduce the resources required for basic supervision and laboratory support and allows the resources (from students, supervisors and technicians) to be used for deeper learning and creates a better project experiences for all involved.

The size of the project family should be between 6 and 10, as fewer leads to too little peer-interaction and little benefit and larger families tend to split into several subfamilies, who work independently of each other.

The project family concept is already being used in other research areas at the authors department (experiences from these areas will be collected and evaluated) and it is expected that it will in the future also be tested in project families, consisting entirely of theoretical projects with no experimental activities.

The concept will be further developed in cooperation with new projects students. The concept and its long-term effects will also be evaluated through interviews with former students, who has graduated less than five years ago, in order to evaluate how these additional competences have influenced their performance in the industry.

The concept is also expected to be used in classic courses, where experimental activities or results will be introduced in order to support an understanding and a critical evaluation of the students own predictions and to support an increased use of the experimental facilities.

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Interactive Web Apps for Visualizations in Engineering Education

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Conference Key Areas: Innovative Teaching and Learning Methods, Teaching Creativity & Innovation, Open and Online Engineering Education

Keywords: Visualization, Interactive Web App, Structural Mechanics, Python Bokeh

INTRODUCTION

One important part of an engineer's work is the description of the physical reality with mathematical models. This results in equations that have to be solved in order to predict the behaviour of a certain physical object. These mathematical models are a key part of today's engineering education. On the other hand, they are abstract and difficult to capture for many students, especially when the physical reality cannot be

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observed in daily live (e.g. when the calculated deflections of a bridge are very small and therefore not perceptible by humans). Therefore, visualization has always been a key issue in engineering education.

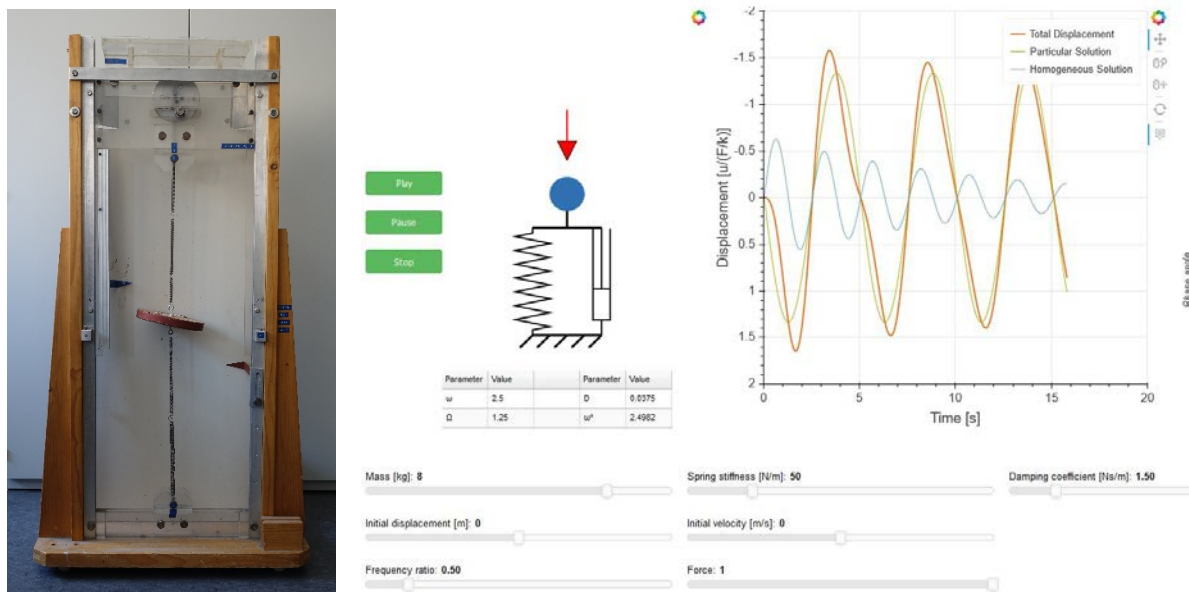


Fig. 1. Two concepts of visualizing the motion of a single-degree-of-freedom-system. The physical model on the left, the interactive web-application on the right.

At our institute this visualisation went through three historical steps:

1. Physical models (Fig.1, left) have been constructed before computers and digital projectors have been available in classrooms. The most important advantage of these models is the fact, that their behaviour shows the physical reality in a well perceptible and descriptive way, which results in a high credibility for the students. The drawbacks are their weight and dimensions, which limits the mobility on campus. Also the effort for assembly and disassembly before and after lecture can be quite high, which results in lower motivation for lecturers to use them. A small workshop for construction and maintenance of these modes at the institute is necessary. Moreover, the use of these models is limited to the lecture room. Students cannot experiment with them at home.
2. After the introduction of tablet computers, Java-based interactive applications, which had to be installed on each single lecturer's computer, have been developed and used for over one decade. Digitizing the models made the visualization more flexible and these interactive applications have been used more frequently. However, one drawback remains: The applications have not been available for the students at home, so they cannot be involved actively.
3. The last step will be presented in this paper. Fig. 1 also shows a web-based interactive application for the same purpose as the physical model in Fig. 1. It is accessible for anybody on the webpage <http://www.bm.bgu.tum.de/en/teaching/interactive-apps/>. Therefore, students can use them at home in the same manner as lecturers use them in classroom. They get actively involved in the visualization (principle three of the seven

principles in [1]). Moreover, computer applications provide – in contrast to physical models – almost unlimited possibilities of visualisation. In the shown example (Fig. 1, right), a time history plot of the deflection of the system is added.

Several studies [2-6] have shown the positive effects of interactive visualization in the learning process. Due to the fact, that programming work has to be done during development, such visualization applications have their origin in the computer science education, e.g. [3-4]. But they have also been used already in several other disciplines e.g. mechanical [5] or biomedical [6] engineering. The drawback of all cited work is, that the user always has to download either a browser plugin or has to download and execute an installation file. In some cases, students face rights restrictions in shared computers, e.g. in computer rooms at university. Moreover, these applications will not run on all operating systems (like Windows, iOS, Android, etc.) without modifications.

Up-to-date web browsers can directly execute feature-rich applications. No additional installations have to be carried out and the applications can be accessed from a smartphone, tablet, or personal computer regardless of the operating system. The initial hurdle for launching the applications is very low, which more likely leads to a frequent usage by the students.

In the following, we explain the used environment for the development of the applications and describe its capabilities using an example application. In addition, we describe methods for analysing the impact of the applications before we conclude with some lessons learnt during the development process and a summary.

1 DEVELOPMENT ENVIRONMENT FOR THE APPLICATIONS

As core element of our programming framework, we chose the open-source, Python-based library Bokeh. Bokeh is an interactive visualization library, that can be used to visualize very large or streaming data sets directly in the web browser. No additional software has to be installed by the client other than the standard web browser, so the applications can be viewed independently of the user's operating system on devices like laptops, tablets, or smartphones.

1.1 Interactivity features

The Bokeh library provides out of the box many essential components for building interactive apps, like sliders, buttons, text fields, drop-down menus, and various 2d plots, including line, bar, scatter, surface, or box plots to name but a few. Missing components can be developed with custom extensions. For example, JavaScript can be embedded using the package *NodeJS* to create a 3d plot like in Fig. 2 on the left.

One key feature of the Bokeh library is an automatic call-back, which updates the data source of the visualization periodically. For example, differential equations can be time-integrated numerically on the fly. The result for each time step can then be linked to the movement of an object.

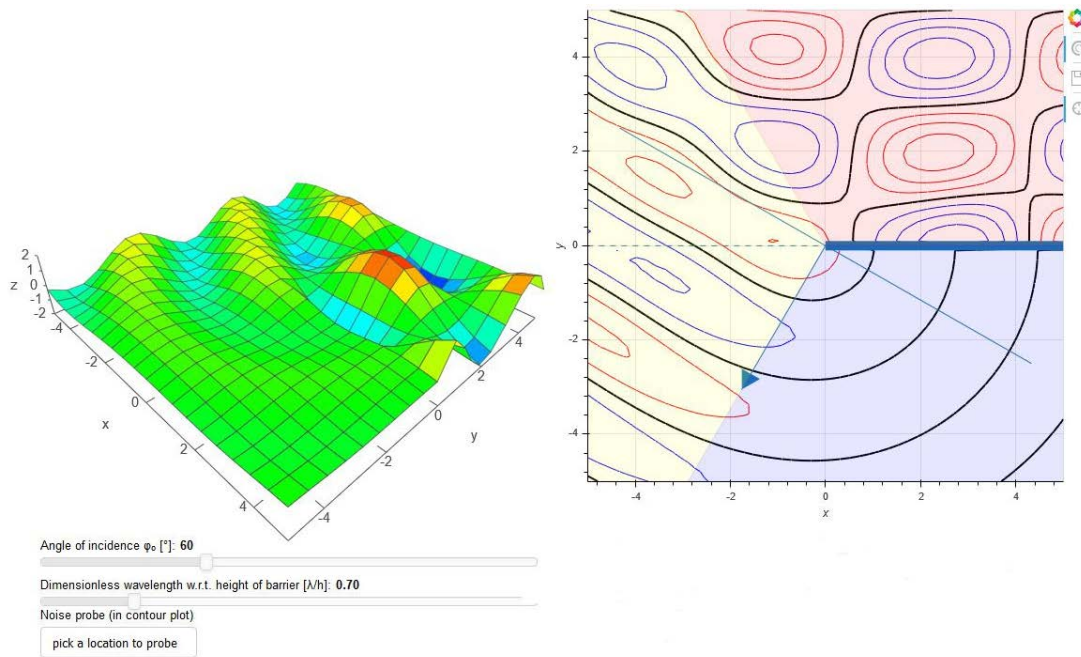


Fig. 2. Visualisation of the sound pressure field due to diffraction at a noise barrier. *Left:* 3d plot realized using an external library. *Right:* 2d contour plot included in Bokeh (The noise barrier is the blue bar; the thin blue arrow indicates the propagation direction of the undisturbed waves.)

1.2 Publishing the Apps

To make the applications available online, a webserver with a Bokeh installation is required. The translation from Python to HTML5, which the web browser needs to display the apps, is performed directly via the Bokeh framework and as soon as the server is up and running, the apps can be accessed.

It is advisable to add a description to each application, so the students can learn about the theory behind the shown phenomena. Using JavaScript extensions, LaTeX code can be used in the description, making it very easy to present even complicated mathematical formulae. A short summary over the features of the app, e.g. which parameters can be changed, is also important. The links to all apps are collected on a landing page on our institute's website, so they can be found easily.

In this App the response due to a harmonic load is visualized. The homogenous and particular solution as well as the total solution are plotted. One can visualize that the homogenous solution is important for the initial conditions and over time its influence tends to disappear according to the damping constant.

<http://www.bm.bgu.tum.de/lehre/interactive-apps/single-degree-of-freedom-system/>

Fig. 4. This example shows how a link to an application can be included into lecture notes together with a short description.

Additional to the online distribution, links to the apps can also be included in lecture notes (Fig.4). Many students work with tablet computers, so they can click on the link

shown in the respective chapter of the lecture notes and work directly with the app, when they are studying a certain topic.

1.3 App example

In the following example, we present an app visualizing the oscillation of a single-degree-of-freedom system in order to show, how the students can interact with the app and get to know the theory behind the oscillator. Fig. 3 shows a screenshot of the app.

The app is structured in three main parts: On the left, the system with its spring, damper, and mass is shown. Below, the system properties can be modified by the user. The graphs show the deflection of the system (in time domain in the middle, in frequency domain with amplitude and phase on the right.). All presented elements are interactive. The system is animated and the plot in the middle is drawn in real time. Clicking on the buttons on the left starts, pauses, or stops the animation. Using the sliders on the bottom, all system properties like spring stiffness, damping ratio, or load-frequency ratio can be modified. All changes here have an immediate effect on the response of the system. One can observe for example that a shift of the frequency ratio to one (to the natural frequency of the system) will immediately increase the response of the system.

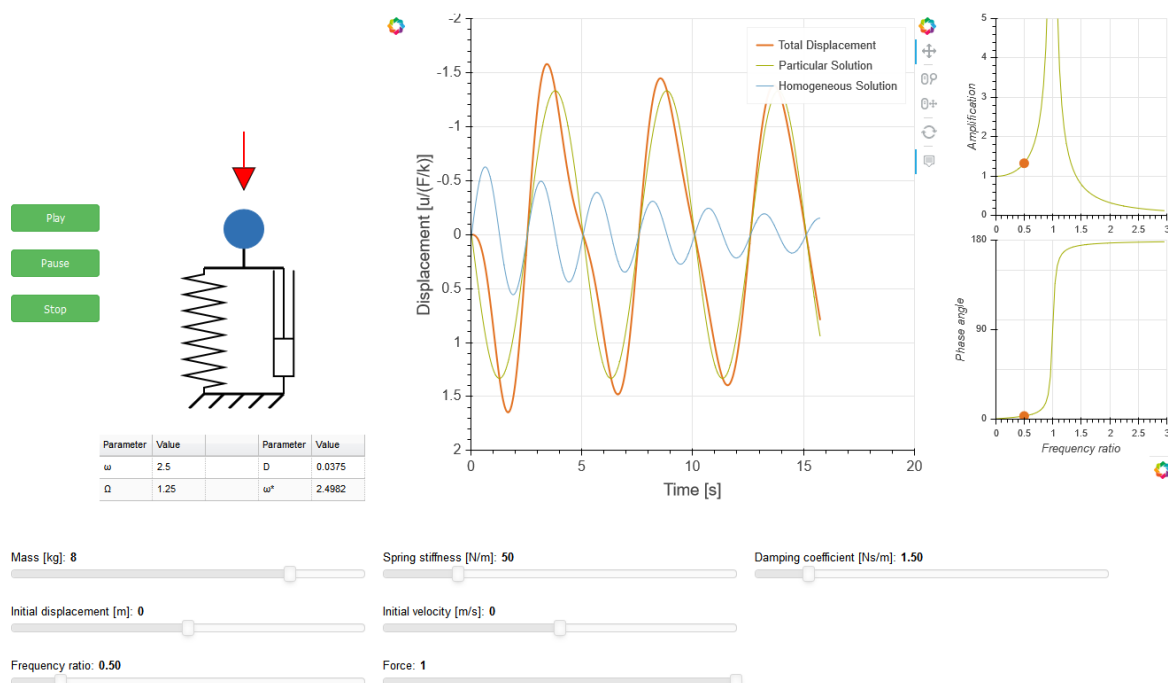


Fig. 3. An interactive web-app showing the behaviour of a single-degree-of-freedom system.

The app can be used during the lecture, where interesting phenomena can be shown to the students, or the students have to find parameters in order to make a certain system response visible.

1.4 Apps available so far

Up to now, we have published several applications in the field of structural mechanics and acoustics. The apps are available on the homepage of our institute

(<http://www.bm.bgu.tum.de/en/teaching/interactive-apps/>) and can be viewed and accessed by everyone. They cover the following topics:

Vector Addition	Column Buckling	Maxwell's Reciprocity
Diffraction of Sound Waves at Noise Barriers	Vibroacoustics of Plates	Discrete Fourier Transformation
Collision	Coriolis Force	Conservation of Momentum
Damped Oscillator – Free Vibration	Damped Oscillator – Forced Vibration	Pendulum (Single and Double)
Rectilinear motion	Response Spectrum Analysis (Earthquake Engineering)	Vectorial Translation

The source code of all applications is freely available on GitHub: https://github.com/ChairOfStructuralMechanicsTUM/Mechanics_Apps. A readme file with more technical details can be found there. This file shall help to reduce the initial hurdle for starting the development of own interactive web apps in the proposed environment.

2 METHODS USED FOR EVALUATION OF THE APPLICATIONS

2.1 Web Analytics

The webpage of our institute with the interactive visualization applications is continuously tracked by the web analytics tool Matomo². The following data delivered by the tool will be analysed:

- Frequency of usage of the individual applications
- Origin of the visits (country, state, town)
- Time spent using the applications

The number of visits from the town of our university can be filtered and divided by the number of students participating at our exams. This will give an impression about how often a student has used in average the applications at home.

2.2 Ordinal 5-point Likert Scale

A questionnaire will be distributed to the students at the end of the current lecture period. The following items shall be rated on an ordinal 5-point Likert scale:

- How often did you use the applications during the semester?
- Could you access the applications easily? / Did they run without problems on your computer?
- Have you been satisfied with the explanations to the applications?
- Could you control the applications intuitively?
- Did the applications allow you a better grasp of the lecture content?
- Do you expect, that you are prepared better for the examination due to the usage of the applications?

² <https://matomo.org>

Additionally, the students may leave a comment and name their favourite application.

3 FINDINGS

The applications are used for the first time during the summer semester 2018. Therefore, the evaluation and the findings based on the methods described in the previous section will be available starting from August 2018. These findings will be presented on the conference in September 2018. However, the reactions of the students after the first lectures in the current semester have been promising, some have already asked whether they can join the team of developers. In the following, we focus on some lessons learnt during the development of the applications.

4 LESSONS LEARNT

A significant programming workload is involved in the development of the interactive apps. This work has been carried out mainly by students, employed through public resources intended for improvement and digitalization in university education. The recruited students have been enrolled e.g. at the informatics department or at our faculty, in programs related to computation (e.g. Computational Mechanics or Civil Engineering with focus on computational methods). Therefore, the students have been in general keen on coding and showed a lot of creativity. They quickly familiarized with the programming environment of Python and Bokeh. On the other hand, perfectionism and endurance for consequent debugging has not been always guaranteed. Therefore, the effort for academic staff for supervising and finishing the programming work has been higher than expected. The active use of the apps in classrooms is expected to lead to improvements of interactivity and bug-findings. The latter aspect may also have a teaching function, where students can learn from errors when observing and reporting unexpected behaviours of an application.

Maintenance of the applications has to be guaranteed for the complete intended period of usage (hopefully more than one decade). The Bokeh library gets continuously improved. Therefore, objects and functions can change their input/output instructions from time to time and the interactive applications must be adapted to the technical progress.

Almost unlimited visualization methods are possible in the proposed environment, as described in 1.1. This should not prevent a developer from keeping the application simple. Students will not use an application, if it takes them too long to understand what they are expected to do with the application. Moreover, the applications shall motivate the students to play around. Therefore, immediate interaction – without reading of instructions – is important. Schweitzer and Brown [3] have already described, how important the mouse-driven interaction (e.g. with sliders and buttons) is. The developer should prevent the user from using the keyboard.

5 SUMMARY

We have proposed a development environment for interactive web-based visualization applications in engineering education. The applications are accessible from everywhere in the internet with an ordinary browser. The users do not need to perform installations on their devices. Some effort has to be put in development and maintenance, but this is in nature of things. The involvement of students in the developing process has led to several running apps and to a positive experience but

is not always a surefire success in terms of stability of the algorithms and programming optimisation. A significant effort of the academic supervisors is always necessary.

Experiences about the frequency of usage and opinions of users will be available within the next months. They will be presented on the conference.

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Summer Studios – Lessons from a ‘small bet’ in student-led learning

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Conference Key Areas: Innovation as the context for EE; Engineering Skills

Keywords: curriculum change, studios, PBL, design thinking

1 INTRODUCTION

Summer Studios developed out of our MIDAS strategy to create the next generation engineering and IT programs at UTS, using a sequence of studios in every program [REFs to be added after review]. MIDAS (More Innovative Design-Able Students) is a response to industry demands for graduates who are able to respond more innovatively to the challenges in our world. This builds on earlier studio implementations at UTS [1-3].

The 2016 national Quality Indicators for Learning and Teaching [4] also highlighted the need for summer offerings; it was decided to test our studio concept across a range of

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disciplines. Summer Studios were born. The Associate Dean for Teaching and Learning's vision was that: "students will be transformed by the summer studio experience and will want that learning to continue all year long". This intention came to fruition, as demonstrated by the data.

Much of the background to this studio experiment is published elsewhere [REFs]. The purpose of this paper is to map out what we think have been innovative approaches with quite a large group of students split across many topics. A key issue was taking the teaching staff through a mindset shift and this is an on-going process.

There are important lessons here for others who are rolling out project-based learning classes in response to industry demands for graduates who are ready for a rapidly changing working world.

2 LEARNING INTENT

Summer Studios were designed to be a generic framework for design-oriented activities as follows, drawing upon long experience in project-based learning [5-11]:

Summer studios are designed to be high energy, high collaboration, project-based subjects where students can engage in real-world design challenges. The studios enable students to negotiate the ways in which they will demonstrate achievement of professional skills whilst working on real-world projects. Facilitated by a mixture of academic experts, industry and community partners, students work in teams to define problems and develop and implement projects.

Using a design thinking framework, students regularly engage in pitching and critiquing work amongst peers. Assessment is pass/fail and comprises a mixture of reflective writing and portfolio compilation and defence.

The subject learning outcomes were modelled on FEIT's graduate attributes [12] – define the requirements, use a systematic design process, apply modelling skills, collaborate and communicate, and manage oneself:

1. *Engage with stakeholders to identify a problem*
2. *Apply design thinking to respond to a defined or newly identified problem*
3. *Apply technical skills to develop, model and/or evaluate a design*
4. *Demonstrate effective collaboration and communication skills*
5. *Conduct critical self and peer review and performance evaluation*

2.1 Student Response

18 teams of academics volunteered to conduct a studio in a range of topic areas (Figure 1). Four of the topics were proposed by students and three of them were ultimately led by students, with academic assistance.

168 students subsequently enrolled and completed (20% women and 16% international), across 13 final topic areas. (5 topics did not attract enough enrolments.)

2.2 Facilitator Training

Thirteen studio leaders and 21 tutors attended four facilitator training workshops:

Workshop 1 – The focus was on transformative experience and how to facilitate beauty in subjects. Three powerful ideas: We learn better by experiencing things; We learn better when we connect new experiences to our past experiences; The experience of art can produce profound shifts in perspective; How might you notice or inject beauty in your studio? This workshop was run by Dave Goldberg as part of his on-going engagement with our team [13].

Workshop 2 – What does success look like in a summer studio? 3 big ideas: The importance of NLQ – Noticing, Listening, Questioning (and the power of ‘what’ questions); What is the ‘sticky story’ of your studio? (Why might a student give up their summer to do it?) Defining studios. What are they? What are they not?

Workshop 3 – Logistics of the Subject – Matters of Assessment. 3 big ideas: Being clear about subject learning objectives (SLOs); Understanding the portfolio assessment – how will the SLOs be expressed in your studio? Backward mapping – What will students be doing in Week 6...5...4...etc?

Workshop 4 – Timing & Mapping out sessions: Structure learning sessions around design thinking stages as inspiration; Facilitation from very structured to a large single project with guidance; Documenting the interplay between knowledge and skill acquisition and engagement through the project.

The common thread throughout the workshops was to offer practical language and steps to unleash a behaviour where it was safe for the studio leader not to know everything about the project. Students would need to be active learners.

Design thinking was the key concept uniting all the studios – empathise with the stakeholders, define the problem, explore solutions, prototype, and test. Other key ideas included continuous, constructive feedback using the language of conversations-in-action, NLQ (noticing, listening, questioning).

1. Activating the Smart City
2. Humanitarian Engineering
3. Challenges and Opportunities of Landfill Design and Reusing closed Landfills
4. Data Science
5. Deep neural networks learning for AI
6. Quantum Computing by Example
7. Brain Computer Interface
8. Control and Automation studio
9. IOT Project using Python
10. DIY medical diagnostic device
11. Robotics rehabilitation studio
12. Vivid 2018 – designing a light display for a festival
13. 3D Printing and Assistive Technology
14. Global Aerospace Challenge
15. Numerical solutions for problems in Structural Engineering
16. Innovation & Entrepreneurship
17. Genome sequencing
18. Natural Language Processing

Figure 1 - Studio topics

There's a new language around design that academics need to acquire to complement the technical knowledge. This impacted the first 2 weeks in particular, where students felt a bit rudderless, not knowing quite what they needed to be doing to understand the problem they had been set.

3 KEY LEARNING ACTIVITIES

The summer studios were run intensively, from 22 January to 1 March, with 3-hour workshop sessions on Monday and Thursday afternoons, and informal, group-oriented work in the mornings of those days.

The first Monday was an all-day launch activity, including a design thinking workshop conducted by our University Innovation Fellows (UIFs).



Figure 2 - Students engaged in design thinking on day 1

3.1 Sprints, Mixes and Scrums

The 6-week period was divided into three, two-week sprints: (i) explore the problem, (ii) explore the solutions, and (iii) develop and test a prototype solution.

Each week, students also met for one hour in a Studio Mix. The entire cohort was mixed across studio boundaries and grouped into 6 classrooms where students had a chance to reflect on their own performance with the assistance of students from other studios.

Students were initially apprehensive about working in the studios with a “mixed bag” of students of different ages, degree majors as well as overall background. Their only prior experience was working in ‘groups’ to complete an assignment in a traditional class. After the studio learning experience, students asked for more opportunities during the year, to integrate with others in pursuit of a common goal because they realised that the ‘differences within a group allowed us to bring more to our diverse skill sets to complete a project at a higher degree’.

The Design Thinking approach was a new concept for most students because they realised they had always tried (and been trained) to think of a single, perfect solution when completing coursework; however, they were challenged ‘to gather information and study the real causes of the problem [which] helps solve it in a more appropriate way’.

Bringing in this approach to class projects is overwhelmingly promoted by this cohort of students. ‘Small teams working together is very powerful and we can be inspired by other people’s creativity’. One student put it very neatly: “Being in a creative environment that promotes and nurtures [a] design thinking framework has led to an increase in creativity in other parts of my life: creativity breeds creativity.”

Students also want the delivery mode of ‘traditional’ subjects to include the *narrative* of how the technical knowledge will help in future engineering subjects as well as future jobs. Students said ‘being able to get a good contextual background of the capabilities and higher level structure of the topic enabled them to find a wide range of resources to investigate and thus find their own path to become proficient at an otherwise very technical and difficult-to-understand area’. They want lecturers to invite industry speakers as guests into the teaching space because ‘that helps to improve thinking and change strategies to get a solution.’

Each week, staff also met in a Studio Scrum, to debrief what was working and not working and what needed to improve. Data were collected every week from staff and

students at the Mixes and Scrums and used as feedback in the next classes through iterative conversations.

The final day included both formal presentations within each studio as well as an Expo of all student work on the final afternoon.

4 STUDENT FEEDBACK

The following statements from the Student Feedback Survey summarise some of the key student reactions:

*The subject provided whole new unique perspective to **collaborate** and come up with a solution, which really helped me a lot to step outside my comfort zone and just have a go at it. The range of tutorials and the work everyone has put out was outstanding. I would really encourage students to undertake this subject.*

*Open ended scope, **freedom and creativity**. I liked how I had freedom to learn using my own practical experiences instead of a regimented assessment schedule.*

*[Specific studio leaders] should both be commended on their teaching and mentoring styles. They were very **approachable and always eager** to steer us in the right direction whenever we encountered difficulty.*

*This is the **standard** that should be set for all the engineering faculty's teaching staff. ... we [will] have ... better learners and ultimately top-class engineers.*

*I really enjoyed the opportunity to work as a **multidisciplinary** team on a large problem.*

*[Specific studio leaders] made the processes of learning really **fun and effective**. Both offered really inspiring ways to enhance my learning. I found the subject rewarding as it enabled me to work with a stakeholder in Nepal and to help communities to improve crop production on their farms.*

*The humanitarian studio gave me a lot of opportunities to develop my **innovation and human centred design** thinking as well as expand my network.*

5 STAFF REFLECTIONS

For most of the academics involved in summer studios, this was the first time that they had conducted a project-oriented class where there were no prerequisites and where there was a mixture of students from different disciplines and different years, which meant quite a range of background knowledge in each studio cohort.

5.1 About students

There were mostly positive comments about the students' engagement in the projects:

- The students were seen to be highly motivated and open to new ways of thinking
- They were interested in the learning materials and transformed their knowledge
- They mastered practical problems and enjoyed the hands-on experiences.
- They asked many questions (most of the time) though some students became quite frustrated in a couple of studios where they felt they were overwhelmed by new concepts. We hypothesised that many students are not used to asking questions in class.
- Students grew in confidence, excitement and courage.

5.2 The teaching and learning process

Many aspects of project-based learning were identified:

- There was a steep learning curve in most studios at the beginning
- Design thinking was key in most of the studios, but this needs greater emphasis. A basic introduction to systems engineering [14] could be helpful.
- Many student groups developed genuine collaboration and group identity through solving the complex problems. They became supportive of each other and made decisions for the benefit of the group.
- Some students were reluctant to explore alternative solutions, tending to fixate on their first idea.

There were some negative aspects:

- In some studios there was a big learning step to get started. However, proper scaffolding of the early stages of the design process is also essential.
- Need a shift in mindset so that students don't see that the first and last weeks as a waste of time.
- The student Mix sessions were not well liked by all students.

5.3 Assessment

The portfolio form of assessment was not well understood by students and some studio leaders. The intention was that students would add to their portfolio each week, including evidence of attainment of each of the learning outcomes as they emerged through the design thinking process.

Next time, we will require a formal technical report as part of the portfolio, to address LO3. This would ensure that the students would properly document the technical issues.

Portfolios are a measure of progress. Most academics need training in understanding assessment as a measure of growth as opposed to evaluation. Assessment should be formative using constructive feedback and not just summative with grading.

5.4 Facilitators

The workshop sessions run in the months prior to the commencement of the summer studios were described earlier. Despite the workshops, some studio leaders seemed unprepared for some of the challenges, particularly the need to help students get started from their existing knowledge base.

Four of the 13 studios had significant involvement by students as facilitators. The space, humanitarian and Vivid studios were effectively led by senior students, with academics providing overall coordination. The smart cities studio was initiated by a senior student who then provided the industry partner for the project as well as some student facilitation in the sessions. The student-led studios had very high levels of engagement and satisfaction.

5.5 Outcomes

At the end of the 6-week session, we asked our studio leaders what they should stop and start with their normal teaching, based on their summer studio experience. They said they wanted to "stop strictly following the topics in a syllabus while putting more effort into integration with other subjects and other disciplines; stop giving too much structure; stop lecturing and start facilitating."

Other things leaders wanted to 'start' were "more curiosity; multidisciplinary learning opportunities; collaborate with peers more; give students more independent work such

as projects; start giving students more structure around design thinking and systems engineering; start getting engineers to communicate better; start co-designing studios with students and academics.”

Overall, it was clear that the studio leaders favour providing students with a *transformative learning experience*. They realised that not every subject must teach students to master the fundamentals before they have the chance to solve real problems in that area. Why wait? They observed that students have the ‘capability to master a practical problem from their perspective in terms of the fundamental, the hands-on, the research and development, while contributing as an individual member to a collective project’: “Observing this capability and the pleasant feelings from the students in their acquisition of knowledge through studio learning remains the best and unique reward for me as an educator.”

Academics want their peers to know there is power in motivating students to learn by engaging industry and together make the *compelling why* of the subject *more obvious*. Studios enable students to “think differently” and all students should be given the time to grapple with a real-world problem in diverse teams.

Therefore, Studio leaders want the same things for students as the students want for each other. That is, to engage students in assessment tasks where students can work in small teams and develop skills in innovation, entrepreneurship and creativity. They believe in promoting both technical rational **and** design thinking skills. They want more emphasis on providing students with real world problems that are industry connected into their daily studies. Studio leaders want students to work within a multidisciplinary environment where they can appreciate other points of view.

6 DISCUSSION

6.1 Highlights

The Expo on the last afternoon demonstrated student delight at what they had achieved. Many students made more progress than they expected.

Consider the story of Nisha, a second-year student who enrolled into the Robotics Rehabilitation Studio. During the Final Presentation, Nisha presented her artefact, a physiotherapy application where the rehabilitation patient moves their fingers in the air to play a virtual piano keyboard projected on a screen. Nisha enrolled with Word as her only computing skill. Her leaders almost turned her away, but her enthusiasm won them over. She learnt programming skills to create her healing device and is so thrilled by her efforts that she entered her work into a competition and won! She is now going to the Virginia Tech Global Challenge in August 2018.

Facilitators now realise how important it is to know where students are at in terms of their existing understanding and to lead the discussion from there. The structural engineering studio was a good example of helping students to progress quickly from a basic understanding of structures to perform complex vibration analysis of a building under wind load.

The four studios initiated and led by senior students were among the most successful studios with high degrees of energy, purpose and outcomes.

6.2 Insights

Better scaffolding was required in several studios where there was a significant amount of learning of new concepts, e.g. in data science and in machine learning. Students need a more structured approach to new ideas.

Similarly, students needed support in understanding the design process, particularly in the first two weeks. This will be supported by additional workshop training next time for facilitators and also for students.

We also need other summer subjects, where a subject can be learned, and taught, in a less constrained way than our normal teaching. The Structural Engineering Studio took this approach, adapting to students' prior knowledge rather than being fixated on a particular set of content.

Students discovered real teamwork and collaboration – not the divide-and-conquer teamwork that often occurs in some projects. Students reported genuinely working together to understand difficult concepts.

6.3 Pleasing outcomes

Several studio participants, both students and staff, wanted to continue the studio activity into the Autumn semester. We are now planning to enable that and also to have a fresh round of studios in Spring and Summer 2019. This feeds nicely into the MIDAS project, where the vision is cross-disciplinary studios in all programs.

6.4 Final comments

Our first aspiration for Summer Studios was to create a community of practice. We believe we are entering the very first stages of cultural change to achieve curriculum renewal. We all know that it takes much longer than one long hot Aussie summer to change teaching and learning practices. Nonetheless, in a small way, we have introduced new *language* into the Faculty through the Summer Studio experience.

Moreover, we know the quickest way to change a system or build a new system is to use this new language. The new language encourages academics to embrace this idea of active learning, turning up authentically, and working together to try to improve something. Once we use *sticky* language to tell a new story and be prepared to change the story as people react to it, we teach people that it is okay to bring about change.

People will have their own stories. In every case, the new language will be rehearsed and communicated repeatedly. This process creates transparency, that we are working on things together to make things better, and that we are listening to students. There is a partnership.

Our second aspiration is to create a Studio where academics can enrol and get the 'experience of the experience' while training how to be an effective studio facilitator. Our focus for next time will be in developing strong facilitation skills around the design process.

Summer Studio was a little bet and a significant undertaking. There were upsides and downsides to report. Each studio was an opportunity for innovation and a source of lessons learned.

The biggest learning outcome is that Studio Leaders need to be better trained and certified. Once they themselves qualify as a Studio Leader, they earn the opportunity to run a studio in Summer 2019. We might frame the chosen as an elite team of advanced facilitators of the future. They will design and facilitate the learning experiences of the future.

We have experienced enough good outcomes to know that MIDAS is on the right track.

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Developing “Architecture and Systems Engineering” Program: An MIT, Boeing, and NASA Collaboration

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Conference Key Areas: University-Business cooperation, Continuing Engineering Education and Lifelong Learning, Open and Online Engineering Education

Keywords: systems engineering, professional development, online education

INTRODUCTION

As global STEM related organizations try to redefine and reform the highly demanding space of workplace education within the digital era, learning and development (L&D) professionals face challenges such as building employee expertise, enhancing skill development, driving meaningful business results, and aligning training programs with organizations' strategic imperatives. “Nearly all experts agree that machine learning, AI, and workplace automation following developments in these fields will replace many jobs worldwide. But estimates of the risk posed by automation have varied considerably.”[1] According to the latest working paper on “Automation, skills and

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training”[2] released by the Organisation for Economic Co-operation and Development (OECD) almost 50% of the jobs discussed in the paper are expected to be “significantly affected by automation”, while among them 14% are facing high risk, 32% medium risk, and 26% low risk [1,2]. Vis-à-vis all upcoming changes, employees also seek to augment their professional skills, advance their formal education, and grow their careers. All of these challenges need to be addressed in a timely, scalable, and cost-effective manner; and many universities have already started exploring the university-business cooperation model as one more possible path towards catering to future L&D needs [3].

Within this framework MIT xPRO, a group within Massachusetts Institute of Technology (MIT), was launched to address these corporate learning needs by collaborating with industry partners in order to develop and deliver online and blended programs targeted to professional learners seeking to expand their knowledge and build their skills.

1 THE PROGRAM

In 2015 MIT xPRO partnered with Boeing and NASA to develop “Architecture and Systems Engineering: Models and Methods to Manage Complex Systems” [4]—a four-course online program leading to a professional certificate from MIT.

The program blends academic theory with industry case studies to help systems engineers design, manage, and optimize complex systems. Throughout the program, students are presented with the latest practices in systems engineering—including how models can enhance system engineering functions and how systems engineering tasks can be augmented with quantitative analysis—and they explore those practices in the context of organizations applying them today. By the end of the program, students are expected to be able to frame systems architecture as a series of decisions, which can be actively sorted, managed, and improved to suit their organization’s needs.

The program is targeted to engineering professionals, directors, and senior managers across a number of industries—aerospace, automotive, medical devices, consumer products, nuclear power, etc.—who are working on the design, architecture, and engineering of complex, cyber physical systems and want to innovate in and optimize their systems.

Currently two instances of the program are offered—a private instance for Boeing and NASA employees, and a public instance available for open enrollment. Students in either instance have the flexibility of taking individual courses (each 4 weeks in duration), or pursuing the professional certificate (4 courses, 17 weeks in duration).

2 COURSES

2.1 Course one: Architecture of Complex Systems

As systems continue to grow in scale and complexity, understanding and managing system complexity is a critical challenge engineers have to face regularly. Course One is designed to help engineers address changes which induce, propagate, and amplify risk in the increasingly complex products and services they are required to develop. In this course, students get a solid grounding in complex systems, analysis of complex systems, and complexity management. [4]

By the end of the course, students should be able to: [4]

- Define a system and articulate examples of things that are and are not systems. Apply system thinking to provide perspective on a given project.
- Define and illustrate the system boundary and use it to identify system interfaces.
- Provide constructive criticism on the system architecture representations of others, including checking for completeness and consistency.
- Articulate more solution-neutral and less solution-neutral framings of a problem, and evaluate how solution-neutral to be for a given problem.
- Construct a Design Structure Matrix (DSM), either by analyzing the design or by converting a graph of the system. Construct a process DSM and identify how it is different from a design DSM.
- Describe rework and articulate the principles by which an analysis of change propagation could be conducted from a database of changes.
- Define the deliverables of the architect, with references to architectural frameworks and their career examples.

Industry examples are drawn from: Boeing, NASA, General Motors, Man Truck and Bus AG, Apple, General Electric, and U.S. Air Force.

2.2 Course two: Models in Engineering

Engineering practice is full of models—from equations to prototypes to simulations. In this course, students are expected to gain a comprehensive understanding of practical and conceptual modeling considerations so they can make more effective decisions supported by modeling analysis. [4]

By the end of the course, students should be able to: [4]

- Explain what types of models exist in engineering and how they can be organized into an overall taxonomy.
- Enumerate the purposes for which models are created in engineering and evaluate the success of modeling for those purposes against their own career experience.

- Evaluate the credibility and fidelity of existing models using a set of clear criteria.
- Evaluate and explain whether it is better to pursue a single model or an ensemble of models in support of a specific problem/decision. This includes the resolution of conflicts when multiple models provide contradictory results.
- Understand the basic principles of verifying and validating models.
- Examine the tradeoffs between the use of physical and virtual prototypes for system verification, validation, and testing. Decide when to invest in additional modeling versus additional physical testing of systems.
- The content deeply engages learners and maximizes learner outcome via videos, readings, discussions, individual and team projects, ungraded and graded problems, peer review, and self-assessment.

Industry examples are drawn from: Boeing, NASA, DSO National Laboratories Singapore, DfR Solutions, General Motors, and General Electric.

2.3 Course three: Model-Based Systems Engineering

This course introduces students to the intent, representations, and functions of Model-Based Systems Engineering (MBSE). Students are expected to create MBSE representations of a system and to articulate the purpose of the representations. From this foundation of MBSE, the course transitions to a discussion of the management challenges of MBSE – model repositories, model curation, and model integration. Students analyze best practices of MBSE in industry through case studies, which enable them to develop judgment about what functions are possible to accomplish with MBSE. [4]

By the end of the course, students should be able to: [4]

- Distinguish the differences between MBSE and traditional systems engineering.
- Describe the intent and basic structure of SysML and interpret a simple SysML model.
- Critique a project's implementation of MBSE using a set of criteria.
- Build a model management plan.
- Reference existing industry examples of MBSE to anchor choices about the scope of MBSE to undertake, and communicate potential approaches using industry examples as signposts.

Industry examples are drawn from: Boeing, NASA, Jet Propulsion Lab, PTC, IBM, U.S. Air Force, MITRE Corporation, MAN Truck and Bus AG, Uber, and General Motors.

2.4 Course four: Quantitative Methods in Systems Engineering

Organizations around the world strive to use quantitative information methods in their systems engineering practices, but many struggle to implement them effectively. This course covers the fundamentals of quantitative methods in systems engineering and provides basic how-to instruction for implementing these methods. [4]

By the end of the course, students should be able to: [4]

- Evaluate concept alternatives in order to recommend a preferred alternative.
- Structure a trade study.
- Identify the multiple key cost and benefit criteria that frame a system decision opportunity.
- Construct a value hierarchy for a stakeholder/beneficiary/decision-maker to inform system design decisions.
- Articulate the core concepts of value-based thinking.
- Choose the relevant axes and representations for a tradespace.
- Interpret the results of a tradespace.
- Identify the fuzzy Pareto front in a tradespace.
- Perform a sensitivity analysis.
- Critique a decision analysis model by identifying sources of uncertainty and variation.

Industry examples are drawn from: Boeing, NASA, Penn State, and General Motors.

3 LEARNING DESIGN

MIT's motto "Mens et Manus", in English translates as "mind and hand", and has always been the driving teaching approach within the MIT campus and beyond [5]. The goal of this online program (and all MIT xPRO offerings for the corporate market) is to bridge the "knowing-doing gap," connect theory to practice, and make the materials skill oriented and application focused.

The following pedagogical strategies are blended to best achieve the learning objectives of the program and individual courses.

- Instructivism (captured by the LEARN column in *Fig. 1*): Teacher-centered learning where the instructor defines the learning goals and presents relevant content, including mandatory readings. Examples in the program include:
 - Tutorial videos enhanced with animations and graphics
 - Text-based pages with supplementary pictures, charts, exhibits and illustrations
 - Assigned chapter readings from assigned textbook
- Constructivism (captured by the APPLY and PRACTICE columns in *Fig. 1*): Learning-by-doing approach that encourages learners to "construct" their own

understandings through the act of creating. Ideally learners create an artifact that a real-world practitioner would create. Examples in the program include:

- Project-based work
- Graded and ungraded practice activities
- Anchored Instruction (captured by the LEARN and APPLY columns in *Fig. 1*): A learning experience is “anchored” in a central narrative such as a case study or piece of media. Learners see new knowledge or skills applied in context. At regular intervals, learners utilize the knowledge or skills outlined in the anchor in various parallel contexts enabling them to cognitively situate instructivist content within the central narrative. Examples in the program include:
 - Case studies
 - Project-based work
- Connectivism (captured by the CONNECT column in *Fig. 1*): Learning through others. Social interaction emphasizes the cycle of sharing and consuming information as a member of a social learning network as a means of refining mental models and forming interdisciplinary connections. Learners are encouraged to make connections and identify patterns between knowledge nodes through their interactions with their peers. They are also encouraged to seek answers to questions from the community, with course staff supporting these interactions. Examples in the program include:
 - Discussion forum collaborations
 - Project-based work collaboration
 - Polls and word clouds with real-time results

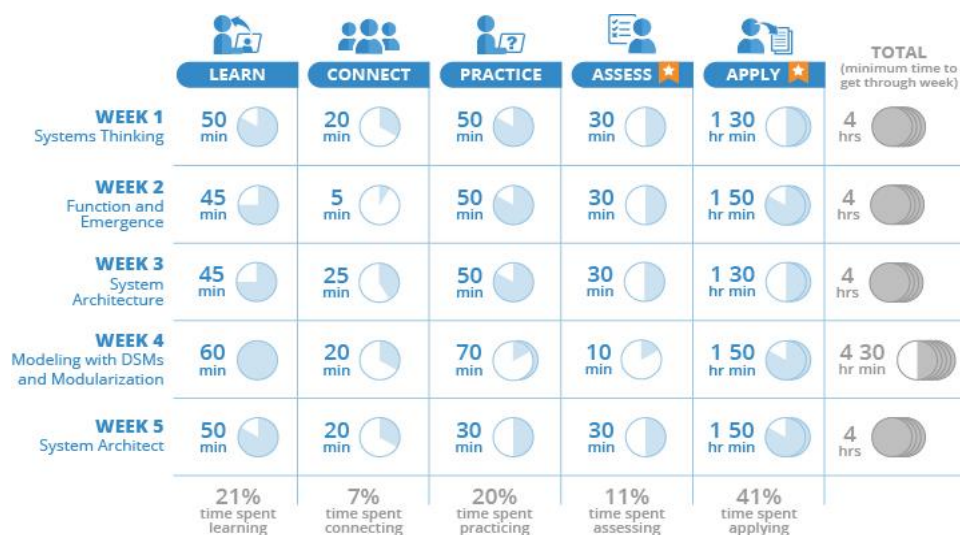


Fig. 1. Program developer estimates, regarding how students are expected spend their time across the different content areas of course one, Architecture of Complex Systems.

4 PROGRAM DEVELOPMENT

MIT, Boeing, and NASA collaborated for one year to develop this program. The first step was for MIT to develop a high level outline of the proposed curriculum accompanied by design suggestions in regards to how the content would be delivered in an online medium. The outline then was reviewed by Boeing and NASA stakeholders for feedback and design input. After several iterations, the three partners came to an agreement regarding the curriculum and the project moved into production mode. Regular check-in meetings were held throughout the year and prototyping, alpha, and beta testing phases were conducted.

5 CURRENT STATE AND FUTURE WORK

The “Architecture and Systems Engineering” program has already been offered 4 times, and to date the program has been completed by over 4,500 students (2,500 Boeing/NASA students, 2,000 open enrollment student. The fifth program run will take place in September 2018. As the program gains traction and recognition, we see an increase in the number of companies enrolling large groups of employees (50-100), while some are requesting private site licenses of the content to deploy across their organizations.

The “Architecture and Systems Engineering” program was a very positive and rewarding experience for MIT, Boeing, and NASA. Key ingredients for success include: having a shared vision of the partnership opportunity, the ability to identify talent and leaders on all sides who were capable of crossing boundaries between academia and industry, strong communication, clear intellectual property goals, and a commitment to investing in each other over the long-term. Furthermore, the “Architecture and Systems Engineering” program has so far been a positive indicator that application-focused, skill-based instruction for workplace learning could take place effectively online. It also supports the initial idea that the academic/industry educational model can be achieved in a scalable and cost-effective manner, although of course a lot of space for improvement still exists. Moreover, MIT has found that this particular model is repeatable.

According to our experience to date the opportunity space for academic/industry partnerships is enormous and offers a new, compelling model for workplace learning. As the space is still new and unexplored, a lot of work remains to be done in order to finalize and suggest a state of the art course and program model. However, our positive findings so far have kept all partners motivated and encouraged to keep exploring this path. Along these lines MIT and Boeing have already partnered on two more programs—one on Additive Manufacturing and another on Engineering Leadership. MIT has also partnered with IBM to develop a 4-course program on Quantum Computing.

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A study of teachers' reflections on teaching and learning

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Keywords: Teaching philosophy, good teaching, teaching and learning, gamification

INTRODUCTION

According to Schön [1] professional knowledge is to a high degree based on tacit knowledge. For university teachers, tacit knowledge includes knowledge about what works – and what does not work - when teaching a specific class of students a specific subject in a specific context. However, it is important to make tacit knowledge explicit for at least two reasons: Firstly, for the individual teacher it may support a more conscious linking of observations and experiences from own teaching practice to general principles of teaching and learning. This linking could enable a systematic analysis and development of own teaching in order to improve student learning [2]. Secondly, it is also beneficial to make one's tacit knowledge explicit in order to discuss teaching and learning with other persons, e.g. during peer coaching of less experienced colleagues, or collaboration on teaching development with colleagues. This unfortunately seldom takes place and leaves teachers in a limbo of solidarity. Therefore, the authors have developed a board game for university teachers to articulate and share their reflections on teaching and learning in a collective process. The game consists of a board and a deck of cards, where each card contains a

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statement related to teaching and/or learning. The purposes of the game are to support a team-oriented approach to teaching and thereby to strengthen communities of teaching practices [3], i.e. to develop groups of colleagues, who acknowledge the individual team members' different ways of teaching and how a manifold of teaching practices fertilises the students' building of skills, competences and attitudes towards becoming professional engineers.

The game has been played at two international engineering education conferences, at an annual education day at a university abroad, and at several faculty meetings at the authors' university. Data have been collected on the selection and ranking of cards. These represent the players' reflections on teaching practices and learning, and on consensus reached within groups of players – reflections which influence and are influenced by teaching practice. This paper documents an explorative study of the players' reflections on teaching and learning based on the selected and ranked cards. In this first study the data has been analysed focusing on the following two questions: What kinds of attitudes towards teaching and learning do the selected cards represent? And which cards are selected most often?

1 RELATED WORK

A well-known means for the individual teacher to make tacit knowledge regarding teaching and learning explicit and to develop a reflective approach towards teaching is to create a teaching portfolio [4]. A teaching portfolio typically consists of a statement of philosophy of teaching, elaborated examples of teaching practices, and a list of completed courses in university teaching and pedagogy [5]. For many university teachers it is not straightforward to write a statement on their philosophy of teaching. Chism [6] writes, *“For action-oriented individuals, the request to write down one’s philosophy is not only mildly irritating, but causes some anxiety about where to begin.”*, and Chism proposes among others dialogue with colleagues to help stimulate ideas for formulating one’s own statement. One way to facilitate a constructive and equal dialogue between colleagues, where some are more experienced than others, is in a game like setting.

Beatty et al. [7] propose, *“a reflective card-sort exercise that helps surface the philosophical roots of personal teaching philosophies and helps teachers create or renew a teaching philosophy statement.”* During a game like session, which is carried out in small groups of teachers or individually each participant is given a deck of 82 teaching philosophy concepts cards to review. Examples of cards: “Critical thinking”, “Learning by doing”, and “Social critique”. In the beginning each player imagines a positive teaching episode, *“when you felt your teaching truly touched your students – a time when you felt inspired.”*, and a negative episode. Thereafter, the idea is that each participant selects cards that resonate with one’s personal teaching beliefs. In a dialogue small groups of players explore themes among their selected cards to group cards into manageable clusters. In the last step of the session each participant begins to write a personal statement of teaching philosophy.

Meier and Thrane [8] have developed a game *Exploring my Teaching*. The purpose of the game is to help university teachers to formulate their teaching philosophy and identify their strengths and weaknesses. Each participant gets a game board and a deck of 41 cards. Examples of cards: “Promoting critical thinking”, “Learning by reflection”, “Learning as a social process”, and “Social critique”. The game board is A3 size, and divided into three areas: “Current teaching ideals” with room for six cards, “Cards I do not associate with” with room for two cards, and “Cards I am curious about” with room for three cards. In the

beginning each player imagines a positive and a negative teaching episode. Thereafter, the player selects the most relevant cards to place in the three areas. In a structured and facilitated dialogue, groups of two or three players explore each participant's selection of cards. Finally, each participant has to write one's own teaching philosophy in one sentence.

2 A DESCRIPTION OF THE GAME

2.1 The Teaching philosophy game

The *T-mind game* (Teachers' mind about teaching and learning) consists of a deck of cards, a game board and a score board. In order to have cards with real-life statements the authors asked colleagues around the university to submit statements about teaching, learning and students, which they have heard recently in the hallways or at the coffee maker. The authors assume that cards with authentic, real-life statements are easier to relate to for teachers in engineering education than more abstract terms like "Critical thinking" and "Social critique". Furthermore, the authors assume that cards with pre-printed statements will reduce potential conflicts between players because nobody has to stand by a personal statement. The authors compiled a deck of 51 numbered cards. Table 1 shows an illustrative subset of collected statements used in the T-mind game.

Table 1. An illustrative subset of collected statements used in the T-mind game

Card #	Text on card
1	When the students enter my course their pre-knowledge is insufficient
2	It can be difficult to create dialogue with the students in classroom teaching
3	It is important that students are not only motivated by the need to pass the exam
4	A lecturer must always be able to have a dialogue with students during a lecture
5	Without lecturing it is difficult to convey the spirit of a course
6	A short Danish textbook is better than a long American textbook
7	The students do not read the curriculum and they show up unprepared
8	My main task as a teacher is to facilitate the students' learning processes
9	The best students must achieve top mark
10	The entire curriculum must be covered in the lectures
11	I work for all students to pass the course
12	The students have to study part of the curriculum themselves
13	Lecturing is more important than giving feedback to students
14	Teaching should not take time from my research
19	It is important to switch between practical exercises and theoretical lectures
25	It's nice when the student asks deep questions that cannot be answered here and now
26	The students' personal development and building of technical knowledge happens in a mutual process
29	My teaching assistant must take care of the exercises. I take care of the lectures.
37	Let the students give each other feedback on their reports
39	It is only through group work that students learn professional teamwork
41	Learning is driven by curiosity
42	Humour is important to create a positive learning environment
51	The modern teaching methods are nonsense

The game board is designed as a red ring target in size A0, which suitable for a group of 4-6 players sitting around the board. On a score board the group makes a record of selected cards

2.2 Playing the game

In the beginning of a game each player gets a deck of cards, a few blank cards and is asked to consider: what is good teaching in the course you are involved in? Each player has to select the five most relevant cards to help answering the question. Players can use one or more blank cards to formulate their own statements. One by one the players put their five cards on the board in order of importance. The most important card is placed at the bull's-eye, and the least important at the perimeter. When placing the cards the player explains his/her selection and weighting of cards (individual reflection). When all players have placed their cards, the group makes a record of the selected cards and their relative importance on the score board. In the second round the group has to try to reach consensus as to what are the five most important cards to answer the question. The group are free to use all cards of a deck and to fill in blank cards. At the end of the round five cards have to be placed on the board and ranked with respect to importance (group consensus). The cards and their relative importance are recorded on the score board.

After the second round has finished each group present their group consensus for the other groups and obtained results are discussed. The purpose of the discussion is to support a team-oriented approach to teaching and thereby to build or strengthen a community of teaching practice.

If time allows a third and fourth round can be played with focus on the question: what is good teaching in the course you are involved in *seen the students' perspective*? The game is played in the same way as in the first two rounds, but focus shifts towards what enhances learning. Playing the third and fourth round can be a good base for a deeper reflection and discussion on what students and teachers find important for teaching and learning.

2.3 Inviting the students

An interesting option is to ask students to play T-mind. One way to do it could be to run two sessions in parallel, where students play in one session and teachers play in another. By the end of the sessions the students and teachers meet and present the obtained results. The results can be compared and differences made visual based on the cards chosen. In this way teachers will get an insight into what their students' find important for teaching and learning.

3 PRESENTATION AND INTERPRETATION OF DATA

The authors have facilitated game sessions and collected score boards at several occasions. In order to get insight into the players' reflections about teaching and learning the authors have classified the cards and developed a measure of how cards were selected.

The cards are classified according to Kugel's model of how professors develop as teachers [9]. The model describes the development in five stages. Kugel writes, *"Typically, when they being their teaching careers, professors focus their concern primarily on their own role in the classroom (stage 1: self). When they have mastered this role ... the focus of their concern shifts, first to their understanding of the subject matter they teach (stage 2: subject) and then to their students' ability to absorb what they have been taught (stage 3: student). With this shift comes a more general shift of focus from teaching to learning, that begins, in stage 3,*

with a focus on helping their students become more absorbent (stage 3: students as receptive). Concern then typically shifts to helping students learn to use what they have been taught (stage 4: student as active) and then to helping them to learn on their own (stage 5: students as independent).” In a dialogue the authors classified the 51 cards according to Kugel’s model. Thus the classification is based on our personal views. Two cards (no. 6 and 51) do not fit into Kugel’s model and are recorded as “no category”. Table 2 shows the classification.

Table 2. Cards classified according to Kugel’s model, [9]

No category	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
	Self	Subject	Students as receptive	Students as active	Students as independent
6,51	14, 22, 29	5, 10, 13,15, 16, 18, 24, 38, 50	1, 2, 3, 7, 9, 11, 21, 23, 27, 28, 30, 31, 34, 42, 43, 45, 49	4, 12, 17, 19, 20, 32, 33, 36, 44, 46, 47, 48	8, 25, 26, 35, 37, 39, 40, 41

The quantitative measure of how cards are selected is as follows. When a card is placed at the bull’s-eye it is assigned 2 points, the second card gets 1.75 point, the third 1.50 point, the fourth 1.25 point, and the fifth card placed at the perimeter gets 1.0 point. Cards which are not selected get 0 point. For each session the weighted sum of the cards was calculated.

In the following data are shown from five occasions: the CDIO 2016 conference (CDIO), the Education Day 2016 at University of Twente (Twente), a meeting for study leaders of B.Eng. educations at our university (Beng), the ETALEE 2017 conference (ETALEE), and a seminar for teachers on a B.Eng. education in healthcare technology (Health). Figure 1 shows the results from first game round (individual reflection). Figure 2 shows the results from second round (group consensus). Figure 3 shown results from third round (individual reflection on what is good teaching *seen in the students’ perspective*).

Figure 1 shows that most statements chosen by the players in the first round (individual reflection) were from stages 3, 4 and 5 of Kugel’s model [9]. Furthermore, the overall distribution of statements with respect to the stages (not the individual statements) seems uniform no matter where the game was played.

When comparing results obtained from individual reflection (Figure 1) with group consensus (Figure 2) a tendency to choose statements of higher stages is seen. The “tail” of statements from stage 1 and 2 does almost not exist in the group consensus. This deselection of statements from stage 1 and 2 indicates that during the group discussion players tend to lift their reflections towards the higher stages.

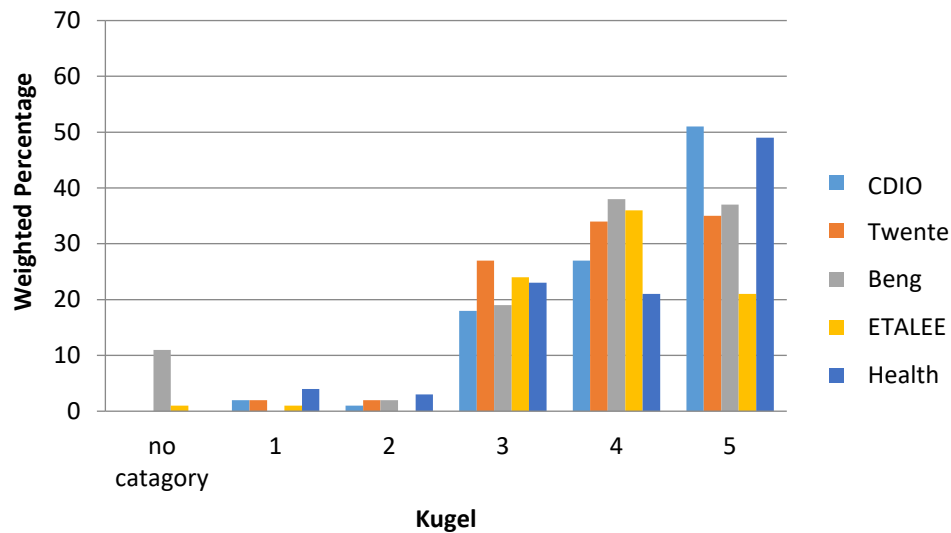


Figure 1. Results obtained for players' individual reflection according to Kugel stages. This part of the game was played at the CDIO 2016 conference (CDIO), at Education Day 2016 at University of Twente (Twente), at a meeting for study leaders of B.Eng. educations at our university (Beng), at the ETALEE 2017 conference (ETALEE), and at a seminar for teachers on a B.Eng. education in healthcare technology (Health).

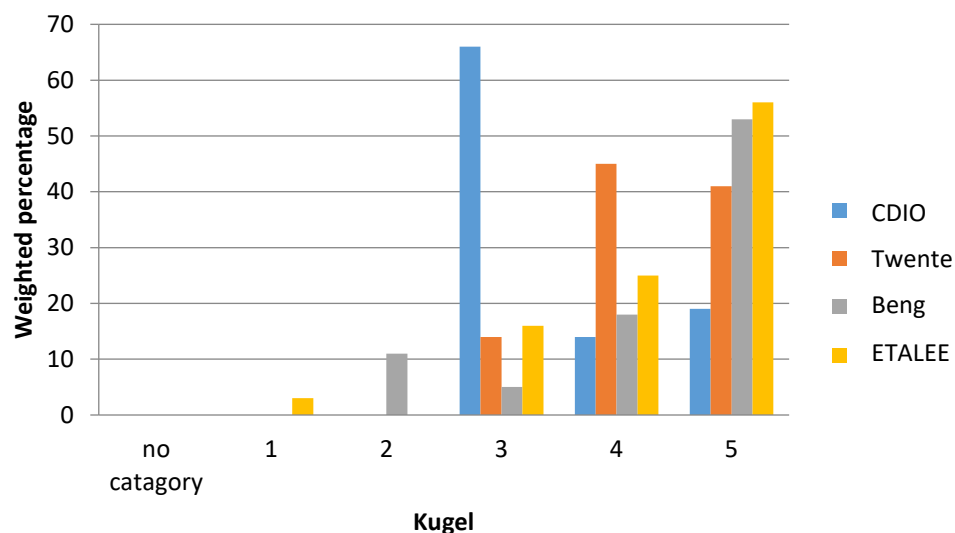


Figure 2. Results obtained for group consensus according to Kugel stages. This part of the game was played at four occasions, legend see Figure 1.

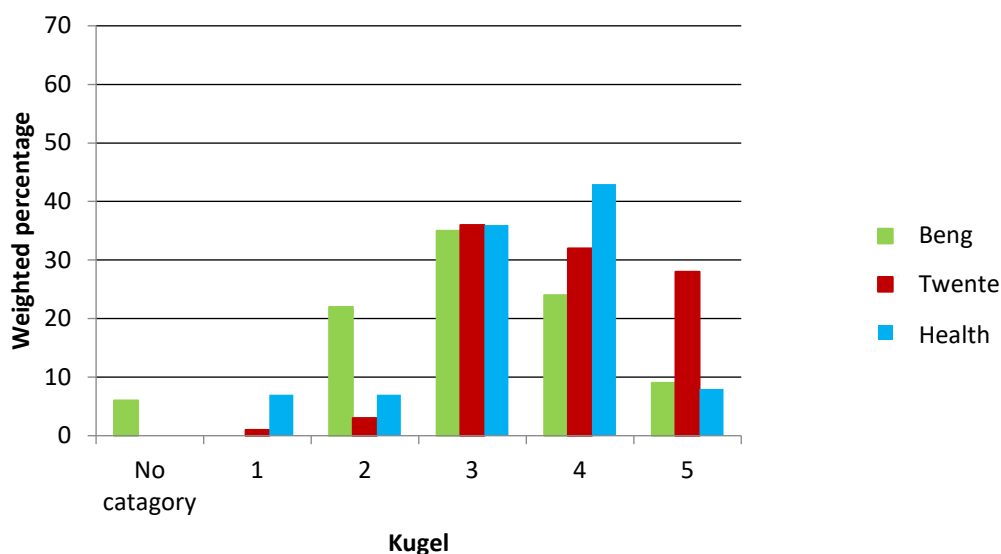


Figure 3. Results obtained for players' individual reflection on good teaching seen in the students' perspective according to Kugel stages. This part of the game was played at three occasions, legend see Figure 1.

When comparing results from round 1 (*Figure 1*) and round 3 (students' perspective) (*Figure 3*) we see that in the third round the players select most cards from stages 3 and 4. At the T-mind session in Twente a higher number of cards from stage 5 were selected compared to the two other occasions (Beng and Health). On *Figure 3* it is interesting to observe that the study leaders (Beng) select many more cards from stage 2 (Subject) than the teachers (Twente and Health). What could be the reason for a difference in perception of good teaching seen in the students' perspective between study leaders and teachers? The authors assume study leaders are more concerned about the students' progression from course to course and about overlap between courses than teachers. The study leaders' concern is mainly related to subjects being taught. Thus, when study leaders are in dialogue with students the focus is primarily on subject, whereas when teachers discuss their course with students not only subject, but also issues like number of exercises, types of assignments and feedback, examination and grading are at stake, and these issues relate to the students' activities (stage 3, 4, and 5).

Data shows that the five most repeatedly selected cards both in round 1 (individual reflection) and round 2 (group consensus) are the following: card 3 (stage 3) "It is important that students are not only motivated by the need to pass the exam", card 42 (stage 3) "Humour is important to create a positive learning environment", card 19 (stage 4) "It is important to switch between practical exercises and theoretical lectures", card 8 (stage 5) "My main task as a teacher is to facilitate the students' learning processes", and card 41 (stage 5) "Learning is driven by curiosity". This authors find this selection of cards very positive. These five statements stretch out a field of issues: student motivation, humour and curiosity, exercises and lectures, and facilitate learning, which are all relevant issues to consider towards the goal of good teaching and learning.

4 CONCLUSION

This paper documents a first explorative study of teachers' reflections on teaching and learning based on empirical data from playing T-mind. The study indicates that individual players tend to choose few cards with statements from Kugel stages 1 and 2 and most cards from stages 3, 4 and 5. Furthermore, the group consensus round lifts the players' thinking, as the lower level cards are deselected during the group discussion. Thus, playing the game seems to change the teachers' thinking in a positive way. This change of thinking does not ensure a changed behaviour of the teacher in the classroom, but it is a necessary condition for changed behaviour. Thus, it is concluded that the group-oriented, collective process in the T-mind game has potential for leading to better thinking and learning.

The outcome of the study prepares the ground for more and deeper studies. Through more game session more empirical data will be collected to analyse. It will be interesting to see if similar results will be found. It is also relevant to deepen the study by analysing the statements that participants have written on the blank cards. Finally, it will be interesting to organise sessions, where teachers and students play the game in parallel and to compare results.

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Error patterns in first-year students' answers to mathematical assignments as observed 2010-2018

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Keywords: Error pattern, feedback, learning model, layered instruction

ABSTRACT

An analysis of 1600+ one-page feedback sheets written by the author (in response to hand-in answers from comparable groups of first-year engineering students to assignments in a 20 ECTS points mathematics course) seeks to identify and classify error patterns. Three major patterns appear prominent: 1) The transfer problem: failing to apply, or wrongly applying, methods erstwhile learned in other areas; 2) The contingency problem: wrongly attaching a property of an example or mnemonic to a general problem; and 3) The failure to correctly use or extend logical conditions. Along with these are others that may be considered variations, but are probably best treated on their own, such as the general issues of failure to separate related, but different, concepts; of failure to make use of specific arguments over general ones (or vice versa); the blindness to the lucky/unlucky choice; and of failure to distinguish between a mathematical entity and its name. These, too, may deserve to be called 'patterns'. Finally, there is the universal 'Thinking fast and slow' (Kahneman) phenomenon: If a task resembles a known one, a previously successful method is attempted, whatever the outcome. The pedagogical/didactical response to an error pattern should be a manifestly layered instruction, distinguishing operational guidance from invitation to reflect upon a deeper meaning, that must needs be expressed in terms somewhat distant from the subject directly at hand. This is akin to Argyris' 'single-loop, double-loop' learning theory, which may be supplemented by the simple, but useful, five-step learning model fact→relation→operation→insight→innovation to make it explicit to students that they may have wrong or unfortunate patterns to unlearn and useful ones to internalize.

INTRODUCTION

Providing feedback on hand-in assignments is an important part of the instruction of students, whether in the engineering disciplines or elsewhere. Since September 2010, the author has annually instructed teams of 1st year students and marked up their assignments in a 20 ECTS point course in introductory mathematics. By writing the feedback in a fixed-format one-page scheme and storing the digital version, the author has collected a 1600+ page log of typical comments. From 2010 to summer 2014, hand-ins were written or printed on paper and the marked-up essays returned to the students along with a print-out of the feedback page. From autumn 2014 onwards, most hand-ins have been electronic, allowing storage of 600+ essays for further analysis.

The goal of the present paper is to find and characterize **error patterns** in the students' mathematical writings. What is meant by an 'error pattern' will – so it is hoped – gradually become clear, since no simple definition is available. The course itself, the format of the feedback sheets, and the general concept of a 'pattern' and its resemblance and contrast to an 'error pattern' are briefly described to provide a background. The disarmingly simple method of analysis and the main result, identification of important patterns, follows. A discussion of possible utilizations of the findings so far – drawing primarily on other observations from teaching engineering students - as well as of intended further analysis forms the last part of the paper.

I BACKGROUND

The course: 01005 *Advanced Engineering Mathematics 1* is a 20 ECTS points introductory mathematics course, mandatory for B.Sc. Eng. students at DTU. The course covers calculus and linear algebra and comprises (2017-18) 2 lectures, 3h tutorials and 3h groupwork per week along with thematic exercises and a 3-week project. The duration is 13 + 13 weeks (winter and summer terms) and the assessment comprises 7 homework assignments, tests in fall curriculum, separate examination in the 3-week project course and tests in spring curriculum. The exams (December and May) are 1+2 hours. Throughout the course, intense use is made of CAS tools, for which on-line tutorials and examples are provided, along with video streaming of the lectures and various other e-learning items. The present author serves as supervisor of the tutorials and marks up the 7 assignments for one class of students each year, and in addition prepares, oversees and instructs in a repetition course in August prior to the re-examination of the 70-100 unlucky individuals who failed the May exam. A class typically consists of 35 students and the number of individual supervisors is accordingly 30+, some catering for two classes. Over the period 2010-2018, the various numbers and conditions have varied slightly: Classes have consisted of up to 40 students, there has been as many as 10 assignments in a year, etc.; but the above is a reasonable outline.

The feedback sheets: Each supervisor develops his or her own style, i.e. the one described here is unique and admittedly somewhat elaborate. In evaluations, student almost uniformly praise the thoroughness of this kind of feedback – and almost uniformly deplore the time spent by the author writing down the many sheets. —

The format, developed from the outset with no specific purpose in mind other than the provision of a just distribution of comments and instructions, comprises (apart from administrative information):

- 1) Copies of the ‘learning goals’ stated in each assignment. These learning goals, each one or two lines long, are marked with a selection of symbols printed in red: ☺, ✓, (✓), ·, -, —, ⊗, indicating a decreasing degree to which the goal was met
- 2) Numbered comments, the numbers referring to similar numbers and brief indications written in the essay during the first pass of markup
- 3) An overall assessment (in words) + a Roman numeral I-V (the only “officially” required feedback
- 4) Hints for improvement

The ‘learning goals’ are a given part of each assignment, typically specifying what the assignment is about, but also with at least two addressing the use of illustrations and the need for clear and precise writing. The numbering of comments and the brief remarks in the essays arise during the first pass through the hand-ins and are thus specific for the individual essay. The comments as well as the assessment and the hints are written in the second pass. They are likewise individual, although use is occasionally made of sheets of standard comments, when an assignment causes many identical errors or mishaps. The assignments typically comprise 10-12 individual questions forming 3-4 problems. There is some year-to-year reuse and variation, but the majority of problems are new from year to year, and although an “official” answer is distributed to the supervisors, most – the author included – work out a solution of their own for use during the mark-up process.

A few words on the concept of a ‘pattern’: Over the years it has become increasingly clear to the author – who also teaches and has taught a variety of other courses in mathematics and topics with a strong leaning towards mathematics – that a common vocabulary is needed for the description of related problems that can be observed in hand-ins and during oral exams when students grapple with abstractions or the words expressing them. Perhaps the best common name for what is sought

for is ‘error pattern’; and the subsequent sections attempt to provide a few handfuls of descriptions of such patterns, distilled from the above-mentioned feedback sheets.

The first that comes to mind in response to the word ‘pattern’ is probably *geometric patterns*, be they discrete (e.g. Grünbaum and Shepard [10]) or continuous (e.g. [11]), with the less regular markings of animals a close second [16]. Psychologists and sociologists speak of *patterns of behavior* (e.g. [9]), and architect Christopher Alexander went a step further and based his *design patterns* on his understanding of *life patterns* [1]. Inspired by Alexander’s ideas, the “GOF Book” (“Gang of four”, [8]) carried the idea of a design pattern into programming as a kind of meta-template, suitable for object-oriented programming. Lately, the concept of a ‘design pattern’ has spread into many walks of life, including education (e.g. [15]). Other than behavioral and design patterns, a third non-geometrical use of the word is important to what follows: *logical patterns* may be either of a mathematical nature (e.g. [2]) or more in the line of philosophical analysis of argumentation (e.g. Flew [7]).

As for the phrase itself, *error patterns* are discussed in [3], [6], [17], [18] and others, all of them providing valuable information and inspiration, but none of them the perhaps rather low-level tool sought for by the present author.

Finally, it should perhaps be mentioned that none of the above writers offer a concise definition of the word ‘pattern’, Grünbaum and Shepard even deploring its vagueness. We shall have to contend ourselves with the words of Green ([9] p. 147):

Finding patterns within the networks that underlie events and relationships can provide useful information. Particular kinds of networks have patterns of connections that make their presence felt in the way systems behave.

and rely on the sweeping generalization of Wikipedia: ‘A pattern is a discernible regularity in the world or in a manmade design’.

II THE STUDY AND THE METHOD

The data has already been described: 1600+ feedback sheets in a fixed format, each containing from 3 to some 15 comments on the quality and merits of a statement, paragraph, section and/or totality of a hand-in essay answering (part of) one of the 10-12 questions in the assignment.

These sheets have been assembled, grouped by assignment and the comments then analyzed. Whenever a comment seemed to have a bearing on a problem deeper than a slip, a misreading, a syntax error in the use of the CAS tool etc., it was copied to a document, still sorted by assignment. These comments were further analyzed and a sub-selection made, now under headings that eventually became the general names of the patterns, as described below.

Three important parts of the analysis was the repeated re-naming of the patterns, the shuffling of comments as the patterns crystallized, and the matching of the last batches of comments to what had become the canon. It should perhaps be emphasized that no attempt will be made at a statistical analysis, since all information is of a qualitative nature and almost every comment unique. Also: At the time of writing this, only 903 sheets have been filtered through the complete cascade of selection and sorting as the identification of patterns and their manifestations seems to have reached a point of stability. Completion of the filtering task is planned as part of step 2, briefly described below, which will also involve revisiting the 600+ essays preserved electronically.

IV PATTERNS OBSERVED

Without further ado, here are the patterns observed, presented with a number and name, described as succinctly as possible and illustrated by the (admittedly sometimes rather indirect) evidence of a few of the extracted comments:

1.1 The transfer problem: This has generated a substantial literature, e.g. [14], where we also find as good a definition as we can hope for:

[...] research on transfer has demonstrated the difficulty of enabling students to recall and apply their science knowledge in novel situations

If, for 'science' we read 'mathematics', and if 'situations' has as general a meaning as possible, we have a useful concept of this pattern. If context A requires/allows operation c , but only the part a of A is truly necessary, the student may be unable to use c in context B, even if a is also part of B. The problem appears to lie in the *conditioning* aspect of learning. Even if a is pointed out, the triggering of the use of c is not elicited: In the mind of the student, c is too strongly linked with the totality of A.

- Du skal faktisk runde *op* [Actually, you should use the *ceiling value* of the number]
- Men hvad véd du allerede om egenværdier? [But what do you already know about eigenvalues?]
- Du lader definitionen gælde uden for cirkelns afgrænsning [You extend the definition to let it hold outside the circle]
- Men de sidste to polynomier er kun lineært uafhængige af hinanden. Når de kombineres med $4 - x$ er der *tre* polynomier, hvoraf kun *to* er lineært uafhængige [But the latter two polynomials are only mutually linearly independent. When they are combined with $4 - x$ there are *three* polynomials, of which only *two* are linearly independent]

In these four examples, the student either fails to recognize 'a', extends 'a' or 'A' to a 'B' where operation c cannot be used, or unwittingly creates a situation where the 'A' must be restored or a 'super-A' must be created and 'super- c ' developed.

Already here, we begin to see the need for a concept of **error patterns**: If the feedback merely corrects the specific error, the student may never reflect upon its nature and therefore miss an opportunity to learn. The error made by the student must be recognized as something deeper than a slip and the comment must elicit reflection. (As can be gathered, the author is biased towards 'Socratic examination').

1.2 Mixed narrative: Continuing in the notation employed above, we may find that the context is B and the operation c , but part of the narrative deals with elements of A either not present or not relevant.

- Det ser lidt mystisk ud på dette sted; men alle udregningerne på næste side er O.K., nærmest som om du først har overvejet én fremgangsmåde og så er skiftet til en anden [This spot looks a bit mystifying; but all calculations on the following page are O.K., as if you had first considered one procedure, then changed to another]
- Og hvad er så den afgrundsdybe forskel på en implicit cirkel og en eksplicit cirkel? (Dette minder mig om en af mine yndlingstegninger: to ret ubestemmelige skikkelser ligger i skyggen af et stort træ, og den ene spørger: Precisely what is the difference between a goblin and a hobgoblin?) [And what is the deep difference between an implicit circle and an explicit circle] etc
- Du skriver det, som om egenvektorerne er lineært uafhængige hver for sig; men det er altså en egenskab ved det samlede sæt [You write as if eigenvectors are linearly independent, each on its own; but it is a property of the assembly]

The first case is a straightforward example. In the second, the student introduces a distinction (implicit/explicit) that does not apply and goes on to argue two cases where only one exists. The third is quite common, assigning a property to the wrong level of a hierarchy.

The mixed narrative pattern deserves a deeper study as it is often interlaced with one or more of the other patterns. There is, nonetheless, reason to grant it status as a full pattern in its own right.

1.3 The contingency problem, a kind of mirror image of the transfer problem: “c can be applied, so A must be the context”, whereupon A is enforced on B or assumed implicit. There are two further complications: The student may *fail* to impose the reduction of the context that makes c applicable; or there may have been an interlude, where a narrow context was superimposed. (Here, an example is necessary to explain what is meant: The student may have learned Taylor expansion, then – some time later – have learned how to analyse stationary points by means of Taylor expansions, then, upon return to a general framework, have established so strong a mental link that ‘an expansion point’ is identified with ‘a stationary point’ or *vice versa*).

The contingency problem has its own literature, e.g. [5], [19]. It can be tricky to spot and almost impossible to correct, because the student will cling to what has once been learned and fail to discover or appreciate the need to *unlearn* some of it.

- Disse sammenhænge er tilfældige [These connections are fortuitous]
- Dette gælder [kun] for symmetriske matricer [This only holds for symmetric matrices]
- Sæt $y = 1$ (konstant), så reduceres funktionen til et tredjegradspolynomium i x [Let $y = 1$ (a constant), then the function is reduced to a third degree polynomial in x]
- Nej, altså: hvis t er konstant, er der ikke tale om funktioner. Tænk igen! [No, really, if t is a constant, there is no function involved]

The first is the general case, the second a specific instance. The third is the variant discussed above, which typically require very clear instructions. The fourth is almost paradigmatic: The letter “t” usually denotes a variable, setting a train of thoughts in motion that has no bearing on the subject at hand.

A final difficulty concerning the contingency problem is that it seems to be absent from literature on mathematics teaching – and little known in Danish educational literature in general. —

2.1 The wrong perspective: This is possibly the most difficult pattern to spot, diagnose and remedy. It may take the form of *overkill*, a kind of “underkill” (a detail hides the general picture), a failure to expressly meet a learning goal, or simply an emphasis on an irrelevant part of the problem or context.

- Sært: først finder du stjernefunktionen korrekt – og så finder du en “stamfunktion”, der bare skulle have været stjernefunktionen?? [Strange: First you find the star function correctly – then you find a function primitive, which should simply have been the star function??]
- Igen-igen: dette er en opgave i matematik, ikke en øvelse i at bruge Maple og tro, at man har fundet svaret, bare Maple har fundet et svar [Once again: This is a mathematics assignment, not a Maple © exercise carrying the bonus that one has found *the* answer if Maple © has found *an* answer]
- Hér slipper du til gengæld ikke: det fremgår tydeligt af læringsmålene, at du skal vise at du behersker Taylor’s formel med rest [Here you won’t go free: It is clear from the learning goals that you must demonstrate mastery of Taylor’s formula with a remainder]

2.2 Mixed concepts: Mathematics has itself to blame for many instances of this, the most common error pattern. “Abuse of notation” and re-use of notation is tolerable among experts but wreaks havoc with the mind of the innocent. The use of the word ‘vector’ is the standard example: Other than being a 2D/3D object known from physics (a *geometric vector* is drawn as an arrow, but really is a representative of an equivalence class), a ‘vector’ can be a member of an abstract vector space or – *horribile dictu!* – the wrongly applied reference term meaning a row or column matrix. To trump this, polynomials are sometimes considered members of a vector space with the natural basis “1, x , x^2 , ...”, elements are written as $p(x)$, and mappings as $x \cdot p(x)$, etc. The author once wrote a four-page step-by-step explanation of a three-line quiz problem, painstakingly unwinding the rapidly changing meanings of the letter x as a number, a variable, a vector, a function, etc.

- Uha-uha: her lader du x-erne (kaldet a) indgå i afbildningsmatricen og gør dermed afbildningen ikke-lineær. [Uh-oh: Here you let the x's (called a's) be part of the mapping matrix, this making the mapping non-linear]
- Der skal skelnes mellem et (lineært) funktionsudtryk og ligningen for planen, også selv om de ligner hinanden til forveksling [One must distinguish between a (linear) function expression and the equation of the plane, even if they are confusingly similar]
- Funktionen indgår ikke i beregningen af massemidtpunktet, der alene er en egenskab ved området [The function is not involved when calculating the mass mid-point, solely a property of the domain]
- Nej, da: fortegnet flytter sig ikke pludselig over på modulus [No – no: The sign doesn't suddenly jump from argument to modulus]

2.3 The incomplete narrative: This has proud historical precedences, cf. Kummel's and Wiles' struggles with the Fermat theorem. The name refers to the gap in the argumentation, especially when it represents the crucial element of a proof or derivation. Other manifestations are the circular argument, the (attempted) proof by figure, proof by example, proof by meta-example (an example cleverly disguised in symbols) and Flew's No-True-Scotsman-Move (where a too-general statement is defended by explaining away obvious counterexamples).

This is by far the most common error pattern and also the one that has generated the longest comments. One very short and one rather long example will have to suffice:

- Jamen 1 og 1 er da ikke forskellige? [But 1 and 1 are not different?]
- Du får aldrig svaret på 'Hvorfor?' [You never get around to answering the "Why?"]
- Skriv en samlet "historie", der kan læses fra den ene ende til den anden. Kunsten er så at kun være detaljeret omkring de væsentlige udregninger – dvs. vise detaljer første gang, eller når noget er usædvanligt, osv. – og at holde et flow, så der er en begyndelse, en midte og en slutning [Write a complete "story" that can be read from one end to the other. The art, then, is to include details only when describing essential calculations – i.e. to show details on their first occurrence on when something is unusual, etc. – and to maintain a flow, thus creating a beginning, a middle and an end]

3.1 The argument is about the wrong issue: Almost ironically, this is fairly easy to detect, but frustrating to mark up/correct, as the comment must contain most of the argument about the *right* issue, leaving comparatively little room for reflection.

- Njah, altså: alle tre områder er udsnit af en kugle, det er derfor, de har samme form for parameterfremstilling [Well, all three domains are sections of a massive sphere, which is why they have related parameterizations]
- Ved ordet "grænseværdi" forstås bare tallet [Here. The word limit only refers to the number]
- Mærkeligt svar: først finder du en, så argumenterer du for, at der er uendeligt mange, og heraf konkluderer du, at der ikke er en... (-!?) [Strange answer: First you find one, then you argue that there are infinitely many, and from this you conclude that none exists]

3.2 The validation-verification dichotomy: See [4]. The distinction can prove surprisingly hard to keep clear. The popular version is:

Verification: *Are we doing this is the right way?* (And thus getting the right results)

Validation: *Are we actually doing the right thing?* (The 'sanity check' – I am indebted to Rune Bundesen for this)

Students are encouraged to add a verification, whenever possible. This may range from a simple estimate to a complete calculation using a different method. The problem arises, of course, when they somehow manage to confirm a wrong result.

- I betragtning af din grundighed: prøv at vænne dig til at tænke: "Hvordan kan jeg checke resultatet på en anden måde?". Det vil både fjerne de ærgerlige fejl og give dig yderligere forståelse af stoffet [Considering your thoroughness: Try to get used to thinking "How can I check the result in a different way?". This will eliminate wexing errors and add insight into the matter at hand]
- Det er ikke sikkert, solve har fundet alle løsninger [One cannot be sure that solve has found all solutions]

At the end of the day, there is a vast difference between getting the right thing wrong and getting the wrong thing right. —

3.3 The empty pattern: This is added, even though it is rarely applicable to the individual (non-) answer. The missing or almost missing answer can take many forms – no text, sporadic text, genuinely nonsensical text, etc. – but can only be analysed in case of repetition. In other words, one can look for patterns of the kind “What is not answered?”, “When is the text garbled?”, “Is there some kind of method in the madness?”

- Selve den sproglige formulering er volapük – men udregningerne er gode nok [The formulation is volapük, but the calculations are sound]
- ...og det samme gælder grafen (-?-) — — 4a) Nej, jeg læste det hele igennem igen: du har totalt misforstået: du ændrer søjlerne, men du skal ændre rækkerne. At det kommer til at gå op, har en anden algebraisk forklaring: rangen af en matrix er lig rangen af dens transponerede [...and the same goes for the graph (?) — — No, I read the whole thing again: You have completely misunderstood. You change the columns, where you should change the rows. That the whole thing fits together has a different explanation: The rank of a matrix equals the rank of its transposed]

The choice of numbering: The reader will have guessed that the patterns numbered **1.x** are considered the most serious or significant, the patterns numbered **3.x** the least. Also **y.1** denotes a blockade or slide, while **y.2** is a mix-up and **y.3** an incompleteness. As more patterns emerge, this numbering is likely to change.

Emerging patterns: Some errors have been observed, but not yet in such numbers that their ontological status can be finally judged: Effects of too strong a faith in a (sometimes self-chosen) ‘authority’ (such as the instructor giving an ambiguous instruction...), failure to follow a procedure, “Laplacian arrogance”, i.e. stating that something is clear, which isn’t – and a really difficult-to-handle failure to observe, what a text actually says, caused, it seems, by an unprepared mind.

Last words on patterns: In several of the patterns – almost all of them, in fact – we recognize the “jumping to conclusions”-way of solving mathematical problems that many students develop during their high school years (Danish *Gymnasium*), where many are among the brightest and find mathematics easy. When confronted with university level mathematics, they must often adapt a new attitude. This process is wittily described in [13].

V DISCUSSION

Students should learn about error patterns and should be given feedback that points out very clearly to them that “This is just a slip”, “This is serious, a 3.1 Argument about the wrong issue”. This, of course, requires that a common language describing error patterns is developed and applied by their instructors and supervisors.

In the opinion of the present author, still more can be achieved by also designing the instruction around a sufficiently simple learning model, allowing lecturers to say, and assignments to state: “This is just rote learning, this is operational drilling, this is for deeper reflection”. Whenever possible, the author suggests a simple five-step ladder:

fact → relation → operation → insight → innovation

where it is to be understood that you are not expected to *first* learn all the facts, *then* learn all the relations, etc. Quite the contrary, you learn a few facts, then a few relations between these, then the

first operation, then go back for more facts, etc. This may seem trite; but anyone who has reflected upon his or her own teaching will occasionally have come across times where one or more steps was skipped or passed too quickly. To quote [12]: You can *present* facts, *prove* relationships, *demonstrate* operations and *tell* about your own insight; while innovation may perhaps be *inspired*.

If instruction is presented in an explicitly layered form, addressing each of these clearly and with feedback stating equally clearly when it is time for the individual student to simply correct a slip or oversight or practice a method somewhat more, versus when it is time to reflect upon an error pattern that must be rooted out, a deeper, better learning can be achieved at very little extra cost — or such is the hope of the present author.

CONCLUSION

When this project was initiated, the hope was to provide simple words and phrases denoting error patterns in first-year engineering students' learning of mathematics. Such patterns had shown themselves with still greater clarity in hand-in answers to assignments and were echoed in the feedback. Analysing a fairly large number of feedback sheet written in a fixed format, the author has so far found nine such patterns. There could well be many more, and the search is still on.

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Examining development of the entrepreneurial mind-set in engineering students

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Conference Key Areas: Fostering entrepreneurship, Teaching Creativity & Innovation, Curriculum Development

Keywords: Fostering entrepreneurship, entrepreneurial mind-set, mind-set survey

INTRODUCTION

Are students getting more entrepreneurial when following courses with a focus on these competences? Engineering students are increasingly being expected to obtain entrepreneurial competences during their education, and the Technical University of Denmark (DTU) has, like many other universities, rolled out a palette of obligatory and elective courses to meet this need. In this study we build on our previous work to ascertain whether there is a significant difference in the mind-set of students who have taken these courses, compared to those who have not. In a previous study we have investigated whether the course design used in an entrepreneurship course for bachelor of engineering science students resulted in development of an entrepreneurial mind-set or not. The results showed that there is a significant positive development, with respect to different traits identified as central for an entrepreneurial mind-set. The students rated them self in the beginning of the course and then again at the end [1]. A survey developed within the KEEN network (USA) was used and

applied for the students' rating [2]. The mission in KEEN is "to graduate engineers with an entrepreneurial mind-set who can create personal, economic and societal value through meaningful work" [3]. One of the bearing ideas in the KEEN network is to promote development of entrepreneurship because of a learning process through Entrepreneurially Minded Learning (EML). The study in the current paper has the same intentions, to understand more in depth how an entrepreneurial mind-set can be developed within Engineering Education and the same survey is therefore used. Understanding and training the development of an entrepreneurial mind-set has been a hot topic in engineering education literature for some time (e.g. [4]). Often it has focused on students, and thus educations, with a special interest in entrepreneurship. However, as entrepreneurship evolves as an important engineering competence in general and not only for students who actively choose to take part in entrepreneurial activities during their education, we would like to take the next step and broaden the perspective to investigate how engineering students in general understand and develop an entrepreneurial mind-set. Therefore, in this paper we investigate the effects of courses that do not specifically set out to develop entrepreneurial competences. This study is an initial study in order to broaden the perspective on the development of entrepreneurial mind-sets among engineering students and to start to combine different theories about mind-sets and their development in order to deepen the understanding of the processes involved.

1. ENTREPRENEURIAL MIND-SET IN ENGINEERING EDUCATION

In order to investigate the development of a mind-set, it is useful define the concept of mind-set and create a framework to analyse it with respect to its development during education. One definition of a mind-set is that it is our ability to use internal personality traits and mental processes that create a readiness to act and to respond to different situations in a certain manner [5]. Our internal beliefs about ourselves, our abilities and our self-esteem are all involved in a mind-set; "A mental attitude that determines how you will interpret and respond to situations" [6]. In order to create an analytical framework, it is central to consider that our attitudes towards our self, develops in a complex interaction between our environment's responses to our behaviour and then how we, in turn, interpret and react to those responses [7]. The same complex interactions also occur in an education context. In order to develop specific mind-sets through education one of the main question is if education and the learning activities the students are exposed to, can train a certain mind-set. In the work by Dweck two different kinds of mind-sets in education are described to be critical as predictors for success in learning and development of new abilities among students: A fixed and a growth mind-set [8]. A growth mind-set is characterised by the belief that abilities can be developed by training and by the way we are educated. A fixed mind-set is characterized by beliefs that a person has inherited certain personality traits and intellectual abilities that cannot be changed [8]. When it comes to the development of an entrepreneurial mind-set, research often point out the concept of self-efficacy as crucial in order to support students' entrepreneurial abilities [9,10]. The theory of Self-efficacy was developed by Bandura and refers to a person's inner beliefs about his or her own abilities to reach certain goals [11]. If we assume that students have a growth mind-set with respect to education then we can propose that they will be open to training positive personal beliefs and therefore adequate teaching can support development of self-efficacy. This idea can find support by research that shows that the attitudes towards a behaviour is an important predictor of how a mind-set can be expressed and that those attitudes are important to how a person can develop [7]. A

mind-set is internal within a person, but how this person chooses to react in a given situation depends on the cultural and social context and what is allowed and rewarded [9]. Also the attitude towards entrepreneurship and the way of viewing it is central to promoting the development of entrepreneurship as a competence and a method for tackling large and abiding problems [12]. Those are some of the theories forming the background to this study.

2. METHODS TO EXAMINE THE ENTREPRENEURIAL MIND-SET

There are a number of reported methods to examine the entrepreneurial mind-set, one of which is that developed within the KEEN network [2]. KEEN developed a set of 18 questions within four categories, namely: Problem solving, Business acumen, Societal issues and Teamwork, together with a series of questions about the respondent, such as sex, level of current education etc. The questionnaire was used before (pre) and after courses (post). A 5 point Likert scale was used and the results showed that on average the students rated themselves very highly (over 4) even before the courses in question started. Nevertheless, the authors found highly statistically significant increases in the students' entrepreneurial mind-set and concluded that the changes made to their courses and curriculum based on Problem Based Learning were a success. Call et al. [4] also reported an ongoing investigation into the link between an introduction of an entrepreneurial curriculum in an engineering course and the impact on creativity and mind-set. They measured entrepreneurial interest pre and post course using a questionnaire reported by Solesvik [7] which has 26 questions grouped in categories of: Intention to become an entrepreneur, subjective norm, attitude toward behaviour, perceived behavioural control, risk taking and self-efficacy. Furthermore, Call et al. [4] measured creativity using the abbreviated Torrance test for adults (ATTA) also pre and post course. To measure mind-set, they used an online survey also in a pre and post course way (<https://www.mindsetonline.com/testyourmindset/step1.php>). However online tests can pose a challenge for ensuring high completion rates both pre and post course.

3. CONTEXT AND METHODS USED IN THE CURRENT STUDY

In our previous work [1], the entrepreneurial mind-set was investigated in engineering students at the bachelor level who took courses either on entrepreneurship or with a close relationship to it. We saw that there was an increase in the entrepreneurial mind-set at the end of these courses, compared to that at the beginning. However no control courses in which innovation and entrepreneurship were not an explicit part of the curriculum were included. This raises the question of whether the results truly were significant or not and whether the differences we noted earlier were meaningful, or could be due to other factors, such as an overall development in self-efficacy. Here we have therefore investigated the development of the entrepreneurial mind-set in two conventional engineering courses, in which innovation and entrepreneurship were not part of the curriculum and compared the results with those we obtained earlier. All courses (both those we reported on earlier, and in the current study) were taught in 2016-2017 and one of the authors of the current work was involved in teaching all of them. All courses involved group work and groups were formed at the start of the teaching.

The first control course was 23532: "Beer brewing and safe food production". This is a 5 ECTS points practical lab course at masters level taught in a pilot plant brewery over a 3 week period with full-time teaching (8-17 each day). It accepts students at

late bachelor or masters level. The course included two visits to microbreweries, and was assessed by two written reports and an oral exam. The main learning objectives were to learn how to brew beer and to learn how to make the Hazard Analysis and Critical Control Points (HACCP) documentation (*i.e.* food safety) needed to be submitted to the authorities to start up a commercial microbrewery. There were ca. 30 students following the course and it had a very applied and commercially relevant focus, but no teaching of entrepreneurial or innovation competences.

The second control course was a chemical engineering course at the masters level on biological purification methods (course 28233) which focuses on the unit operations used in the biotech and pharma industries. This is a 5 ECTS points theoretical course taught in 4 hour blocks over a 13 week period involving lectures, 5 guest lectures from industry, 2 reports, homework and in-class calculation exercises and a 4 hour written exam. There were ca. 50 students actively following the course. The main learning objective was to be able to design (on paper) a process for the purification of a given biological molecule. This course was very much orientated towards giving engineering students skills needed for process design and there was no teaching of entrepreneurial or innovation competences.

A third course (23552 “Innovation in future foods”) was included where learning objectives on innovation and entrepreneurship were the primary focus. It was a 5 ECTS points practical course which accepts bachelor and master students in which the main learning objective is for the students to be able to invent and make a new innovative sustainable food prototype and develop the business case for its commercialisation. Although only 5 ECTS points, this involves substantial extra-curricular effort and ran nominally over a 13 weeks period with teaching in 4 hour blocks each week. It involved lectures, guest lectures, practical and field work and ended with a ‘venture-cup’ type competition. There were 8 students and development of innovation and entrepreneurial skills is a core learning outcome.

3.1 DATA COLLECTION

The KEEN entrepreneurial mindset questionnaire was modified by eliminating the student specific questions (sex, age etc), leaving only the key questions needed to assess the entrepreneurial mindset (Table 1). This was done in order to reduce the overall number of questions to ensure a high completion rate of honest answers. A hardcopy of the survey was then given to each student on the first day (pre) of the relevant course and again on the last day of formal teaching on the course (post), but before the exam. It was filled out by the students in the class room on the day it was handed out and collected immediately to ensure a high participation rate. The same procedure was followed on the last day of the course, in which close to 100% of the students following a course were present. The surveys were filled out anonymously, but the students were asked to indicate the education they were taking. The students were given strict instructions to fill out the survey as honestly as possible, with answers corresponding only to their current mind-set.

4. STATISTICAL ANALYSIS AND RESULTS OF THE SURVEY

The result of the survey and a statistical analysis are presented for courses 28233, 23532 and 23552. The pre-test is referred to as pre28233, pre23532 or pre23552 and the post-test is referred to as post28233, post23532 or post23552. Data for all courses were collected in 2017. This gives 6 batches of answers named as described above.

Data consists of 32 observations from pre28233, 33 observations from post28233, 24 observations from pre23532, 26 observations from post23532, 8 observations from pre23552, and 8 observations from post23552. For all questions (Table 1) the answers were given on a 5 point Likert scale: 1 indicates "Strongly disagree"; 3 "neutral" and 5 "Strongly agree".

Table 1. Entrepreneurial mindset questionnaire used in the current study¹.

Nr.	Mindset in question	Mindset type ²
1	I am able to recognize problems that exist in the world around me.	P
2	I am good at devising multiple solutions when solving problems	P
3	I continue trying even after I have failed.	P
4	I ask relevant questions to clarify situations and gain new knowledge.	P
5	I am able to independently gain new information from various sources.	P
6	I accept responsibility for my personal actions	P
7	I accept responsibility for the work I produce, including mistakes	P
8	I think outside the box and am creative.	P
9	I understand and identify with the feelings, experiences, and motives of others	T
10	I am aware of my personal strengths and weaknesses	T
11	I can identify strengths and weaknesses in others	T
12	I am able to determine whether I should lead or follow in different situations	T
13	I can develop and maintain working relationships with peers	T
14	I can develop and maintain working relationships with supervisors or superiors	T
15	I am capable of resolving conflict	T
16	I am able to verbally organize and communicate ideas appropriate to the situation.	B
17	I am able to organize and communicate ideas in writing appropriate to the situation	B
18	I understand basic principles of business.	B
19	I understand how marketing is used effectively within an organization.	B
20	I understand the concepts of finance in a business setting.	B
21	I assess opportunity and recognize unmet needs.	B
22	I assess and undertake reasonable risks.	B
23	I can develop my own vision.	B
24	I think and behave ethically	S
25	I am aware of how global issues influence society	S
26	I serve the needs of others.	S
27	I try to make environmentally sensitive decisions.	S
28	I aim to make a positive impact on society.	S

¹ From [10]. ² P= problem solving & critical thinking; T=teamwork; B=business acumen; S=societal issues

The data were collected on paper to ensure that the answers were given in an anonymous way and it is thus not possible to have paired observations (i.e. which pre and post questionnaires come from the same student). Having had that information would have allowed a more powerful statistical analysis and it is worthwhile to consider whether it can be possible to get that information in future studies. As a part of filling out the questionnaire the students are asked to state their study direction. Unfortunately, this was not done by all the students, which would have been useful to see if there are differences between different educations.

4.1 Statistical analysis

The mean scores for each mind-set category (Table 2) show a tendency that after having attended one of the courses the scores are higher than before attending. However, for group S in course 23552 there is a small decrease. All the changes are

insignificant ($p > 0.05$) except for group P in course 23532. This is unexpected since entrepreneurial competences are not taught there, however, due to the possibility of mass significance problems this could be only by chance. It can also be seen that the students rate themselves highly before the course start (well over 3.5 in most cases) and even higher Pre scores (all over 4) were reported by Carpenter et al [10]. Interestingly the B categories (business acumen) are statistically significantly lower compared to the other mind-set categories, whether Pre or Post scores. However, the scores for P, T and S appear similar to each other (although statistically different) when compared before the course and is also seen when compared after the course.

Table 2. Average values for answers in the mindset categories of P, T, B and S

Course	Pre	Post	Significant difference ($P < 0.05$)	Mindset category ^{1,2}
28233	3.98	4.07	No	P
23532	4.07	4.35	No	P
23552	3.92	4.30	No	P
28233	3.81	3.81	No	T
23532	3.74	3.95	No	T
23552	4.04	4.18	No	T
28233	3.43	3.60	No	B
23532	3.41	3.63	No	B
23552	3.48	3.85	No	B
28233	3.85	3.85	No	S
23532	4.12	4.22	No	S
23552	3.95	3.88	No	S
28233	3.77	3.84	Yes	Overall mean
23532	3.84	4.04	No	Overall mean
23552	3.85	4.07	No	Overall mean

1. P= Problem solving and critical thinking; T= Teamwork; B= business acumen; S=societal issues

2. Overall mean represents the mean score for all questions for the course under evaluation.

When the results (*i.e* no significant change pre versus post) found in Table 2 for control courses are compared to what we reported for the course “High-Tech Entrepreneurship” in (2016, 2017) [1] we see some important differences. Most importantly, for all four mind-set groups, a significant increase was found in the scores after taking that course compared to before (p -values < 0.005) [1]. When compared to the control results in Table 2, we can thus conclude that the course on high-tech entrepreneurship did indeed lead to a significant increase in the entrepreneurial mind-set. The strongest effect seen by Rootzén et al [1] was in the mind-set group S where it was estimated to be 2.1. For the rest of the groups it was estimated to be 0.61 (P), 0.69 (T) and 0.66 (B). S was estimated to be much lower before the course and reached the same level as P, T, and B by the end of the course [1]. This pattern is not seen in the new data for the control courses.

5. DISCUSSION AND FUTURE WORK

Overall the average ‘Pre’ scores are high (over 3.4) in the study we conducted here, as well as in our previous study [1], and also in the KEEN study [2]. Given that 3 represents neutral agreement with the statement questioned (Table1) and 4 represents ‘agree’, the observations suggests that on average, at best only 3 (or even 2) points on the scale are being used. The results suggest that the 5 point Likert scale used here should be modified in future work to allow more differentiation between mind-set at the start of a course and that at the end. This would allow more detailed

analysis of the student self-rating in a survey. However the results raise other questions about the mechanisms in play when the students answer the questionnaire, which may skew the results. For example whether the students are able to judge themselves on entrepreneurial competences if they do not already have knowledge about what is being asked for? Are the students' expectations about how they are supposed to be as engineering students a hinder for honest answers to surveys of this kind? Do the students in the previous study [1] have a greater interest in entrepreneurship and can judge their own abilities better?

The results suggest that on average the students believe that they do not have low entrepreneurial traits or self-efficacy before the courses start – even for control courses. However, it is well documented that only a low percent of the population will end as entrepreneurs. It could be speculated that the massive focus on innovation and entrepreneurship education over the last 10 years, even at the junior-high and high-school level has led to a high baseline competence in these areas. In support of this, the 2018 Global Entrepreneurship rankings show that Denmark is ranked 6th in the world (USA being number 1; Switzerland number 2). This raises the question of how education should be conducted to raise the students from an already apparently high entrepreneurial mind-set level to an even higher one that will result in improved innovation and entrepreneurship in society. Pedagogical approaches are probably needed, where there is better alignment between education and real-life entrepreneurship, and where a growth mind-set towards education is ensured [8] and students self-efficacy is consciously trained [11]. To assess the effect of these, more complex and mixed approaches towards education and teaching, studies with a triangulation approach may be required in order to capture the nature of development of an entrepreneurial mind-set among the students. A longitudinal study where students' development of entrepreneurial mind-set and competences are followed during a longer time would be probably be useful. These considerations will form the basis for a larger study about the development of entrepreneurial competences and mind-sets among engineering students in cooperation between DTU, in Copenhagen, and EPFL, Lausanne, within EuroTech University Alliance.

7. SUMMARY AND ACKNOWLEDGEMENTS

We have employed a survey used by the KEEN network to investigate the development of the entrepreneurial mind-set in control courses where innovation and entrepreneurship were not specifically taught and compared these to courses where innovation and entrepreneurship were a central part of the learning objectives. Surprisingly, the results showed that there was a weak trend (not statistically significantly) showing a positive development in the entrepreneurial mind-set in the control courses. Furthermore, the students score themselves very high on the questions posed, both before and after a course. The results raise questions about the adequacy of the surveys used as the only tool for quantifying development of the entrepreneurial mind-set in engineering students. It also indicates that more parameters must be included in a study. Those could for example be to investigate if the faculty teaching courses apply a growth mind-set as their teaching strategy. Such a strategy in itself can be a reason for students to experience that they develop on the traits that define an entrepreneurial mind-set in the KEEN survey. To shed further light on this, DTU and EPFL have initiated an inter-university collaboration and the results will be presented in a future reports.

We thank Hanne Løje at DTU-Diplom for resources to digitise the survey answers.

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Inventory of drop-out rate, interventions and conception in Physics during the first year of study at the Faculty of Electrical Engineering

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Conference Key Areas: Innovative Teaching and Learning Methods, Engineering Skills, Educational and Organizational Development

Keywords: STEM education, drop-out rate, FCI test,

INTRODUCTION

The current situation at Slovak technical universities shows a decreasing trend in the number of students interested in studying STEM subjects. Also, the number of students who prematurely end in the first year of study because they are not able to study at university for a variety of reasons is quite large. Therefore, we joined the project readySTEMgo in which our university set the following goals:

University of Žilina fulfilled the following goals during the implementation of readySTEMgo project:

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- to analyse the drop-out rate freshmen at the University of Žilina and try to decrease the number of drop-outs,
- to evaluate the effectiveness of our intervention tools.
(Some of them were the Summer Course of Physics organized before starting of the semester and interactive Physics lectures organized during Introduction to Physics (first semester) and Physics I (second semester).)
- to plan to learn from our project partners and try to implement their best practices at our university.

1 DROP-OUT RATE OF FRESHMEN

Our previous research revealed that about 30-50% of freshmen drop out during the first year of studying [1, 2].

Table 1. The drop-out rate in University of Žilina. The first number in table stands for the freshmen who drop out during their 1st year, the second number indicates the number of enrolled students.

	2013/14	2014/15	2015/16	2016/17
Faculty of <i>Electrical Engineering</i>	134/412 = 33 %	134/310 = 43 %	110/235 = 47 %	56/233 = 24%
Faculty of <i>Civil Engineering</i>	116/246 = 47 %	62/126 = 46 %	59/109 = 54%	141/196 = 72%
Faculty of <i>Mechanical Engineering</i>	167/340 = 49 %	118/256 = 46 %	70/180 = 39 %	68/235 = 28%

One of the factors influencing the drop-out rate is low prior freshmen knowledge of mathematics and physics (based on internal discussion with students). Another one is their negative attitude towards STEM subjects [1]. Therefore, the question arose how to improve the knowledge of the low-achieving students. One of the possible solutions to this problem was to supplement the lack of freshmen knowledge at the beginning of their studies.

2 INTERVENTION TOOLS

Therefore, we offered our freshmen the pilot introductory summer course, which aim was to enhance the prior knowledge and to foster participants' awareness in most frequently used concepts from higher mathematics and physics as well as to develop their knowledge in calculus. We started with the courses at the beginning of the academic year 2015/16. The Summer Course, which is discussed in the article, was held before the start of the winter semester of the academic year 2016/2017 and it consisted of 20 lessons and lasted five days. The course was attended by 82 freshmen (students Faculty of Electrical Engineering (FEE) and Faculty of Mechanical Engineering (FMI)), out of those 47 belong to FEE.

To determine the level knowledge of physics at the beginning of the semester, after taking part in the course entitled The Introduction to Physics and after taking part in the course entitled Physics I, we used the standardized Force Concept Inventory (FCI) test [3]. The FCI test is mostly used conceptual test concerning introductory mechanics concepts. We used the FCI test to measure the effectiveness of teaching and development of the students'

conceptual understanding of introductory mechanics. The FCI is available online in many languages.

3 IPMACT AND EFFECTIVENESS

The FCI pre-test was attended by 82 students, the FCI post-test was attended by 38 students, subsequently, the paired test was done (36 freshmen of FEE and FMI). All the students taking part in the Summer Course increased their knowledge level. The average percentage of students' successfulness in the FCI pre-test was 26%, and the average percentage successfulness of 36 students in the FCI post-test after attending the Summer Course was 41%.

To enhance understanding of Newtonian mechanics, students were divided into two groups during their first semester. The control group had traditional lectures focus on quantitative calculations and analysis. The experimental group had interactive lectures which allowed students to model and analyse the motion of objects via videos using program Tracker. By overlaying simple dynamical models directly onto videos, students could see how well a model matches the real world which improved their qualitative understanding [was discussed in 4].

The FCI test was done by FEE freshmen during their first year of study. The pre-test was carried out at the beginning of the term during the first week (September 2016) and it was attended by 223 students (in Fig.4 N = number of students). The post-test was carried out at the end of the semester in the 13th week (December 2016) and it was attended by 207 students. This testing took place in the first semester. Subsequent testing after completing the course Physics I was completed at the end of the 13th week during the summer semester (May 2017) and it was attended by 133 students. Out of whom, some students were no longer in the study at the end of the second semester, some decided to start preparing for the entrance examination to medical universities (mainly biomedical engineering students), others decided to leave and go to work, some failed to complete the test because it was time-consuming (more as 30 minutes) and it was difficult for them to concentrate until the last 30th question.

4 RESULTS AND DISCUSSION

The results of our research carried out previous years and at several faculties showed that the students' knowledge level has increased at the end of summer courses [4] as well as at the end of the first semester after attending interactive lectures [5 – at Faculty of Civil Engineering]. However, it should be noted that despite the increase of the knowledge level of our students, it still does not reach the input knowledge level of students studying at universities abroad and our freshmen even did not reach the minimal threshold (60% of the FCI test) so they are not able to understand Newtonian mechanics effectively [5, 6]. Therefore, it is necessary to think about the results and look for systematic solutions starting from secondary schools so the low prior knowledge of physics and mathematics was not the reason for drop out during the first semester.

Successfulness of students of FEE who participated in the Summer Course of Physics after first semester
 $N = 47$; $M = 77.12$; $SD = 30.41$; $Max = 100\%$; $Min = 0\%$

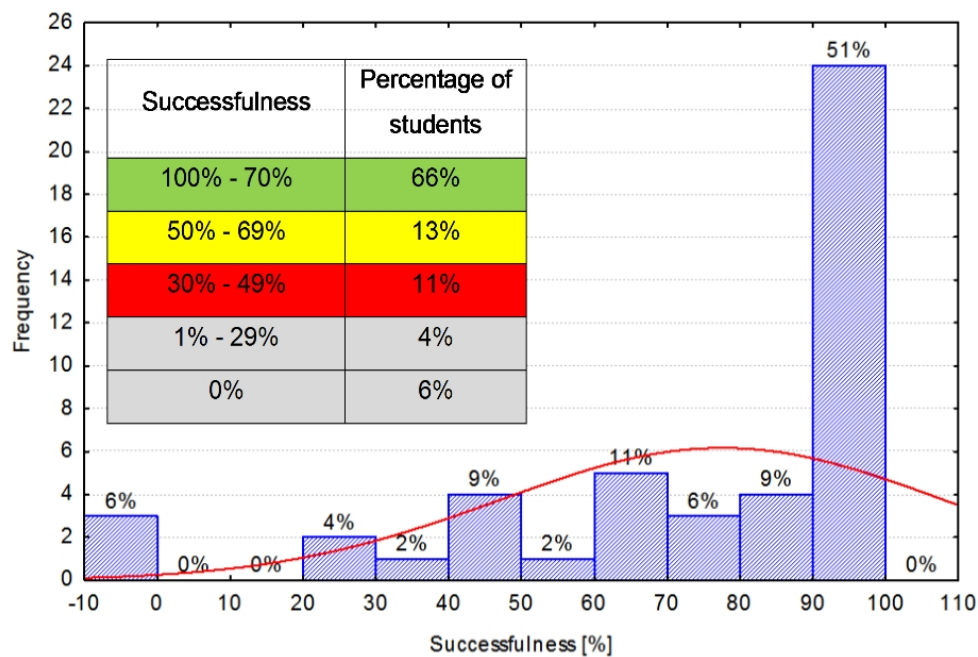


Fig. 1. Successfulness of students of FEE who participated in the Summer Course of Physics (Successfulness represents the percentage of the total number of credits gained during the first semester in terms of ECTS (30 credits = 100%)).

Successfulness of all enrolled students of FEE after first semester 2016/17
 $N = 226$; $M = 75.32$; $SD = 31.42$; $Max = 100\%$; $Min = 0\%$

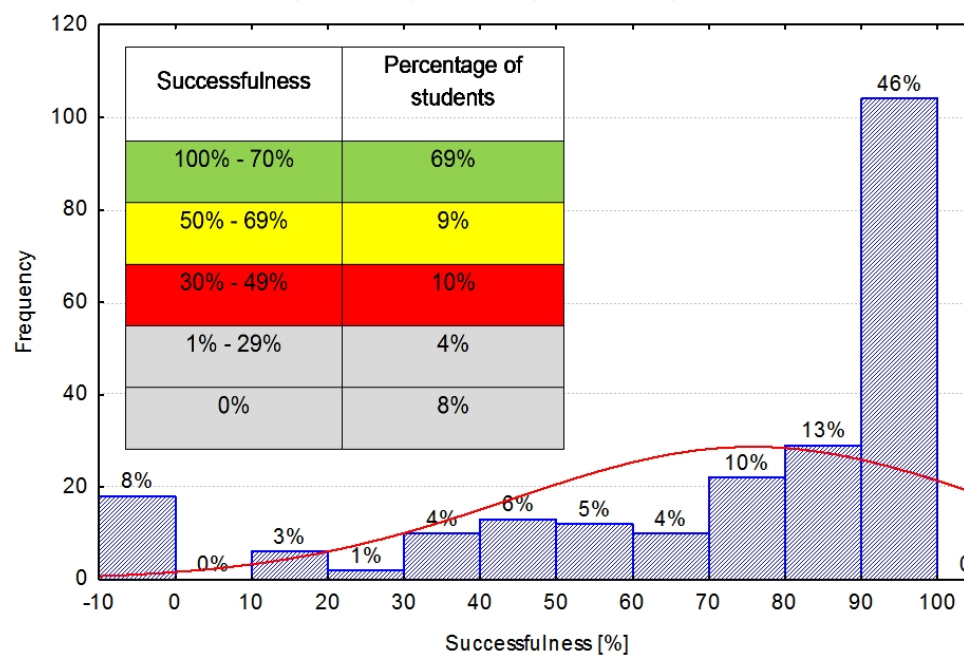


Fig. 2. Successfulness of all enrolled students of FEE after first semester 2016/17

Next Fig. 1 shows the comparison of successfulness of freshmen who participated in the Summer Course of Physics in comparison with the successfulness of all enrolled students at FEE after first semester 2016/17 (Fig. 2). However, it is too early to state whether this tool is the appropriate one in terms of influencing students to continue in their study because the results presented in Fig. 1. and Fig. 2 are comparable. On the other hand, in combination with other interventions such as the attractiveness of interactive methods and formative feedback strategies, it may be one of the key tools. Based on the tables above, only 22% of students are at risk; however, the drop-out rate in academic years 2013/14, 2014/15, 2015/16 was about 33 – 47% [2].

Finally, Fig. 3 shows the successfulness of all students (185) at FEE after the first year 2016/17. The drop-out rate at FEE in 2016/17 after Summer Course of Physics, interactive Physics lectures using the video analysis and simulations (VAS) method of problem tasks) and their integration into STEM (Science, Technology, Engineering and Mathematics) study programme and the implementation of intervention tools into our educational system (tutor, big brother/sister) was reduced to 24% at FEE.

As you can see in Fig. 3, 79% of students (green ones) do not need special attention. They are able to fulfil their duties. 7% of students (yellow ones) need to be *pushed* to study more, 4% of students (red ones) need our guidance and full attention. They need to be *caught by their hand* and led. 9% of students (grey ones) paid no attention to their studies and they did not even try to pass either their written or oral examination in order to gain their credits. (41 students (18%) prematurely failed to finish their studies during the 1st and 2nd semester.)

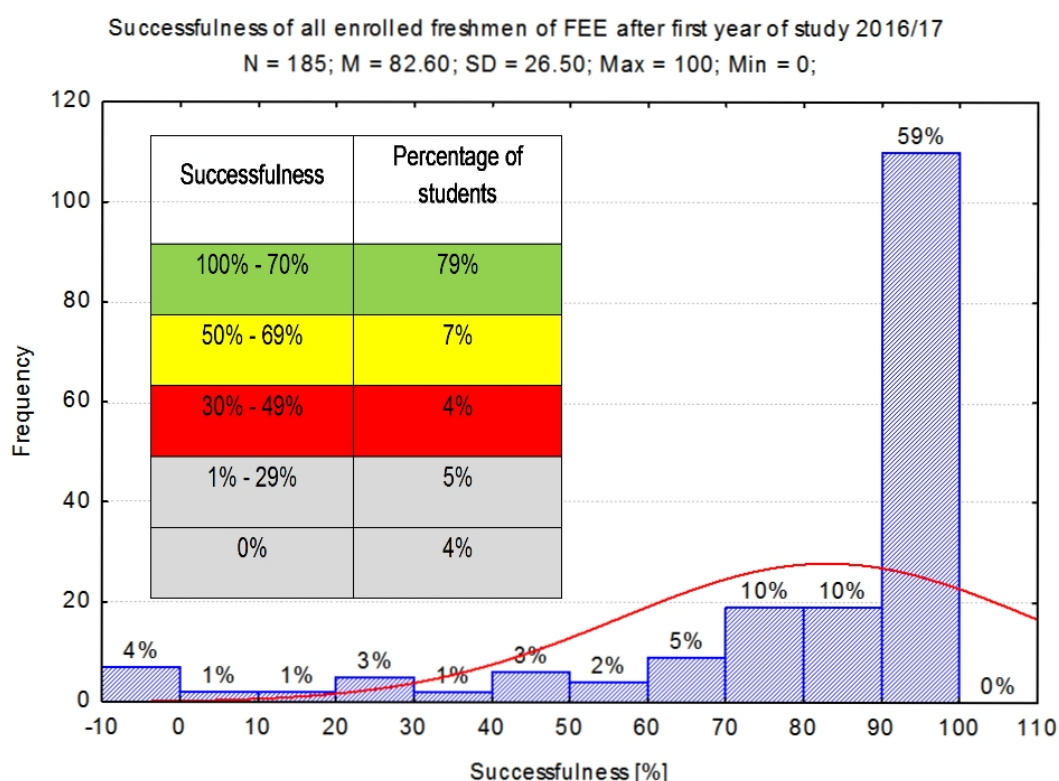


Fig. 3. Successfulness of all enrolled freshmen at FEE after first year of study 2016/17 (Successfulness represents the percentage of the total number of credits gained during the first year of study in terms of ECTS – 2 semesters (60 credits = 100%)).

4.1 Conception in Physics during the first year of study

We used a paired Student's t-test for further analysis. We used only answers of those students who took part in both pre- and post-tests plus answered all questions. As a result of pairing, the number of students was reduced to 100.

Average success rate (in Fig.4 M = mean) of 100 students in the FCI pre-test was 30.43%, and average success rate of students in the FCI post-test after attending The Introduction to Physics was 44.20% and after Physics I was 47.33%. What is surprising for us that the median in the FCI post-test after attending Physics is a little bit lower than after attending The Introduction to Physics I. Fig. 4 shows the FCI pre-test and post-test results.

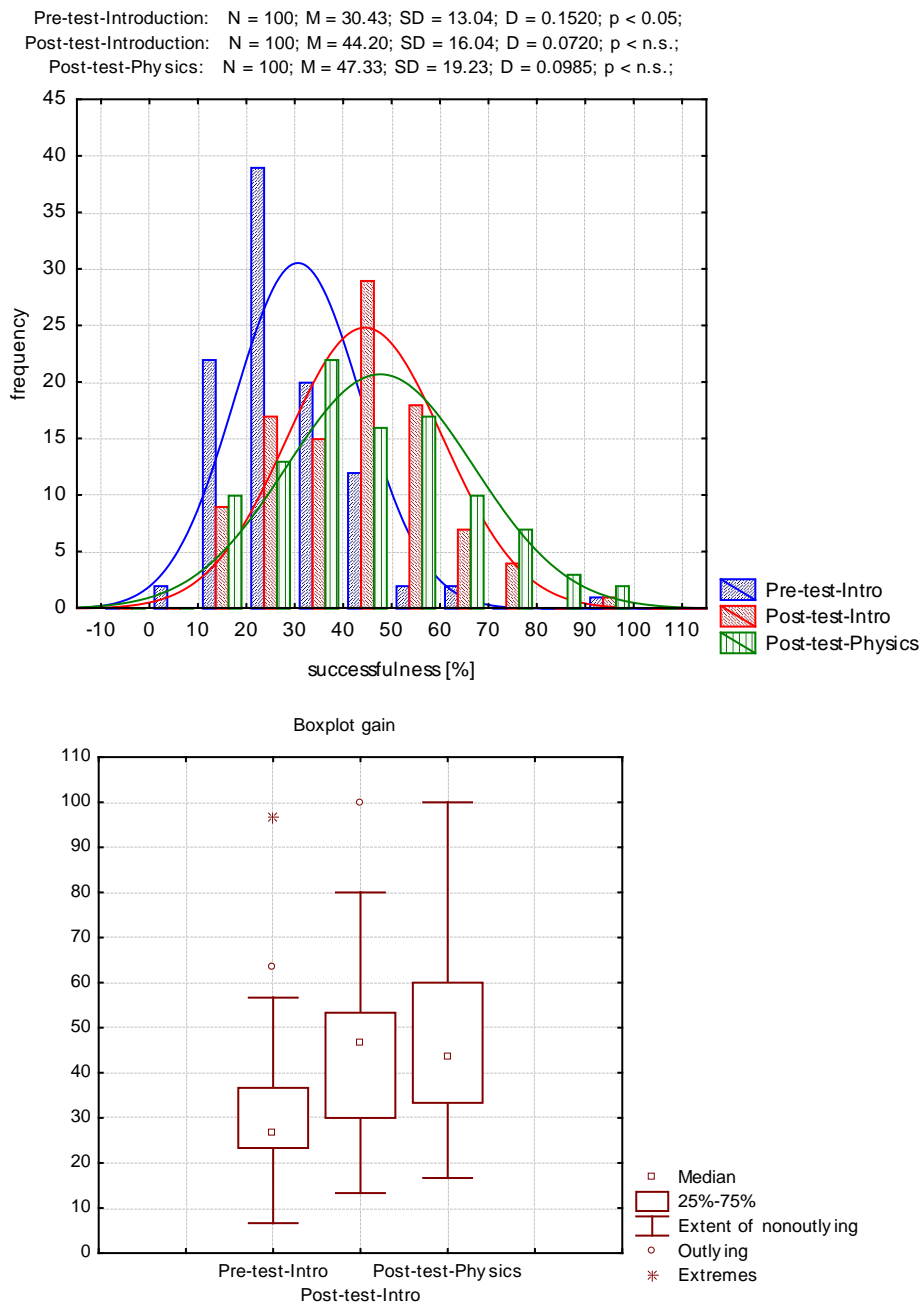


Fig. 4. Numerical data for the histogram and boxplot

The evaluation of the post-tests and the pre-test at the beginning and end of the 1st and the 2nd semester (Fig. 4) confirmed the statistically significant difference between mean at the beginning and the end of the 1st semester ($P < 0.001$, $t_{\text{stat}} = 9.68 > t_{\text{critical}} = 1.98$) and between mean at the beginning and the end of the 2nd semester ($P < 0.01$, $t_{\text{stat}} = 2.78 > t_{\text{critical}} = 1.98$). (The post-test at the end of the 1st semester was considered the pre-test at the beginning of the 2nd semester).

Based on gained data we cannot state that the Summer course helped to eliminate the drop-out rate. The only thing we can prove is that the drop-out rate was reduced. We assume that the drop-out rate was reduced due to interactive lectures during the first year of study. In the future, we would like to find out the way how to verify the effectiveness of our interventions with regard to the drop-out rate; to be more specific, the focus will be placed on the Summer course.

5 SUMMARY

The common goal of the readySTEMgo project was to deliver the best scientist and engineers by providing a study environment that (1) optimally supports the development of STEM skills and (2) engages into learning outcomes that lead to high employment of future graduates [7, 8]. The main achievements of the readySTEMgo project were working on lowering the drop-out rate of freshmen, figuring out which intervention tools seem to be most appropriate and the implementation of intervention tools into our educational system.

Using the Summer Course of Physics, the Interactive Physics lectures using the video analysis and simulations (VAS) method of problem tasks and their integration into STEM (Science, Technology, Engineering and Mathematics) study programme and the implementation of intervention tools into our educational system (tutor, big brother/sister) the drop-out rate was reduced to 24% at FEE after three years from starting implementing the readySTEMgo project.

By implementing this project, we have started an initiative to support mathematics and physics, worked on better guidance for students interested in the STEM study program. In future, we plan to continue organising the summer course of mathematics and physics, using interactive lectures and focusing on not only the cognitive skills but also the noncognitive skills of our students.

ACKNOWLEDGMENTS

This work was supported by the by the Slovak Grant Agency KEGA through the projects No. 012TU Z-4/2017, No. 029ŽU-4/2018 and project Erasmus+: Strategic Partnership: Early identification of STEM readiness and targeted academic interventions (readySTEMgo): grant Decision number: 2014-BE02-KA200-000462. Authors would like to thank to David Koch from Arizona State University for providing the FCI.

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Practical Education of Quantum Engineers

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Conference Key Areas: teaching creativity & innovation, the teacher as a supervisor, engineering skills

Keywords: quantum technology, engineering, CDIO,

INTRODUCTION

We are currently in the midst of a technological transition commonly termed “the second quantum revolution”. Building on advancements in our ability to control,

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² ulrich.hoff@fysik.dtu.dk Two photons generated probabilistically into separate spatial modes. By detecting a photon in one mode, a single photon is conditionally prepared in the other mode.

manipulate, and detect quantum objects, accumulated over the past decades, quantum physics phenomena such as entanglement and superpositions are now employed as resources for novel quantum technologies such as quantum computers, quantum cryptography, and quantum sensors. Expectations are high, and the emerging technologies are foreseen to impact and benefit society at large. However, there is a shortfall of creative and innovative quantum engineers with an in-depth grasp of quantum physics and practical experience with the relevant experimental techniques, who can bridge the gap between fundamental science and engineering and take a lead in the quantum innovation process. This was also a central issue in the *Quantum Manifesto* [1] which paved the way for the recently launched EU FET Flagship on Quantum Technologies.

Here, we report on the recently initiated undergraduate course “Experimental techniques in quantum technology”, held at DTU Physics in January 2017. Targeting practical education of quantum engineers, the course implements elements of the CDIO (Conceive-Design-Implement-Operate) framework [2] and stimulates creative and innovative problem solving in the context of quantum technology. The task we pose the students is: *Pick a quantum technology, implement it, and make it operational in 3 weeks!*

1 COURSE PREPARATIONS

In the following sections we summarise our considerations about the learning objectives for the course and how to enable the students to meet the set goals within the framework of the course.

1.1 Learning objectives

A key role for quantum engineers will be to merge research and technology. This requires a profound understanding of quantum physics, its experimental implementation and the techniques involved, and not least the ability to explain and discuss both theoretical and practical aspects of an experimental setup. Equally important skills for quantum engineering, belonging to the core of engineering in general, relate to participation in teamwork efforts towards practical solutions to concrete bounded problems. Those are exactly the competences the CDIO framework seeks to enhance through project-based learning. Last but not least, an engineer working in quantum innovation should be careful and meticulous about her work and able to document and justify all actions taken on the grounds of empirics and analyses. Those are basic requirements for engineering and research in general, but even more so for emergent technologies where the competition is strong and possibilities for taking out patents should be kept in mind.

The above considerations were condensed into a set of learning objectives for the course as presented below. Except for the subdivision into categories of objectives, the learning objectives given in the course description were exactly as follows:

A student who has met the objectives of the course will be able to:

(Quantum engineering specific objectives)

- *Transform elements of quantum theory into practical quantum technology*
- *Analyse the properties of quantum light sources*
- *Explain the different techniques used in a particular quantum technology*
- *Discuss experiments in quantum optics*

(CDIO related objectives)

- *Diagnose and evaluate technical imperfections in experiments*
- *Identify, design and implement optimal data analysis strategies*
- *Organize, plan and carry out collaborative work in group projects*

(General scientific and engineering related objectives)

- *Document experimental lab work*
- *Present and defend experimental work*

1.2 Resources and course plan

At DTU Physics we have recently established an educational facility, which enables students to gain hands-on experience with some of the phenomena underpinning quantum technologies through advanced quantum optics experiments. The facility includes 5 sets of commercially available experimental setups (Figs. 1 & 2) which offer students the opportunity to investigate on their own e.g. the phenomenon of quantum entanglement via tests of Bell's inequality with entangled photons [3].

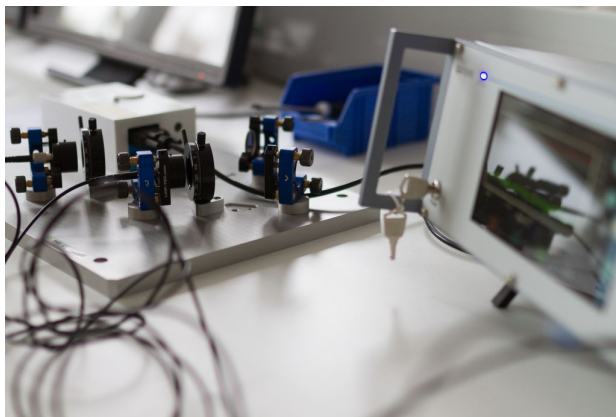


Fig. 1 quED entanglement demonstration setup from qutools GmbH.

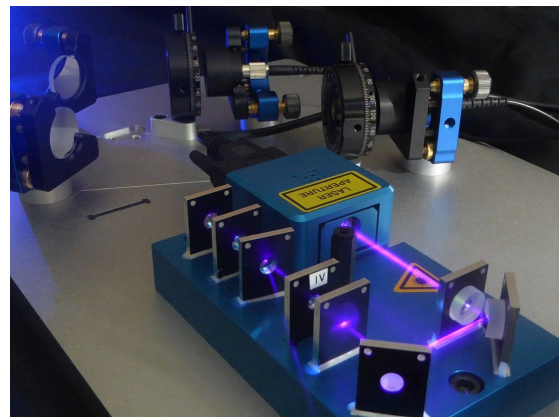


Fig. 2 A look inside the quantum light source that generates entangled photon pairs in the quED setup.

Apart from quantum light sources capable of delivering both heralded single photons² and entangled photon pairs, the experiments also include avalanche photodiodes (APD) for single photon detection, manual and automated polarisation

² A pair of photons is generated probabilistically into separate spatial modes. By detecting a photon in one mode, a single photon is conditionally prepared in the other mode.

optics, and data acquisition. In the context of the course, the setups constituted the experimental backbone, giving students access to research grade systems and technologies and enabling hands-on creativity about implementation of quantum technologies. During the course, the experimental setups were relocated to a dedicated teaching environment for which the students had all-day access. This was done with the purpose of facilitating build-up of an intense and intimate innovation atmosphere that stimulated teamwork and technological creativity. Furthermore, the infrastructure at the department provided access to the following resources throughout the course: a broad selection of measurement equipment, electronics, a supply of optics components, fine mechanical workshop, 3D printing, and a high performance computing infrastructure for data analysis.

The course was designed for a 3-weeks period, and a total workload corresponding to 5 ECTS credits or 138 hours. The CDIO structure is inherent to the task we posed the students, but to make the structure more visible and force the teams to set deadlines for their progression stages, it was also implemented in the course schedule. The planned structure for the course is summarised in Table 1.

Table 1: Tentative course structure

Phase	Description
0	<p><i>Course start (day 1)</i></p> <p>Pre-test (written questionnaire and assignments) to gauge students' theoretical and experimental background in quantum physics and their proficiency in programming, instrumentation/data acquisition, data analysis, and documentation/presentation.</p> <p>Introductory lectures on quantum key distribution (QKD) [4] and quantum sensing with NOON states [5] including a number of problems the students could choose to address for each technology.</p> <p>Hands-on experience with experimental setups.</p>
1	<p><i>Problem selection / Team formation / "Conceive" (day 2-3)</i></p> <p>Formation of project teams (3-4 people) based on chosen problems.</p> <p>Conceiving of the actual problem to be solved through discussions and literature study.</p>
2	<p><i>"Design" (day 4)</i></p> <p>First iteration of problem solution and plan for experimental implementation.</p>
3	<p><i>"Implement" (ramp-up end of week 1 + week 2 + beginning of week 3)</i></p> <p>First implementation ► experimental feedback ► re-iteration of design ► modification/extension of implementation.</p>
4	<p><i>"Operate" (week 3)</i></p> <p>Demonstrating the feasibility of the implemented solution. Data acquisition.</p>
5	<p><i>Preparation for evaluation (end of week 3)</i></p> <p>Summary of problem, chosen strategy, actual work done, and faced challenges. Selection of key results and data to present. Preparation of poster.</p>

Since students from different departments and hence with different educational backgrounds and experiences was expected to attend the course, a pre-test was prepared for the first day to gauge their proficiency in areas central to the course.

Subsequently, a brief introduction to quantum technology was given together with more detailed presentations of the two emerging technologies selected for the course and central issues for those. On that basis the students were asked to choose what technology to work on and form project teams of up to 4 people. Throughout the remainder of the course, no lectures were scheduled and the authors took the role of supervisors rather than teachers. Upon request from the students, short lectures introducing new theoretical or experimental concepts were given when required for the further progression of the teams. Each team was requested to keep a detailed logbook documenting their progress, data, and internal discussions and considerations about how to solve problems or what strategy to follow. Once every day a brief supervision meeting was held with each team, for which they were requested to prepare a short summary of the findings, progress and challenges of the previous day.

Due to the open curriculum of the course and the focus on process rather than achieving a pre-defined goal, a passed/not passed evaluation form was chosen. The final evaluation was arranged in the form of a mini conference open to the rest of the department. Each team was required to present their quantum technology and document and defend the progress made towards an implementation of it in the format of a scientific poster. In addition to the continuous discussions with the teams, this enabled an evaluation of the students' understanding of their topic and ability to engage in a discussion of it and thereby assess their ability to meet the general scientific learning objectives.

2 COURSE REALISATION

In the end, 7 students attended the course. Given the pilot test character of the course and the amount of experimental equipment available, this turned out to be a very suitable number. Three teams were formed, two teams (2 and 3 people) working on QKD and one team (2 people) working on quantum sensing.

During the design phase, it became clear that the two different types of projects involved challenges of very different character. Whereas the quantum key distribution projects required the students to make only small modifications to the existing setups, but a vast amount of programming for automation, data acquisition, and analysis, implementation of quantum sensing required that team to layout and construct an entirely new optical setup. As our undergraduate students are generally very skilled and experienced in programming but much less so in experimental optics and laser physics, this enabled the QKD teams (Fig. 3) to advance much faster than the quantum sensing team (Fig. 4). In the end the latter team did not manage to achieve a successfully operating system. The design was implemented but they were unable to demonstrate the expected quantum-enhanced performance. Despite

the disappointment of several failed attempts, the team maintained a constructive and enthusiastic approach. After realising that they would not be able to reach the 'operate' phase within the given time frame, they took a step back to discuss, reconsider and re-iterate the design. This was an important example of how the process-oriented and active approach to learning can turn negative results into a precursor for deep learning [6].

In contrast to the negative results on quantum sensing, the efforts on QKD were much more fruitful and resulted in operational systems implementing the B92 protocol [7]. Furthermore, the teams were able to proceed with investigations of quantum properties of the system such as photon indistinguishability via Hong-Ou-Mandel interference [8], measurements of the second order quantum coherence of the employed heralded single photon source [9], and characterisation of the total detection efficiency.



Fig. 3 Discussion of the QKD system performance.



Fig. 4 The quantum sensing team implementing their interferometer design.

Characteristic for the entire course was that all participants showed a very high level of engagement and motivation for the projects and appreciation of the “real-world” problems and challenges associated with the practical approach to quantum engineering. This was confirmed by the students’ answers to a Course Experience Questionnaire at the end of the course. On a scale 0-5, the questions ‘*Course stimulated enthusiasm for further learning?*’ and ‘*Course motivating?*’ both got an average score of 4.57. On the other hand, the problem-based approach and the responsibility for progression and learning being with the teams themselves, somewhat disconnected the students from the syllabus. This was reflected in an average score of 3.71 to the question ‘*Having a clear idea about where to go and what was expected?*’. A related concern was expressed in a comment from one of the students: ‘*The course schedule was very vague and too open.*’ This should be kept in mind for future courses and addressed through the supervision process and a clear introduction to the CDIO framework. Such planning and structure related issues result from the teachers’ lack of experience with implementation of CDIO. As one of the students added: ‘*It was obvious to us that it was the first time the course was*

taught'. However, despite the shortcomings the students' overall evaluation of the course was generally positive as exemplified by the statement: *'All-in-all a good 3-weeks quantum course which I am sure will become really great after a few trials'*.

3 CONCLUSION AND DISCUSSION

In conclusion, we have prepared and conducted a first pilot testing of a problem-based undergraduate course on practical education of quantum engineers, building on the CDIO structure and principles. The motivation was to establish a frame for creative and innovative thinking about practical implementation of quantum technologies that fosters deep learning and can be used as a boot camp for training the next generations of quantum engineers.

The experiences acquired so far are generally very promising, as are the evaluations and feedback from the students. We are confident that the problem-based approach is an adequate way to stimulate quantum innovation while at the same time creating awareness of the associated real-world technical problems and challenges. With only 7 students attending this first and so far only iteration of the course, the evaluation data is, however, unarguably wanting in quantity. Several consecutive runs with a large course volume would be required for development and documentation of a successful implementation of CDIO principles in quantum engineering education. Larger course volumes and faculty involvement would also allow for an increased focus on industry relevant aspects such as project management and introduction of project sponsors [10]. However, the highly specialised components required for harnessing quantum phenomena for technological innovation poses an economical barrier for up-scaling the course volume as the costs for establishing suitable workspaces (CDIO Standards 6) are immense. As quantum technologies mature, this issue could partly be resolved through industry-based projects [11] co-financed by the involved industry partners. From an educational point of view, this would enable learning in a real-world context, while for the industries a rather small investment would buy a valuable link to fundamental research, currently driving the quantum innovation process, as well as a unique opportunity for early recruitment of quantum engineers.

It is clear that a single project-based course is insufficient for spurring quantum innovation. Hence, we believe the curriculum for a future quantum engineering study programme should give students at least two encounters with the CDIO approach, cf. CDIO Standards 5. The 3-weeks period, in which the present course was given, is suitable for a first experience with project-based learning and could address any part of the basic engineering curriculum or an interdisciplinary cross-field of several [12]. This should then be followed by a long-term (full semester) project, preferably industry-based, specialised on a particular quantum technology. Combining existing theoretical courses at DTU Physics, which provides students with profound theoretical understanding of quantum physics, with a series of progressively challenging CDIO projects would constitute a strong and inspiring framework for

educating engineers with optimal skills for advancing the field of quantum technology.

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Fostering 21st Century Skills through Interdisciplinary Learning Experiences

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Conference Key Areas: Teaching Creativity & Innovation, Innovative Teaching and Learning Methods

Keywords: Interdisciplinary, Active learning, 21st century skills, Design principles

INTRODUCTION

Digitalisation in developed economies has changed the skills required for many jobs. Preparing engineering students for the 21st century workplace is a challenge. Indeed, novel technology-rich work environments combined with ill-defined, open-ended problems require diverse teams to deal with them [1]. To prepare students, emphasis on design thinking, real world thinking and interdisciplinarity are key. However, we argue that many higher education curricula for engineers are severely siloed and rarely allow for such interdisciplinary educational activities. To address this issue, this article asks the following research question: *how can courses be effectively designed to foster 21st century skills?*

To answer this question, this article presents 3 case studies of interdisciplinary courses tackling 21st century skills. From these different case studies covering from 1 to 5 years, involving a total of 300 students and 20 educators, we extract 5 design principles to help future course designers and researchers. We used mixed methods to analyse the case studies. We relied on interviews with teachers, in-depth surveys from students evaluating the teaching (SET) as well as activity traces on online interaction technology used in the courses. We use a design-based research (DBR) approach, as reviewed by Anderson & Shattuck for educational research [2]. In this approach, we went through several iterations of each case study (one per academic year) to extract five learning experience design principles that can be reused by other researchers and practitioners.

1 RELATED WORK

The skills required for successfully navigating the workplace in the digital age are often referred to as 21st century skills. Such skills, rather than being specific to a particular discipline, are transversal. "Success lies in being able to communicate, share, and use information to solve complex problems, in being able to adapt and innovate in response to new demands and changing circumstances, in being able to marshal and expand the power of technology to create new knowledge, and in expanding human capacity and productivity" [3]. Binkley et al. [3] provide a framework based on an analysis of a dozen of different frameworks to help educators and course designers to think about assessing 21st century

skills. They have identified four groups of skills: ways of thinking, ways of working, tools for working, living in the world.

Ways of thinking shift away from more straightforward thinking skills such as recall or drawing inferences towards higher order thinking skills, which require more focus and reflection, such as: (1) creativity and innovation, (2) critical thinking, problem solving, decision making, and (3) learning to learn and metacognition.

Ways of working include skills to manage interactions in a more decentralized work environment. Such an environment requires more elaborate (1) communication skills to convey information to others, as well as more astute (2) collaboration skills, to work more efficiently with others, who can also be from different intellectual or cultural backgrounds.

Tools for working cover new skills needs in terms of (1) information literacy in general, which include research on sources, evidence, or biases, as well as (2) technology literacy. These skills includes understanding how to effectively use digital and analog tools to support different work tasks, but also understanding their potential limitations and ethical implications.

Living in the world covers skills to live in a world which has become more interconnected and where it is not enough to be familiar with local issues, as actions can have global consequences. These skills include (1) citizenship, (2) life and career, and (3) personal and social responsibility – including cultural awareness and competence.

It seems unlikely that traditional education programmes are best suited to developing such attributes and this has, in a sense, been recognised for many years. In the late 1990s and early 2000s, the ABET and other accreditation requirements were reformulated so that they focused on skills or competencies rather than the titles of courses taken. This meant that programmes were no longer constrained to offer particular courses, and instead, they were free to approach competencies in a way that was, in the words of Ollis et al. [4, p. xiii] “freed from disciplinary blinders”. This was also reflected in the development of a number of engineering schools, which aimed at better integration of social issues alongside technical disciplines as well as better integration of design thinking, and group processes within engineering education [5]. However, in many cases, e.g., [6,7,8], such interdisciplinary approaches continued to be seen as add-ons to already crowded curricula rather than substantively integrated components. In this context, Kazerounian and Foley [9, p. 762] for example, have argued that the dominant paradigm in engineering education teaches that there is a known correct answer and that the student’s task is to find this answer as quickly and efficiently as possible. As a result, “factors (...) that impede creativity are far more profound and dominant in the engineering education than they are in sciences education and (...) in liberal arts education”.

2 CASE STUDIES

Below we present 3 case studies of interdisciplinary courses at our institution that foster 21st century skills. Table 1 presents an overview of the course formats and population, whereas Table 2 illustrates how each course maps 21st century skills following the framework provided by Binkley et al. [3]. We briefly present each case study and highlight the most interesting characteristics.

Table 1. Case study overview

Case Studies	Format	Students in Year (background)	Lecturers
Case study 1: Social Media	14 weeks, 90 min per week (6)	Y1: 60 (60 STEM) Y2: 48 (48 STEM) Y3: 62 (49 STEM, 13 design) Y4: 51 (39 STEM, 12 design) Y5: 64 (48 STEM, 16 design) Y6: 66 (53 STEM, 13 business)	2 (engineering, Information systems), 3 guest speakers
Case study 2: Humanitarian Technology	14 weeks, 90 min per week	Y1: 23 (STEM) Y2: 57 (STEM)	2 (history, information systems), 4 guest speakers
Case study 3: Prototyping	Y1: bloc week (21 hours) Y2: 14 weeks, 90 min per week	Y1: 6 (3 business, 3 geoscience) Y2: 51 (35 STEM, 16 business, 1 political science)	3 (design, information systems, economics), 1 guest speaker

2.1 Case Study 1: Social Media

The social media course introduces Master students to human computer interaction methods relevant to designing social media platforms. The course is in its 6th Year and currently counts 66 students, (44 STEM, 12 business). In previous years, there were also around 12-15 design students in the class (in Year 6 the design students could not attend due to calendar conflicts). The course is divided in two parts. The first part consists mainly of lectures and ends with an individual mid-term report. Students are required to peer review 5-10 reports. The second part of the course focuses on teamwork. Students are asked to form interdisciplinary teams and design a novel social media solution using lean entrepreneurial methods (e.g., value proposition canvas, agile development). At the end of the semester each group is required to perform a presentation and deliver a report.

A Student Evaluation of Teaching (SET) was conducted in Year 5 with 59 participants (out of 69 students). The results show that most students are satisfied or very satisfied with the course (71%). Interdisciplinarity was appreciated by a large majority of student (87% report having enjoyed working with students from other programs) and 82% see how the interpersonal skills they practiced doing the project will be useful for working in an interdisciplinary environment. This was also reflected in the student comments. One of them noted "It was nice to meet and collaborate with people from [the design school]", another wrote "Interesting interdisciplinarity!", a third "It was cool to work with [name of the design school] students". However, a few students raised some issues. For instance, one of the design student complained that she/he did not "like the moment when we assign groups by default because only one person from [the design school] by crew." Another one had the impression that most of the work was done by the designer in the group. Indeed with the unequal number of students from different backgrounds, interdisciplinarity was enforced by assigning one designer per group. In the latest iteration this rule was relaxed. Peer review of student reports was also appreciated by most students (72% agreed that they received useful feedback from peers and 76% thought it was useful for them to assess the project of their peers). However in the first iteration of the course, students complained because the peer review assignment was too time consuming. At the time they had to review 10 two-page reports. We reduced the number to 6 subsequently.

2.2 Case Study 2: Humanitarian Technology

The humanitarian technology course introduces bachelor science/engineering students (57 in Year 2) to humanitarian technology. More specifically the course discusses how information

technology transformed the humanitarian sector over the last ten years. It also shows how the technological revolution may cause undesired effects like marginalizing people who do not have the skills or the means to access information technology. The course is divided in three parts. The first one consists mainly of lectures with several guest speakers from the humanitarian sector. The second part exposes students to technology by doing hands-on exercises (e.g. analysis of satellite imagery using geographic information systems). The third part focuses on teamwork (groups of 5). Students are instructed to critically analyse a digital tool used in a specific context by a humanitarian actor. At the end of the semester, all groups present their project and deliver a report.

A SET was conducted in Year 1 with 18 participants out of 23. The SET showed that 72% were satisfied or very satisfied with the course. Students' feedback highlighted the "living in the world" perspective of the course: "I find this course really interesting, because it addresses really important current issues. The fact that guest speakers came during the course, made it even more interesting". Despite mostly positive comments there was some demand for more "debates between participants" as one student noted. In Year 2, this issue was addressed by including more hands on activity and debates. For instance, we used a digital interaction system to gather opinions and trigger face-to-face debates. A SET conducted in Year 2 with 46 students out of 57 showed an overall higher satisfaction level (85%) and a high satisfaction for the new digitally mediated debates (83%).

2.3 Case Study 3: Prototyping

The prototyping course introduces bachelor students to design thinking methodologies. After a pilot conducted in Year 1 with 6 participants, Year 2 counts 51 students (35 from science/engineering, 15 from business, 1 from political science). The course is centered on teamwork (groups are interdisciplinary and formed by the lecturers). The core task of the teamwork is to design a prototype to nudge behaviour towards a more sustainable campus. The particularity of the course is the fact that in every lecture there is a majority of time devoted to short time-boxed hands on activities preceded by short theoretical introductions. Hands on activities include creative tasks such as ideation, analytical tasks such as defining a user journey map, or evaluation tasks, such as providing feedback to other students. The heterogeneous nature of the audience (i.e. affiliated to different schools/sections) implies that students find it hard to work together outside of class so that time spent together in class therefore becomes even more valuable;

A SET was conducted in Year 1 with all 6 students. In addition an in depth observation by two pedagogical counsellors was conducted and the experience was documented. Overall the workshop was deemed useful. Participants found the iteration loops and creativity involved in the process particularly interesting "being able to use a number of creative tools allowed me to regain my old-world imagination and, automatically, ideas and concepts that I probably would not have found without them." It should also be noted that there was an interpersonal conflict in one of the groups, which was resolved after the intervention of a mediator. Time pressure was both regarded as stimulating but also as something preventing reflexivity. A SET evaluation in Year 2 with 30 participants out of 51 showed that 89% were satisfied or very satisfied with the course. Further, 96% agreed or strongly agreed with the usefulness of giving/receiving feedback from fellow students; 90% agreed or strongly agreed with the usefulness of having hands-on activities. Time pressure and interdisciplinarity were also generally viewed as positive (74% and 80%) but it also met with some level of disagreement (10% and 7%). It should be noted that in Year 2 there was also an issue with a group that had to be split up and members reassigned due to conflicts.

Table 2. Mapping between case studies and 21st century skills

21st century skills (Binkley et al 2012)		Case study 1: Social Media	Case study 2: Humanitarian Technology	Case study 3: Prototyping
Ways of thinking	Creativity and innovation	Collective Ideation	Assess innovation	Ideation, sketching
	Critical thinking, problem solving, decision making	Peer review	Peer feedback Critical ICT assessment	Peer feedback, user-centric, test driven
	Learning to learn, metacognition	Agile process	Connecting information and arguments	Agile process
Ways of working	Communication	Presentations, report	Presentations, report	Presentations, report
	Collaboration	Teamwork	Teamwork	Teamwork
Tools of working	Info. literacy	Evidence-based design	Research on sources	Evidence-based design
	ICT literacy	Social media design skills	ICT in crises	Maintain a blog
Living in the world	Citizenship	Social Media	Humanitarian Issues	Sustainability
	Life and career	Produce results	Produce results	Produce results, Manage Time
	Pers & soc. resp.	Interdisciplinarity	Interdisciplinarity	Interdisciplinarity

3 DESIGN PRINCIPLES

Based on the best practices evaluated iteratively in the case studies described above, we present five design principles to help design learning experiences for the 21st century.

3.1 Content that matters

Learning experiences should be built around content that matters, societal issues and real world thinking (Living in the world). Our case studies underline the fact that societal issues such as humanitarian work, or sustainability can be transversal goals for graduates who are particularly engaged when confronted with addressing important challenges. Such topics require thinking beyond one's own expertise to weigh diverse competing knowledge claims and to make decisions without clear right answers. It should be noted that in the case studies the content gives the context of the course, and the real learning outcomes are based around the process (whether creative, critical, or entrepreneurial).

3.2 Timeboxed hands-on activities

Learning experiences should integrate active timeboxed hands-on activities. Involving students through active learning activities has been found to be an effective way for them to learn (Ways of thinking) [10]. Students should be introduced to adequate tools to support hands-on activities, whether low-tech, such as visual canvases to structure ideas, or high-tech, such as online platforms to share resources (Tools for working). Our case studies showed that time pressure can make the course more enjoyable, but it should be well scaffolded as it can potentially frustrate some students. Integrating documentation and

reflection in such fast pace activities is challenging as students can find it hard to pause and reflect upon their learning.

3.3 Meaningful peer interaction

Learning experience should take advantage of the presence of students to foster peer-to-peer interactions and peer instruction (Ways of working). Our case studies show that interaction between students is appreciated. Peer review can also be used successfully, whether of assignments or informal deliverables. Furthermore group interactions around brainstorming, sharing opinion, understandings or debates, can be effective when scaffolded adequately. To do so, there can be a range of tools that can be used (Tools for working), from low-tech options such as stickers to vote, sticky notes or drawings, to high tech options such as social media apps or shared online artefacts.

3.4 Build interdisciplinary teams

Learning experiences should include students from different disciplines and bring them to work together in interdisciplinary teams (Living in the World). Our case studies show that working in interdisciplinary team is appreciated by students, but can present difficulties. The difficulties of working in interdisciplinary context range from communication differences, often referenced to as “he/she does not speak my language”, to change in perspectives and attributing values and importance to different things [11]. Thus, it is essential to scaffold these interdisciplinary groups effectively. For instance providing students with outside mediation or better yet with tools to identify and resolve conflicts.

3.5 Bring perspectives through a diverse teaching team

Learning experiences should include diverse teaching perspectives. Along the maxim “practice what you preach”, it is important that students understand that interdisciplinarity is not something that only comes from them, but is also practiced by the teaching team. For teachers, to be confronted to the perspectives of others enables them to get a sense of what students are experiencing. Including external speakers is one way of bringing different perspectives, another is to co-teach courses in interdisciplinary teams.

4 CONCLUSION

Designing interdisciplinary learning experiences to support transversal 21st century skills is challenging and such skills cannot be expected to be developed in full through a single course. In this paper, we drew five principles to help design diverse learning experiences on three case studies, which spanned over several years and included 488 students. With the advent of online education, it is crucial that universities rethink the added value of bringing students to campus.

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Developing Engineering Students' Entrepreneurial Mindset

Case Study: Technical Innovation Project Course

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Conference Key Areas: Innovative teaching and learning methods, University-business cooperation, Fostering entrepreneurship

Keywords: Entrepreneurial mindset, Self-assessment, Project work

INTRODUCTION

Entrepreneurship as a competence is considered today as one of the key skills needed in the knowledge-based society and economy. It applies to all spheres of life, helping people to develop their skills, knowledge and attitudes needed when achieving their goals.[1] It is not important only for the students aiming to start up an own company, but to all the university students who will enter in the demanding working life, and start building up a career, when life-long learning, and team, leadership and innovation skills are vitally needed.

Teaching entrepreneurial skills during the Master's studies enables to raise the students' awareness of the skills needed in the working life in a complex world. It thus helps them to take ownership of their own success when leaving the university and starting to create their career. The skill set cannot be learned in one go, but it takes

continuum to develop oneself from the beginner's to the advanced or expert level. The entrepreneurship skill set is best learned through experience, in an environment that fosters entrepreneurial thinking and activity [2, 3]. Teacher feedback and self-assessment can give additional support in the progress.

European Commission (EC) has promoted entrepreneurship in education since 2012 [4], and the development of the entrepreneurial education has progressively grown on European level. Entrepreneurship Competence Framework (EntreComp), a tool for improving the entrepreneurial capacity of European citizens and organizations, was developed by the EC. It introduces key components of entrepreneurship as a competence, a shared conceptual model for entrepreneurial learning, and a list of learning outcomes that anyone can refer to when demonstrating a certain level of proficiency in entrepreneurship competence.[5] Funding for educational development projects which focus on increasing the entrepreneurial skills and mindset, is provided e.g. by the European Innovation and Technology Community (EIT).[6]

This is a case study done in Aalto University where the Technical Innovation Project course was revised as part of an EIT funded project. New teaching and assessment methods were needed for assisting the students to develop their entrepreneurial mindset, and understand that this is the competence needed in the future working life. This paper discusses on how the students' entrepreneurial skills developed during the course: Did students learn entrepreneurial thinking and gain a right kind of mindset for recognizing and solving problems, as indicated in the learning outcomes of the Technical innovation project course?

1 TECHNICAL INNOVATION PROJECT (TIP) COURSE

This course was prepared by modifying an existing technical project work course that had been run at Aalto metallurgical master's program for two decades. In the old project course, a traditional approach was taken as the aim was to solve a technical problem, pre-set by the university staff. The students had to try to reach close to the technical level of the staff, without any industry involvement.

Developing a new course became possible in the fall 2016 within another, EIT RawMaterials funded, educational project which included a 'training the trainers' session, and personal mentoring for a course development – explained in detail in our previous work [6]. The entrepreneurial teacher mentoring, provided by the Aalto Ventures Program, offered support for the teachers in implementing entrepreneurial mindset into the technical teaching practice.

The new TIP course was piloted in the fall 2017, and this study has been conducted during the pilot. Students with two different academic backgrounds met on this course: 2nd year master's students from the Sustainable Metals Processing program at the School of Chemical Engineering (SMP; 8 students, where 0 female), and 1st year master's students from the international joint program European Mining Course (EMC; 15 students, 3 female). This led into a group of altogether 23 students, having

knowledge in both mining and metallurgy, which is a possible skills scenario also in the working life teams. The Intended learning outcomes for the new course are:

- The student can share his/her expertise in a multidisciplinary team
- The student can evaluate added value of process, service or product
- The student can present findings in an international seminar
- Creates international network of peers and company representatives

According to the TIP course's learning outcomes, the students learn to use entrepreneurial thinking in problem solving by understanding the customer needs and how their solution can bring added value. In addition, the aim is that the students recognize their own expertise as well as their role and input in the teamwork, by reflecting with their multidisciplinary teammates. One tool in this recognition process is the self-assessment questionnaire where students can follow their learning progress.

The old project work course had two different parts: advanced lectures on the current topics given by professors, and a technical problem-solving project. The students presented their findings in a written report and oral presentation; the tasks were prepared individually. As the students are in the final stage of their studies, the first modification of the new course was to change the lecture part into workshops where students learn working life related skills, entrepreneurial mindset and leadership. The focus was not on providing information but rather on practising these skills through different exercises, partly prepared at home and partly at the workshops. They prepared weekly personal and professional development logs, in order to support their professional growth by reflecting. The aim was to get the students to reflect on the experiences they already had from working on their field (summer jobs), and have a safe environment to try out different methods in the workshops. This reflective work was individual, and along with the points from the workshops provided them 50 % of the course grade.

The other part (and 50 % of the course grade that was common to the project team) was the project work prepared in teams of 3-4 students. The team approach was selected as in the working life many of the projects are executed in multidisciplinary teams, and this far during the master's studies the students had prepared most of their tasks individually. The idea of the project was not a pre-set problem solving, but instead the teams were given a theme: *"Understanding the whole value chain from ore to metallic product"*. As the students came from two different majors, they needed to combine their knowledge in order to obtain high results in the project. After this, the project leaders were selected, and with the industrial representatives nine more detailed focus areas were chosen, such as *"Arsenic in the metallurgy process"*, *"wastewaters"* or *"future of metals"*. As presented in Fig. 1, the idea of the entrepreneurial mindset project is as in any entrepreneurial action: listen to the clients, discover and identify issues and problems that need to be solved. The first interviews with the company were set for the students in order to get them to start the projects

as soon as possible. The teams interviewed the company representatives, and carefully listened to which issues there would need solving. After that, they decided in teams, which were the problems in their area they would start working with.

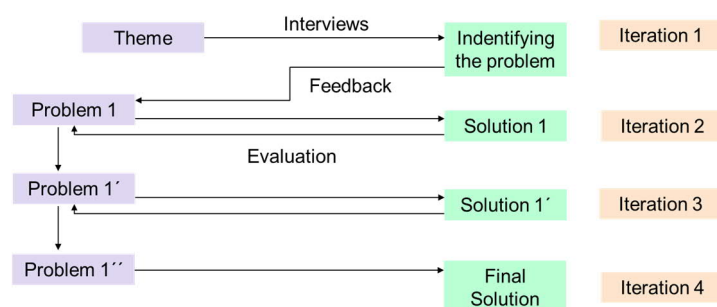


Fig. 1 Schematic presentation of the entrepreneurial mindset project work flow.

The timeline of the course teamwork is presented in *Table 1* where it can be seen that a lot of time was committed for discovering a proper problem. For most of the students this was a new experience, and they felt a bit uncomfortable, but discovering their own problem got them very motivated working on their tasks. The teams presented these problems as pitch presentations, and got feedback on the relevance of the discovered problems from the university staff. After the feedback, following the iterative loop, most of the groups modified their problem, and conducted more interviews with industrial representatives in order to get a better view on how to focus more in the problem. In the next pitch, also the original company mentors were present for providing their feedback.

Table 1. Timeline of the entrepreneurial mind-set project

Week	Project timeline	Week	Project timeline
37	Team building and preparing the agreement	44	EMC at Excu (interviews), further validation
38	Interviews of client - > identify needs	45	Feedback 3: Validated 3 solutions
39	Feedback 1: Customer needs + agreements	46	Visual Angle
40	Further interviews - wider angle	47	Final Presentations
41	Stakeholder analysis – identifying the players	48	Project reflection
42	Feedback 2: Description of relevant problem	49	Course reflection
43	Brainstorming 100 solutions - Selection of 3 solutions and validation	50	-

After the second pitch session, the teams brainstormed altogether 100 solutions and selected the three most relevant ones to continue with. The idea behind the large number of solutions is that it forces the students to provide other than the most obvious solutions (might first sound ridiculous, but can give other team members ideas for modifying them further). After this, the students validated these three ideas, and pitched them for the staff. The validation could be a technical one, or based on customer interviews or analyses, but furthermore an economical evaluation was needed, too. From the feedback of this pitch, the teams could decide what to present as their final results, and what to focus on in order to have a deeper knowledge of the

idea they would present in a seminar to the university staff, and the company representatives.

As the students are less familiar with working on this kind of projects, the workshops supported their task: e.g. how to have a proper brainstorming session, or provide constructive feedback, about leadership, team forming and reflection by utilizing art. In addition, the students needed a lot of guidance with their work. It turned out that many of the teams would have benefitted from weekly mentoring sessions (that will be implemented in the course next academic year). The feedback from the pitching sessions was extremely valuable, but added to the verbal feedback, the staff wanted the students to know with which grade their project was pre-evaluated. For this purpose, a bonus system was used: for ordinary performance, the team just obtained "ordinary salary" but for the teams that had well understood what was expected and whose project was pre-evaluated with a high grade, an additional cash bonus was given (not real money though). The bonus was announced in front of all the teams, so the teams could benchmark themselves in comparison with others. Some found this a very helpful indication on how their team was performing in this new task.

Four short videos on how the course was conducted, can be found in Youtube:

Part 1: Assignment <https://www.youtube.com/watch?v=ps-BeyrUHHU>

Part 2: Feedback <https://www.youtube.com/watch?v=9oCnnDjbEKA>

Part 3: Validation <https://www.youtube.com/watch?v=IA07ZGZHsp0>

Part 4: Using Art <https://www.youtube.com/watch?v=xqNeZLnyHpA>

2 THE SELF-ASSESSMENT

In order to address the research question at this course, the students performed self-assessment as part of their personal and professional development log. The students evaluated their own performance on the following questions at the beginning and at the end of the course. The evaluation uses a scale from 1 to 5 where the mentioned competence is (1) not recognizable, (2) insufficient, (3) developing, (4) good, or (5) excellent.

Table 2. The average of the student self-assessment at the beginning and at the end of the course, and the difference between them.

	Question	Beginning	End	Difference
1	I recognize my own professional strengths	3.59	4.31	0.72
2	I am competent in working in teams	3.91	4.24	0.33
3	I recognize the roles I take in different teams	3.36	4.29	0.92
4	I am able to communicate my ideas to others in team	4.00	4.29	0.29
5	Leadership	3.27	3.67	0.39
6	I am able to provide constructive feedback	3.50	4.10	0.60
7	I am able to present my findings for large audience	3.32	4.14	0.82
8	I am able to identify customer needs	3.27	3.71	0.44
9	I am experienced in professional reflection	2.36	3.64	1.28

As the TIP course students are on advanced level, they already possessed to some extent many of these work related skills. Especially, they felt they already had skills in teamwork and in sharing ideas with team-members. Yet, they were not so confident in leadership, identifying customer's needs, recognizing their role in a team or presenting their findings for larger audience, because this has not been in the focus of their previous studies. Most of them had insufficient or no skills in personal reflection before the course. The TIP course purpose was to provide them more of these skills, and help them to recognise their professional growth before they exit the university.

At the end of the course, the students evaluated having good or excellent skills in recognizing their own professional strengths. According to the course teacher, this is a very good result. The TIP course is placed ideally in the master's studies, right before the student needs to find the Master's thesis project. Recognizing one's strengths is an asset for the student, and it helps him/her to find a good thesis project. The students also evaluated having very high skills in working in teams (recognizing their role, sharing their ideas and feeling competent). As well, the presentation skills improved significantly with all the students during the course. However, the leadership skills were not reported to change that much, which according to the teacher, could be related to the fact that only one student in each team had the leadership position. The biggest difference shown was with the professional reflection skills, mainly due to the very low starting level. This is an excellent result as reflection is a very important tool for life-long learning. As the students would benefit on these skills during their entire study time, an introduction to these skills should come already earlier on their study path, says the teacher. On this course, the reflection is based mainly on the students' own working life experiences.

Overall, the students evaluated that almost all of their evaluated skills had improved during the course, and at the end, they reported to have a 'developing or good' entrepreneurial skills level. The aim of the self-assessment was to help the students reflecting their own competence levels, and help themselves to see the development of the desired skills.

3 ENTREPRENEURSHIP COMPETENCE FRAMEWORK (ENTRECOMP)

EntreComp is a comprehensive, flexible and multipurpose reference framework designed to help you understand what entrepreneurship as a key competence means for lifelong learning. [5]

EntreComp is made up of three competence areas: Ideas & Opportunities, Resources, and Into Action. Each area consists of 5 competences, making altogether 15 competences. Beneath each competence, there are a number of different threads, describing what the particular competence really means in practice. Each thread has associated learning outcomes across 8 progression levels with increasing level of autonomy of the learner and decreasing external support: foundation, intermediate, advanced and expert.

3.1 Comparing the self-assessment results with EntreComp

The self-assessment results compared with the EntreComp progression levels show that our students mainly have competences in the foundation, intermediate and advanced levels, as far as the progression levels are comparable. In the *Table 3*. we can see that all the three competence areas of EntreComp are covered by the TIP self-assessment.[5].

Table 3. Self-assessment compared to respective main competences in EntreComp

Question	Competence area	Competence(s)
1	Ideas & Opportunities, Resources, Into Action	creativity, self-awareness & self-efficacy, motivation & perseverance, learning through experience
2	Into Action	working with others
3	Resources	mobilizing resources
4	Into Action	working with others
5	Into Action	taking initiative, planning & management, working with others, learning through experience
6	Resources	mobilizing resources
7	Resources	mobilizing others
8	Ideas & Opportunities	spotting opportunities, creativity
9	Into Action	learning through experience

4 CONCLUSIONS

In this case study, a traditional technical project work course was transformed into a new project course that supports students' entrepreneurial competence growth. With the students' self-assessment, the success of this change was studied. The new course involves, not only multidisciplinary teamwork where students by interviewing company representatives discovered a relevant problem to focus on, but also workshops that support the development of the students' entrepreneurial personal and team skills.

As the students evaluated their own competences, they could recognize their increased skills and knowledge, and learn to position their competences better on a given scale. This, leading to a greater self-awareness, will improve their ability to promote themselves to potential employers after graduating from university [1].

Part of the new methods used here still need improving, as this is a very different and new approach for the student project works. The students needed a lot of support in identifying relevant real-life problems, and developing a clear picture of them. However, after the course, most of them felt very enthusiastic and connected to their projects as while looking for solutions they felt they could influence on their tasks. It was not possible for any student to prepare this project alone, but teamwork and knowledge from different academic backgrounds was needed.

Students learn entrepreneurial thinking via solving real life problems, and motivated students create something out of their personal interest. Learning should not be strongly directed from outside as motivated learning can turn into a process where new knowledge and innovations are created. [2, 7]

EntreComp seems a useful tool for anyone in helping to understand the entrepreneurship competence as a whole. For assisting students in developing their entrepreneurial skills, supporting materials and tools are welcome. EntreComp is a good material for teachers, and for students. As there is a promise of a self-assessment tool based on the EntreComp framework to be developed [1], we are looking forward to trying it on the next execution of the TIP course. A matching tool would enhance the results' evaluation both for the students themselves, and for the teachers.

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*Teaching Engineers on Innovation and Creativity
Innovation, Creativity and User Oriented Product Development in Engineering
Education*

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Conference Key Areas: Teaching Creativity & Innovation, Gender and Diversity in EE,
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Keywords: innovation, creativity, gender, diversity

INTRODUCTION

An interdisciplinary master class called “Customer needs meet the technical market” is now thought at Technical University of Munich for more than seven years in the study programmes of industrial engineering as well as electrical engineering and information technology. It focusses on aspects of product development and the inclusion of end users’ perspective into the innovation and product development process [1]. Hence, it highlights the importance of diversity and gender aspects in science and product engineering throughout all stages of technological products’ innovation process from the idea up to the market launch. The goal of this interdisciplinary class is to make students aware of different target groups in potential

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markets and their background [2, 3]. It introduces different methods of user integration, e.g. market research and open innovation on the background of sociological as well as gender and diversity studies theories and frameworks. In addition, the strategy of Diversity Management is discussed and its relevance for product engineering and marketing using the example of mixed teams [2]. Students' deep understanding of product engineering, design and product innovation process management tools is needed which is worked out in a problem-based-learning framework [4]. Furthermore, the importance of creativity and creative processes [5] for innovation are highlighted and several techniques for fostering creativity in product engineering processes are introduced and practised exemplarily.

This paper would like to discuss in detail the didactical goals, methods and exercises used in the master class on innovation in product engineering at Technical University of Munich and therefore contribute to further development of engineering education regarding teaching gender and diversity with their links to creativity and innovation in engineering.

1 RATIONALE

In our changing world of work, opportunities to up skill are increasingly important. Digitalisation [6] and Industry 4.0 [7] are changing not only the landscape of work-life [6, 8] but also of university education across all disciplines [9]. Therefore, it is crucial, maybe even more than ever before, to look out of the box when it comes to engineering education. Since 2005, hence for more than a decade now at Technical University of Munich, the professorship of Gender Studies in Science and Engineering teaches engineering students with social science and gender studies methods, also to foster gender sensitive didactics and educate on the impact of gender and diversity in engineering education [9]. In order to explain this, we need to go back in time a bit:

When university didactics developed slowly after years of virtually a standstill in Germany in the 1960s, criticism on the prevailing scientific system and approaches to university and study reform were voiced from within the natural and engineering sciences from the very beginning, too. One might have thought critique would have been the domain of humanities and social sciences. These critics might have been perceived predominant, but this might be a deceptive view [10]. Together with the Aachen physicist Brigitte Eckstein, an initially small group of academic faculty members at various locations of technical colleges and universities in Germany addressed the connection between active learning and critical thinking for the training of future generations of engineers. Via their scientific contacts to the United States of America, and especially to the Massachusetts Institute of Technology (MIT), they brought the ways of thinking of Ruth Cohn (especially thematic interaction [11]), Kurt Lewin (group dynamics, inter alia [12]) and David A. Kolb (learning style inventory [13]) into their concepts for a changed engineering education [14].

Ever since the 1960s, the development of didactics towards critical thinking and active learning processes in engineering education, per contra among other things to traditionally predominant ex-cathedra lectures, evolved and is currently also part of concepts of inclusive learning environments [15, 16] to change the identities of future engineering professionals [17].

This historical foundation is crucial for our understanding of engineering education as one branch of higher education didactics [18]. By this, engineering education deals with not only the specific teaching, learning and content of engineering, but as well with the tasks of engineers in professional practice and society. Its goals therefore are expanded from sole

transfer of technical knowledge and skills to a broader view of engineering as a profession for and with society as a whole which is bound to include all students in a class [16] regardless their major study programme or background.

In the interdisciplinary master class “Customer needs meet the technical market” discussed in this paper as an example, we seek to push engineering students of the study programmes of industrial engineering as well as electrical engineering and information technology to the limits of their comfort zones and provoke unusual questions which they are usually not confronted with during their study programmes. By doing so, our didactical goal is to teach them gender sensitivity, creativity and innovation for their future careers and raise awareness and responsibility on various levels on among these future engineers.

2 SCOPE

The interdisciplinary course “Customer needs meet the technical market” started in winter semester 2010/11 for the international study programme of industrial engineering as a master class in the study field of compulsory optional subjects. By this, the module became part of an international study programme called “Consumer affairs”. Ever since it reoccurs in every winter semester. It was modulated as one of two classes for the module “Consumer Psychology & Gender Studies” with a total of 6 ECTS [19], the course itself is worth two semester periods per week and 3 ECTS, therefore half of the full module. Furthermore, it was modulated as an elective subject in the master study programme of electrical engineering and information technology with two semester periods per week and 3 ECTS as well. By this design, the target group for this course usually consists largely of consumer affairs students with very heterogeneous and diverse backgrounds, also because of the international joint degree master programme that is implemented within the consumer affairs study programme. Nonetheless, a hand full of electrical engineering students and some from other study programmes such as mechanical engineering or architecture join the courses, too. This combination of elective subject-students and compulsory optional subject-students from various study programmes, different bachelor’s degrees and background requires teaching to be more deliberated. Therefore, an inclusive learning environment [15] ought to be fostered.

The initial course concept was rather traditionally, for a social sciences class at least, conceptualised with twelve different topics on the subject of the course presented by the students in small groups. These twelve group-presentations covered various topics and aimed at covering the course topic in a narrowing manner. For example, these included: “The Identification of target-groups”, “Cars for women”, “Handbags for men and mobile phones for elderly persons: The diversity-perspective in product development”, “Innovation processes, innovation dimensions and innovation types”, “Open innovation – user integration in innovation processes”, “Lead User Methodology” and “Creativity – the key to innovation”.

The presentations were grouped into four topics:

1. Customer needs – what for?
2. Innovation and Creativity
3. Diversity-Management
4. Innovation-Management

For each of these topics, a block date was aligned consisting of six to eight course hours including breaks. By this model, students were able to better coordinate this class with their already fully packed study programme schedule.

The class is scheduled only for winter semesters and from year to year it is constantly developed further and adapted to tweak its methodology and content based on new insights from science and didactics as well as on student's formalised feedback through evaluation sheets and informal oral feedback at the end of the last course day.

3 METHODOLOGICAL APPROACH

Within the course "Customer needs meet the technical market", problem-based-learning [4] is the main didactical methodology to teach profound as well as first-stage insights for engineering students outside of their subject area. Many topics, especially creativity and innovation processes are not taught by presentations but also by short exercises of twenty to forty-five minutes duration in small groups between three and six students. For example, to think about methods of fostering creativity, a short exercise where chains of ideas ignited by pictures licensed under creative commons (e.g. cc-by [20]) are carried out in class. A collection of thirty pictures, one example shown below in *Fig. 1* are printed and handed out to student groups three to six students, depending on the number of students participating in the course. These groups thereafter loosely associate thoughts and ideas that emerge from looking at these pictures, preferably without describing their content in explicitly and note them down.



Fig. 1. Cornfield Kid, cc-by-2.0 by Sam Cockman at flickr [21]

After fifteen to twenty minutes, each group presents their result to the class while the corresponding pictures are shown via LCD projection.

In order to look at the process of innovation management and innovation processes, basically in enterprises, we introduced a short idea competition in the class. Students are grouped together by three to five persons and have to come up with a creative idea for a new technological product within a given constraints, e.g. a wristwatch. After two weeks, the groups present their ideas to all participating students and the lecturers and also commit one group member to a selection committee. This jury thereafter assesses the ideas presented

by all groups before, whereas each jury member abstains from voting in case of own group involvement in order to avoid biases. This, but just as a short excursus, is implemented to exercise democratic methods, processes and measurements in engineering education [22]. After the assessment, a small prize, usually a card box full of sweets and candy, is given to the winning team as an award, which they frequently share thereafter with all students of the class.

With the commencement of winter semester 2015/16, the course was slightly revised, on basis of the responses and needs of students in the preceding years. Even though these changes were not implemented abrupt, the winter semester 2015/16 constitutes a milestone. Notably the e-learning concept of blended learning [23] was successfully applied, whereas e-learning and traditional learning settings in class were combined. As e-learning platform, a Moodle installation at Technical University of Munich is used [24, 25]. On Moodle, not only the course's literature and information is made available but also the students publish their works and findings during the course.

Starting from the winter semester 2017/18, the blended learning was optimised and the course schedule was adapted to the student's increasingly full study programme schedules. Hence, the master course "Customer needs meet the technical market" now consists of five fortnightly parts composed of merely two topics, whereas the course dates were limited to 3.5 hours. The topics of these five half-days were:

1. Customer needs – what for?
2. The Role of Gender and Diversity in Marketing
3. Innovation and Creativity
4. Managing Creativity
5. Reflection

Furthermore, group presentation of the texts were buried in favour of an elevator pitch-method. For these, all students have to read through the literature on the two topics of the corresponding day. This literature consists of six to eight ready-made texts from social science, gender and diversity studies and product development as well as from other disciplines and is about 80 pages in total. In class, two students thereafter are randomly chosen and assigned to a three-minute talk on the texts read on one and another subject of the day. For these strictly three minutes, the students ought not to summarize the text that (should) have been read (and preferably understood) by all participants, but they highlight the most important aspects, key take-homes and surprises or astonishments of the literature given to them. By this, the student assigned to the topic, e.g. "Integration of diversity aspects in science", does not only reproduce knowledge from the literature for the class orally, but also gives insights into their interpretation and prioritisation. Afterwards, a discussion in class follows in order to broaden and elaborate the topic again.

For the blended learning aspect, in winter semester 2017/18, we assigned the students for the first time to each produce a written summary of each of the five course dates and upload to Moodle within seven days from each course day. These half-pagers were made available to all students of the class afterwards within the Moodle course for the corresponding semester and therefore everyone could benefit from the summaries written and insights gained by the other participants of the class. The grading of these papers also takes place in Moodle. In this semester, for the first time the course was held by two lecturers.

To further develop and adapt the course “Customer needs meet the technical market” we use evaluation forms and feedback talks with students.

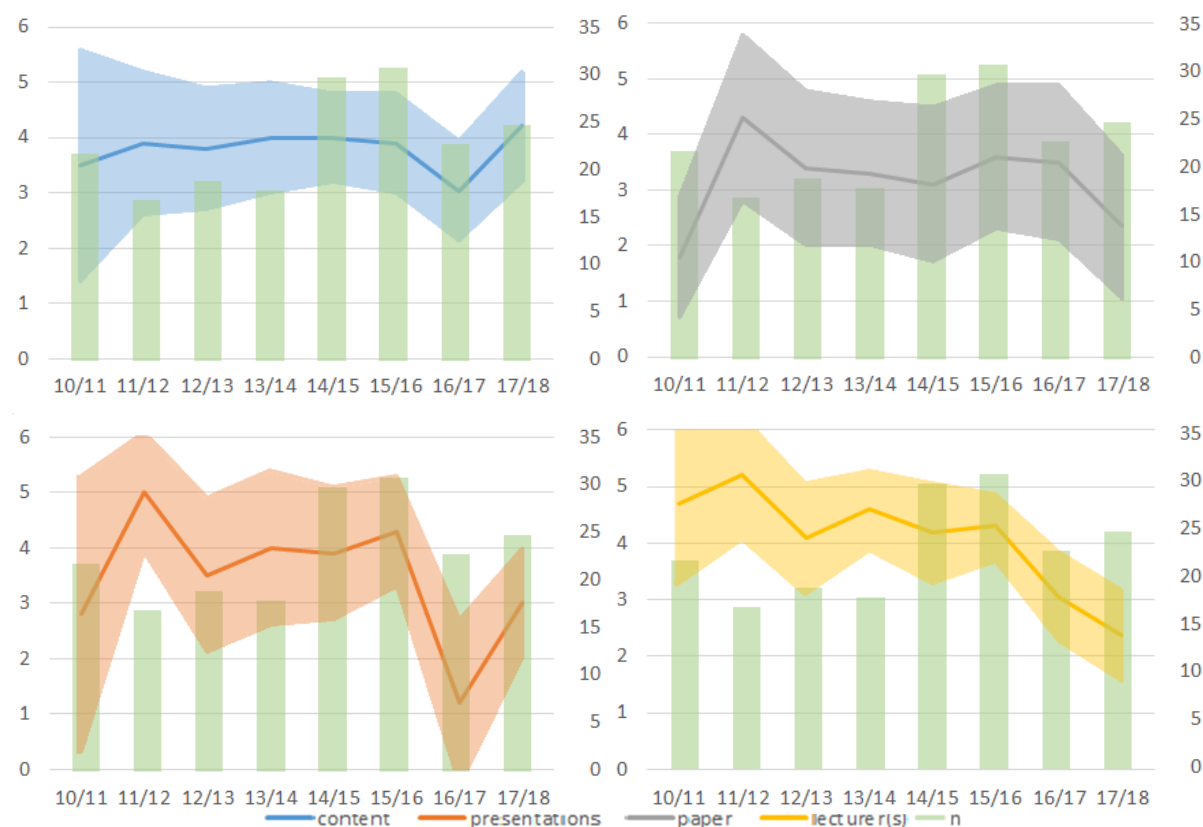


Fig. 2. Course evaluation results summarised

As shown in *Fig. 2* above, the evaluation forms main part consists of four categories:

1. Content and skills (blue, upper left quadrant)
2. Presentation (if required) (orange, lower left quadrant)
3. Paper (if required) (gray, upper right quadrant)
4. Lecturer and learning environment (yellow, lower right quadrant)

Questions included here are for example “The content meets my expectations.”, “There are enough opportunities to practice the presentation.” or “The lecturer was well prepared”, to name a few. *Fig. 2* includes not only the average values over the various semesters (continuous lines) for these four categories and their standard deviations (opaque zones) in each quadrant, but also the number of evaluation forms returned (n). Therefore, the y-axis on the right-hand side represents the scales of n whereas the y-axis on the left-hand side represents the values of responses on a Likert scale (1 to 5, [26]). The x-axis represents the corresponding winter semesters from winter semester 10/11 to winter semester 17/18. The value of n obviously is fluctuating heavily and depending on the size of the course’s audience in each semester, too. Furthermore it has to be noted that the evaluation was until winter semester 2014/15 consisting of 22 questions, whereas four counted in for content (1), two for both presentation (2) and paper (3) and three for lecturer (4). These questions were expanded faculty-wide in winter semester 2015/16 to seven questions on content (1) and five on lecturer(s) (4). Other question groups were also altered. In addition, the sequence of the scale was inverted from 1 for “disagree completely” to 5 for “agree completely”, but for

Fig. 2, we reversed those back and ditched the new question to have more or less comparable results. Because standardised feedback in evaluation forms bears bias to some extent, we also include informal oral evaluation rounds, which give us valuable insights and feedback.

4 FINDINGS

Positive evaluations dominated the feedback ever since the course “Customer needs meet the technical market” was implemented in winter semester 2010/11, particularly the informal oral feedback. Especially highlighted were the numerous exercises and the problem-based-learning approach which seem to be, even in winter semester 2017/18, more or less uncommon and noteworthy to the students learning experience at Technical University of Munich and elsewhere [27]. Nonetheless, the students struggled with a lack of lecture-oriented teaching they perceived. Some students all of the years voiced feedback whereas they wished to have more of an ex-cathedra teaching and also some of the topics were perceived to be dealt with more fundamentally than students would have expected. Especially the perception of the depth of the topics covered changed after the blended learning concept was introduced and after group presentations were ditched in favour of elevator pitches as teaching and learning success measurement methods. It seems, students were more unhappy with presentation of topics by their ilk due to the level of complexity some student broke down the knowledge. Even though this might be due to the interdisciplinary and internationality of the study programme, it is a welcomed side effect of the development undertaken in this course over the years.

Furthermore, the course led to multiple master theses written at the professorship, e.g. on “Gender Differences in Attracting and Recruiting Candidates for STEM Positions via Social Media Channels”.

5 CONCLUSIONS

We could show, by using the example of the course “Customer needs meet the technical market”, how a systematically approach of introducing critical thinking and active learning in engineering education might look like. It showed that by this, we were able to work towards an inclusive learning environment [15] and foster a broader view of technology impact and engineering core curricular content among students of diverse study programmes and backgrounds. By doing so, it is possible to further development of engineering education regarding teaching gender, diversity with their links to creativity and innovation.

Further research is nonetheless foreseen on didactics and methods for undergraduate students and non-traditional learning environments, e.g. massive open online courses (MOOCs), where only first appraisals concerning gender and diversity were conducted so far [28] and not much sustainable research is available yet on didactics towards critical thinking and active learning.

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Is team performance in project based PBL better if all team members have the same work ethic?

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Conference Key Areas: Recruitment and Retention, Educational and Organizational Development, Engineering Skills

Keywords: Peer Learning, Cooperation, Engineering Education, Retention

INTRODUCTION

All Engineering Educations at Aalborg University uses Problem Based Learning as learning method. On each semester, the students work in groups of 5-7 members on a 15 ECTS semester project supported by courses.

Groups with good communication and collaboration has a higher potential for peer learning and a successful sharing of knowledge than groups struggling to communicate and collaborate. A study in 2016 [1] showed that the most well organized and collaborative groups worked full time on the project at the University but also worked a lot on the project at home. Other groups preferred to do most project work at home and only meet at University for courses and a couple of meetings a week to discuss the progress of their project and assign new tasks. The well-organized groups used peer learning more than the other groups and received better marks.

These results was presented for students studying within IT in the beginning of their first semester 2017. In October, new groups was formed and the students used the

knowledge to form homogeneous groups where either all members wanted to work full time at the University or all members preferred to do most project work at home.

This paper investigates if these groups perform better with good communication, collaboration, and lower dropout rates than another cohort with less homogeneous groups, by analysing and comparing written process analysis from each group, average marks for the projects and student dropouts.

1 BACKGROUND

A study in 2016 [1] showed that first year student group at Aalborg University within IT studies could be categorized in three:

- A. **The well-organized group that shares knowledge and socialize:** “This group meets almost every day to discuss the project and its progress. The tasks are distributed both individual and sometimes in smaller groups. Although the group do most project work at the University, each group member also do a lot project work at home, communicating regularly with the other members. All knowledge gained in the project is shared by reading and discussing the documents produced. The group spirit is high and the group members meets outside University for sports, gaming, cinema, party, a beer, etc.”
- B. **The organized group that shares most knowledge:** “This group often uses Monday for planning project activities for the whole week. Specific tasks are distributed on an individual level and usually this work is done at home, communicating regularly with the other members. At University, the group uses the time to discuss the results of the performed tasks and the progress of the project. All documents is shared and usually read by all members, but in some groups there might be a few members not reading all documents. If there is something a member do not understand they can ask and the author will try to explain. The group spirit is not as high as in the A group. The group members do not socialize outside University”.
- C. **The unorganized group that do not communicate and share knowledge nor socialize neither at University or outside:** “This group is not organized formally and only meet after lectures to “give each other homework”. Then they go home and rest after the lecture. They do the individual homework with very little communication. They share the produced documents on e.g. Goggle Docs but it is only a few group members that read the documents and they do not discuss any documents. There is only informal review of the documents. The group spirit is low and although the members can make fun and fool around sometimes at the University they are not mates and do not socialize neither at the university nor outside”.

The study [1] investigated the hypothesis: “It seems obvious that groups with good communication and collaboration who is working most of the time in their group room has a higher potential for peer learning and a successful sharing of knowledge than

groups struggling to communicate and collaborate and often doing most of the project work individually at home”.

The results of the small study (74 students) proved the hypothesis right and the results from the project exam showed that groups labelled A generally received higher average marks than groups labelled B and C. Groups labelled C was generally receiving low average marks.

2 THE EXPERIMENT

The group classification from 1 was presented to the students of a new cohort starting in September 2017 to help them identify what kind of group they were in and be more aware of the consequences in terms of learning, collaboration and marks. After the presentation the students were asked which group they would like to be in and on an average individual level app. half of the students indicated by a quick show of hands that they thought they would prefer to be a member of an A group, and the other half would rather be in a B group. No students was attracted to the C group.

The first 1½ month the students are randomly placed in groups of 6-7 to work with a small project (5 ECTS) aiming at giving them a brief introduction to project work at Aalborg University and the first experiences of how to collaborate on a project and share knowledge. The experiences is analysed and reflected in each group and plans for improvement is made before they start on a longer project for the rest of the semester, app. two month (10 ECTS).

The group formation for the new project is handled by the students based on both interest for a specific project proposal and knowledge about the other students. The investigated cohort was all IT students but they had signed up for two different studies: **Software Engineering** (SE - 127 students) and **Computer Science** (CS - 88 students).

Each study has to form groups for the projects internally, but all of the students follow the same courses and share a team of supervisors to facilitate the individual groups.

Before the group formation process the students study a catalogue of project proposals and each student has to type in the project proposal they prefer and then there is two hours where the students can meet with other students with the same interest in project proposals to discuss the project and form groups.

The SE student had to form no more than 19 groups and the CS students 12 groups. Most of the project proposals had been chosen by more than 10 students so more than one group could be formed based on each project proposal. This made it possible for the students to form groups based on other topics: work load, ambition, work method etc.

Some of the first SE students that typed in their selected project proposal also typed their preference for which type of group they wanted to be in and many of the other SE students followed this idea. This information was used in the group formation process of the SE cohort to form groups where all members had a preference for either the type A group or the type B group. The CS students didn't type in their group preference so it is expected that more groups were formed where some students

preferred to work as a type A group and other to work as a type B group, which potentially might lead to conflicts about where and how to work on the project.

It was decided to investigate if the SE groups performed better with better communication, collaboration, and lower dropout rates than the CS cohort did.

3 METHOD

The two cohorts of students will be compared by analysing a written process analysis, the average mark for the projects and student dropouts from each group.

3.1 Process analysis

The process analysis is a shared written document where each group right after handing in their project report write and reflect about what happened in the group when working with the project, why it happened and how to improve the performance in the next project. Each group have to analyse how they have collaborated and solved eventual conflicts, how they have planned and controlled the project and how they have shared and helped each other to learn all the knowledge produced.

These written documents was analysed to find out which classification (see 1) each group belonged to and if they have used peer learning when sharing knowledge from the project.

Feedback is provided for the groups on their process analysis. A teacher comments in writing the quality and fulfilment of the learning goals for the process analysis and write some questions and comments to help the students reflect deeper. No marks are given but the teacher noted down the mark he would give for the quality of each process analysis to be used as data for comparing the groups in each classification.

3.2 Average marks for projects

The results of the project work from each group is documented in a project report and the process analysis. Both documents is a part of the project exam where each group starts presenting the results of their project and process. Then questions is asked to each student to test the knowledge about the different project subjects and there is a discussion with all students participating about the methods and theories used, the pro and con's and lessons learned. Based on both written documents (project report and process analysis), and each students performance during presentation, questioning and discussion, individual marks are given for each student.

The marks for each student in each SE and CS group is collected to calculate the group average marks. To be able to identify each group according to the classification made using the process analysis the group number is known but not written to keep anonymity of the groups.

3.3 Student drop out

This paper is comparing the behaviour of two cohorts of students working in groups with a big project (10 ECTS) running for two month. Concerning drop out is it interesting how many student that leaves their group during the project period.

Some students leave their group because they don't want to continue their study, so they officially stop studying and is registered as "drop outs". In some groups conflicts between the group members about how the project work should be done becomes so big that a group member leaves the group to become an individual student either voluntarily or forced out as a result of a counselling with the supervisor.

The number of drop outs can be extracted from official statistics and the number of individual students enrolled for exam at the end of the semester can be found in the exam plan.

4 RESULTS

4.1 Process analysis

The results from the analysis of the process analysis can be seen in *Table 1* for the Software Engineering students and in *Table 2* for the Computer Science students. Many of the groups had labelled them self as A groups and some as B groups (see 1). Several groups had invented an extra classification in their analysis: a group that like group A preferred to be working at the University almost full time, but could see some benefits by having one or two days a week where they worked at home. This category is labelled A light. No groups labelled them self a C group but from their own description of group behaviour it was possible to identify a few C groups in each cohort.

Table 1. Number of SE groups in each classification (see 1),
their use of Peer Learning and marks for quality of their process analysis

Classification	Groups SE		P.L.	Marks in Danish 7-step and European ECTS scale						
	number	%	%	12/A	10/B	7/C	4/D	2/E	0/Fx	Av.
A	10	53	100	2	2	4	2			5,8/C
A light	4	21	100	1		2	1			7,5/C
B	3	16	33			1	1		1	3,7/D
C	2	11	0					1	1	1,0/E-F

Table 2. Number of CS groups in each classification (see 1),
their use of Peer Learning and marks for quality of their process analysis

Classification	Groups CS		P.L.	Marks in Danish 7-step and European ECTS scale						
	number	%	%	12/A	10/B	7/C	4/D	2/E	0/Fx	Av.
A	7	58	100	1	1	3	2			7,3/C
A light	2	17	100			1	1			5,5/C
B	1	8	100					1		2/E
C	2	17	0				1	1		3,0/D-E

The results from the two cohorts shows that although the SE students used the group classification deliberately to form homogeneous groups when it comes to preferences about how when and where to work on the project, the CS groups also ended up being quite homogeneous. In both cohorts the A and A light groups all used peer learning when sharing knowledge and ended up with good and high marks for the quality of the process analysis whereas the B and C groups only use peer learning in one B group in each cohort and all except for this group in the SE cohort ended up with low marks for the process analysis.

4.2 Average marks for projects

The individual marks for the project exam for each group is converted and truncated into average marks on the Danish 7 step scale and the European ECTS scale. The results is presented in *Table 3* and *Table 4* for each of the classifications from *Table 1* and *Table 2*. The average of all groups in each classification is the average of the average group marks before truncation.

Table 3. Number of SE groups in each classification (see 1),
their use of Peer Learning and average group marks for the project exam

Classification	Groups SE		P.L.	Average Marks in Danish 7-step and European scale						
	number	%	%	12/A	10/B	7/C	4/D	2/E	0/Fx	Av.
A	10	53	100	3	5	2				9,5/B
A light	4	21	100		1	1	2			7,0/C
B	3	16	33		1		1		1	4,5/D
C	2	11	0				1	1		3,9/D

The results from the project exam of the SE students shown in *Table 3* clearly shows that the students from the A and A light group performed considerably better at the exam than the B and C groups which indicates that their project reports was better and they had learned more about the subjects from the projects. The one B group that used peer learning to share knowledge got a high mark.

Table 4. Number of CS groups in each classification (see 1),
their use of Peer Learning and average group marks for the project exam

Classification	Groups CS		P.L.	Average Marks in Danish 7-step and European scale						
	number	%	%	12/A	10/B	7/C	4/D	2/E	0/Fx	Av.
A	7	58	100		3	3	1			8,2/C
A light	2	17	100		1		1			7,7/C
B	1	8	100		1					8,8/B
C	2	17	0				1	1		3,85/D

The results from the project exam of the CS students shown in *Table 4* shows that the students from the A and A light and the B group performed considerably better at the exam than the C groups which indicates that their project reports was better and they had learned more about the subjects from the projects.

4.3 Student drop out

From the official statistics counting students every month the development in the number of SE and CS students is found: How many started in groups, stopped during the semester and the final number enrolled for exam. From the exam lists the number of students in a group for the exam and the number of individual student is found. All this information is presented in *Table 5*.

Table 5. Development in number of students in SE groups and CS groups during the semester, both in total numbers and in percentage of number of starting students

Study	Number of students						Numbers in %		
	Starting in groups Nov. 1 st	Stopped between Nov. 1 st Jan. 2 nd	Enrolled for exam Jan. 2 nd	Individual students Jan. 2 nd (exam)	In group Jan. 2 nd (exam)	Left group during sem.	Stopped during semester	Individual students	Total left group
SE	127	5	122	5	117	10	3,9	3,9	7,8
CS	88	6	82	5	77	11	6,8	5,7	12,5

Table 5 shows that app. the same number of students (5-6) in each of the two cohorts has stopped studying officially (dropped out) during the semester and during the same period a similar number of students has left their group to continue the semester as individual students. The SE cohort has app. 50 % more students as the CS cohort, so the percentage of students leaving a group is lower in the SE cohort than in the CS cohort. To find out if the difference in the percentage of drop out students is a special case for these cohorts the drop out rate is collected from statistics for the previous four years (see *Table 6*), using the total number of students from the IT school as reference.

Table 6. Drop out rate in percent for all students from the IT school, Software Engineering and Computer Science students from 2013 to 2017

Study	2017	2016	2015	2014	2013
IT school total	5,4	6,8	7,1	7,3	8,1
Software Eng.	3,9	7,9	7,8	1,9	8,3
Computer Sci.	6,8	7,6	17,3	12,1	13,7

Table 6 shows that during the 4 years before 2017 both SE and CS has a higher drop out rate than the average for the whole IT school, except for SE in 2014 where students from another study was allowed to change to SE during the semester. In 2017 both SE and CS has a lower drop out than usual indicating that the more homogeneous groups is better for the retention of students.

5 DISCUSSION AND CONCLUSION

Based on the results from the process analysis (4.1) and the average marks for projects (4.2) there is more similarities than differences between the two cohorts of students. This proves the expectation from 2 about differences in student preference for A or B group in the SE and CS cohort wrong, so the experiment has failed to prove SE groups more homogeneous than CS groups.

The reason for this could be that the CS groups have used their knowledge about the group classification when forming groups although they didn't put their preferences in writing before the group formation and they probably also was inspired by the SE students.

Only the drop out rates (4.3) shows the expected difference between SE and CS students, but if we go back in time there is a tendency that CS has higher drop out rates than SE students.

Interestingly the number of A and A light groups in both cohorts is 75 % which is considerably higher than the students own expectation for preference shown by raise of hands in the start of the semester (50 %) and the results from the previous study [1] showing 50 % A groups. This is indicating that the information about group classification in the beginning of the semester have had an impact in the students consciousness about that using more time for project work at the University pays of in terms of better group collaboration, group spirit, peer learning and marks.

The conclusion of the paper is that although the expected difference in SE and CS groups has failed to show the number of A and A light groups in both cohorts has grown and they get better marks than half of the B and all C groups, which is strengthening the proof of the hypothesis (see 1) from [1]. The procedure of presenting the group classification for the students at the start of the first semester will therefore be continued and if possible expanded by more formal procedures for using the classification as a part of the group forming process. The intention is to promote that the students form groups based on both interest of project proposals and what kind of group they want to be in according to the classification.

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A music festival as innovative living-lab learning in engineering education

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Conference Key Areas: Innovation as the context for Engineering Education, How Learning Spaces support innovative Teaching & Learning, Fostering entrepreneurship

Keywords: Living lab learning, Start-ups, Project design, Problem-based learning, University-business cooperation

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INTRODUCTION

Innovation and entrepreneurship is high on the education policy agenda and consequently also in engineering education. The Technical University of Denmark (DTU) does a significant effort to establish a variety of opportunities by encouraging their students to work with project development and entrepreneurship. As a part of their education, DTU students is offered the opportunity to work with the organizers at Roskilde Festival (RF) with a broad range of real-life engineering design challenges (RF is a large music festival with about 100.000 visitors and 32.000 volunteers).

This paper outlines the collaboration framework between DTU and RF; a living-lab learning platform developed between the two organizations. More than 650 engineering students have participated between 2010 and 2017. The collaboration provides a unique context for students to conceive, design, develop and implement their own ideas. Our research is based on analysis of data and results from student projects aggregated between 2010 and 2017. In this paper we have a special focus on projects exploiting a commercial potential and present cases of student entrepreneurship realized through festival projects. Furthermore, we have analyzed the characteristics of the cross institutional setup that supports, coordinates and facilitates the platform.

1 ROSKILDE FESTIVAL – A PLAYGROUND FOR ENGINEERING EDUCATION

DTU has innovation as one of the top priorities [1], and the development of an innovative culture among the students is part hereof. With this in mind, learning environments with different external partners engaging students to work with engineering problems in practice are encouraged. One of these partners is Northern Europe's largest music event, Roskilde Festival (RF).

Large scale festival events require an array of professional skills that includes a variety of engineering disciplines. At RF temporary settlements that last for a few weeks are established and large numbers of visitors occupy this artificial city. A great demand on many aspects of engineering is thus present, for example concerning acoustics, waste, sanitation, infrastructure, interactive art installations and crowd safety solutions, amongst others. The festival can be described as 130.000 enthusiastic, mostly young people, on a very limited space, causing severe stress on the infrastructure in that all kind of facilities and services are used in a hard, challenging and sometimes untraditional manner. These extreme conditions make the festival an excellent place to test and experiment on new products and services.

RF runs for eight days in the beginning of July. It has been running continuously since 1971, and during its operation the festival area temporarily becomes the 4th largest city in Denmark. The majority of the visitors and volunteers camp on specific camping grounds at the festival site. The festival site and the camping area with the belonging infrastructure are built every year on an empty green field with only very scarce permanent infrastructure, e.g. drainage (in total the area is about 400.000 square meters).

The festival is a non-profit organization and employs only about 50 full time employees. This makes the festival heavily dependent on contributions from volunteers. While 800 volunteers are working all year around, this number raises to about 32.000 volunteers during the festival. Approximately 80.000 partout (300\$) and 20.000 (150 \$) single day admission tickets are sold every year [2].

2 EDUCATIONAL PERSPECTIVES AND PRINCIPLES

The overall goal of the collaboration is to establish an attractive living-lab learning environment challenging the students in innovative thinking and engineering work. Key issues are problem-based and project-based learning which are important learning objectives in engineering education across all disciplines. Furthermore, it is essential that the students learn to understand the importance of customer requirements, and therefore the student projects must be of interest to the festival, consequently a prerequisite for all projects is a project 'anchor' person within the festival organization. According to Lehmann et al. [3] modern engineering challenges is a combination of social, societal and technical issues. A music festival is a chaotic environment to maneuver and we find it a perfect playground to cater the challenges described by Lehmann et al.

The learning platform is an opportunity for all study programs at DTU and not limited to specific engineering disciplines. Therefore the platform by definition has to embrace a variety of disciplines and didactical principles as well as students at undergraduate and graduate level.

As part of the platform DTU offers regular courses relevant to the challenges encountered at the festival. Apart from these regular courses, the festival collaboration is mainly carried out through so called special courses, i.e. courses designed to specific student interests.

3 METHODOLOGY

The authors of this article have been engaged in the collaboration as coordinators from respectively DTU and RF meaning that we both are actors and researchers at the same time. This gives us on one hand the advantage that we have experienced the challenges in the collaboration, but on the other hand are we also aware that our personal engagement can influence the research.

Our research is based on:

- Analysis of data and results from student projects aggregated from 2010 until 2017. This includes topics, study lines, number of students.
- Surveys among students participating in the collaboration addressing evaluation of support and results.
- Survey among start-ups' teams addressing support for the processes leading to student-driven start-ups.
- Analysis of the institutional setup supporting and facilitating the platform, including meetings and on-going dialogue with key stakeholders. Evaluation and processing of lessons learned have been on-going joint activities between DTU and RF from the start of the collaboration in 2010 until today.

A key element in the collaboration is selection of student projects for the coming festival. The process starts with an open call for project ideas at DTU as well as RF, where informal feedback, sparring, and pre-screening sessions are offered. From this pool of ideas the students are invited to prepare project plans describing aim, relevance, methods, results, economy etc. for their project. This preliminary phase normally results in a pool of relevant and well-described project proposals, and from this, the coordinators from DTU and RF in common select the projects to the coming festival.

4 RESULTS

4.1 How to organize the collaboration – the institutional setup

Essentially the outcome and value creation of the partnership is the student's learnings, as well as the usefulness, projects bring to the festival. Furthermore, the collaboration has resulted in the development of an institutional setup or platform, which facilitates the collaboration (Figure 1). The blue boxes refer to the CEO level and the red boxes to tasks and processes at the operational level. Student activities are indicated by the green box. The student projects are carried out under supervision from academic staff with domain and scientific expertise; furthermore an organizer from the festival is assigned to ensure alignment with the festival's interests. At DTU two project coordinators (engineering students) are responsible for daily operations, where core activities are to promote the collaboration and provide feedback and sparring on project scope and relevance to the students. A project manager at DTU Administration is responsible for the administrative and economic aspects of the collaboration. We have experienced that it is important to have an open-minded contact and dialogue between the DTU coordinators (engineering students) and the RF Student Platform (festival volunteers). We have placed these two groups in the center of the figure to emphasize their role as essential facilitators for the collaboration.

To the best of our knowledge this platform is novel as a living-lab platform and we reflect on the institutional setup which facilitates the platform. We consider these observations and reflections as important findings, and we believe that they can be of value to others with the ambition of establishing similar activities.

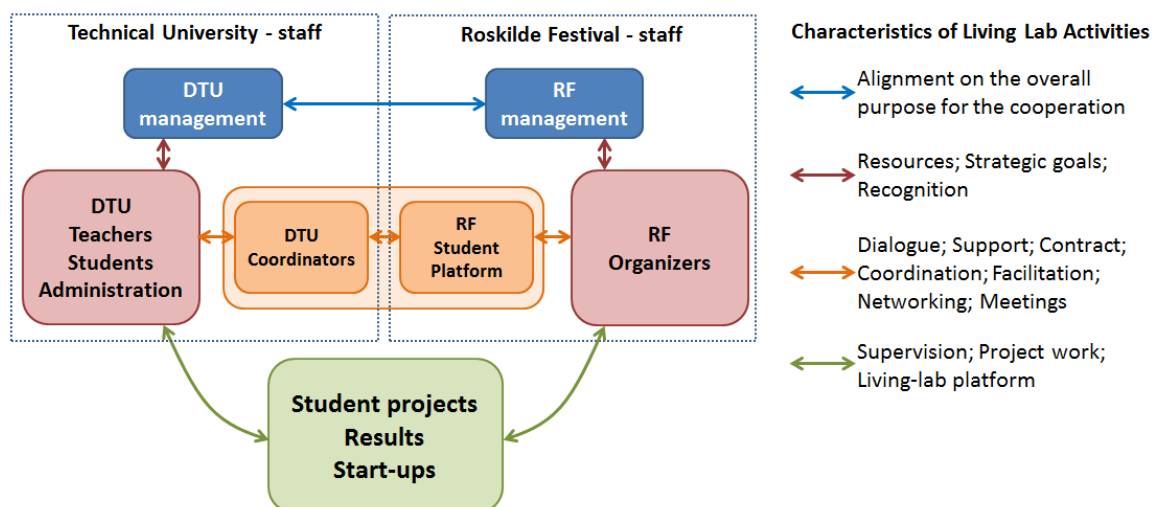


Figure 1. Institutional setup and overall tasks, services and processes of the platform.

4.2 Student participation and study programs

Many students have been interested in the collaboration, and survey results show, that the majority will recommend fellow students to join the collaboration. RF is a strong brand among young people in Scandinavia, and many of the students have previously been festival guests. Descriptions of student activities can be found at the website for the collaboration, [4]. Table 1 outlines the number of participants, projects, study programs, teachers and RF contacts. Figure 2 presents an overview of student projects categorized according to disciplinary themes of interest for the festival, especially sustainability (socially and environmental) and waste management.

Table 1. Student projects, participant's RF contacts and DTU teachers (2010-2017).
The asterisk indicates estimated numbers based on limited historical data.

Year	Participants	Projects	Study programs	RF contacts	DTU teachers
2010	20*	2	Not recorded	Not recorded	Not recorded
2011	20*	7	Not recorded	Not recorded	Not recorded
2012	130*	20	Not recorded	Not recorded	Not recorded
2013	99	25	14	21	21
2014	101	23	17	22	12
2015	90	21	19	10	17
2016	87	19	22	16	12
2017	83	21	21	16	15

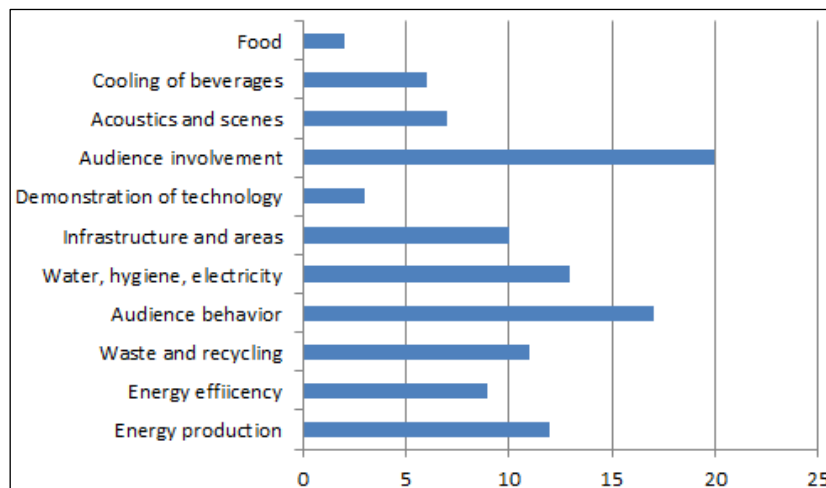


Figure 2. Categorization of number of student projects in disciplinary themes (2012-2017).

We believe that the collaboration offers relevant and diverse 'real world' cases for engineering education from various disciplines. Analysis of the data reveals that the festival collaboration is very attractive among students from 'Design & Innovation', and we believe that it is due to the problem-oriented and project-based approach to learning that is being taught at this specific study line. From 2013 to 2017 the collaboration has included students from 27 out of the 63 programs that the university offers (Table 2). Due to the nature of the festival, students from acoustics, electrical, environmental, civil and mechanical engineering disciplines are regularly participating in the festival projects.

Table 2. Overview of top 10 study programs (2013-2017).

The category 'other' includes students from 17 different study programs.
Students that have participated with administrative support functions are not included.

Study program	Number of students
Computer science and engineering	9
Environmental engineering	32
Physics and nanotechnology	10
Biotechnology	15
Civil engineering	27
Production and construction	20
Electrical engineering	55
Acoustic science and technology engineering	49
Design and innovation	128
BEng mechanical engineering	8
Other	107

4.3 Student driven start-ups

With inspiration to the work by Ruth Graham ([5] and [6]) focusing on university environments that promotes entrepreneurship and innovation cultures, a positive outcome of the platform is its ability to incubate student driven start-ups. Graham highlights that interlacing entrepreneurship and innovation as part of the university strategy combined with management support in concise activities is a core driver for successful implementation. Another central aspect is the role of student led entrepreneurship community, which is highlighted as an increasingly prominent driver for successful implementation. Concrete experiences from this platform are well in line with the work presented by Van Rijnsoever et al. [7]. They show that incubators-incubation can provide a systematic method for business assistance to early stage start-ups. This among others through a network broker mechanism which help to expand a start-up's network, e.g. by providing referrals or organizing networking events.

We have experienced that the festival attracts entrepreneurial-minded students and ten projects have resulted in student driven start-ups (Table 3).

Table 3. Student driven start-ups listed according to their year of first presence at RF.

Project & year	Description and website link
Bio-fuel Generator 2011	<i>Deep frying oil for electricity production.</i> Diesel generators and fuel supply system designed to utilize old frying oil from the food stands at the festival.
Volt 2012	<i>Mobile charging as a service system.</i> Power banks are offered to festival participant as a subscription service.
Cutlab 2012	<i>Modular and collapsible seating.</i> A CNC milled system named 'kubio' to create flexible seating installations.
Dropbucket 2013	<i>A disposable cardboard waste bin.</i> Used at festivals and events to encourage participants not to litter. Winner of Red Dot Design award 2015.
Peefence 2013	<i>Flexible urinal system.</i> A low cost urinal which is easy to install and flexible in terms of applications. Winner of Danish Design Award 2018.
Sitpack 2014	<i>A foldable seat.</i> Prototypes of the foldable seat were tested with festival participants and the product was later crowdfunded
Papernote 2015	<i>A digital-physical snowdrop letter.</i> Interactive digital fabrication concept for the production of personal snowdrop letters at the festival.
Allumen 2017	<i>Algae that produce light from bioluminescence.</i> The effect is used utilized for concert and arts projects.
Containdom 2017	<i>New type of packaging for condoms,</i> which allows for the packaging to be utilized as a disposal container before the condom is discarded.
Glød 2017	<i>Portable lantern</i> made by partially recycled parts with an interactive functionality where colors and light changes according to sounds nearby.

The open literature stresses the importance of collecting feedback from stakeholders early in a product development process, e.g. Ulrich and Eppinger [6]. We have learned, that the unique needs of the festival and its visitors, allow the students to innovate for niche markets, which are often very difficult to penetrate without insider knowledge and close collaborations with the stakeholders. Our survey among the start-ups teams have resulted in the following findings:

- The majority of the projects had the first encounter with potential customers at the festival. The teams responded that this experience was highly important and effective in their learning and marketing of the products and services.
- The living-lab test environment at the festival was evaluated to be highly beneficial in obtaining valuable technical insights about the products/services. Insights reported to be an inspiration to directly changes of the design.

- There is room for improvement in connecting the festival platform to the overall innovation eco-system at DTU. There seems to be a lacking support in how to take the project further after exceeding the support from the platform.
- Finally, it is valuable feedback from the teams, that they will recommend the collaboration to peers with a similar motivation for student driven start-ups.

5 LESSONS LEARNED – CONTRIBUTIONS TO LIVING-LAB LEARNING

5.1 Overall format of the collaboration

The CEO support from both organizations has been crucial; in form of resource allocation (man power, money) and responsiveness together with clearly visible recognition of the collaboration. In short the management style can be characterized as bottom-up, appreciative, vision-driven and emphasizing students as festival co-creators. At DTU and RF the daily management and operation of the collaboration has been anchored in overarching support sections and not at a specific university department or festival division enabling organizational robustness and room for new ideas.

5.2 The necessity of flexibility and agility of the living-lab platform

Students have different interests and experiences and therefore it has been important to offer different learning activities. Further, it is of importance to the university that the majority of the students can earn merit for their work when participating. This variety of requirements has been ensured through four different ways to participate. It is crucial that the students have supervisors at the university in order to ensure fulfilment of educational requirements and to ensure high quality project work.

Table 4. Four different learning activities in the collaboration

Type	Characteristics	Merit
Courses dedicated to the festival (e.g. waste, acoustics)	Continuous support from dedicated research staff to take responsibility for the course.	Yes
Project on festival case in existing university courses	A fit must be identified between a specific festival case and the learning objectives in an existing course.	Yes
Dedicated special course	A special course in collaboration with academic staff at the university. Project outcomes are defined in dialogue between students, academic staff and the festival.	Yes
Extracurricular project or support team	Students can engage in the festival collaboration without any relations to merit giving activities. They can work on specific projects or support functions.	No

5.3 The role of the project coordinators

For the DTU coordinators and RF Student Platform important tasks are to establish and maintain network/relations within both organizations. It is an all year ongoing activity as the planning of a festival event takes one to two years. In order to keep a broad all year attention to participate in the collaboration the DTU coordinators and RF Student Platform are aware of the impact of storytelling and therefore successful and especially innovative and entrepreneurial projects are published in internal media within the two organizations. In order to keep a close contact between the DTU coordinators and RF Student Platform meetings are regularly arranged discussing activities concerning evaluation, follow-up, new projects, planning etc. The DTU coordinators and RF Student Platform play an essential role on four dimensions: i) they understand the core values of both organizations and they can act as interpreters in the dialogues between the two organizations, ii) they facilitate and coordinate the

identification and scoping of the projects, iii) they contribute to establish an attractive knowledge sharing living-lab learning platform, and iv) they provide practical and professional support to the projects. We see the DTU coordinators and RF Student Platform as key actors in the collaboration, and referring to the work by Wenger ([8] and [9]) and Kimble et al. [10], we understand their function as coordinators similarly to the role of boundary brokers. Boundary brokers can introduce elements of one practice into another. Brokers are members of multiple communities and are able to make effective connections between them; they make coordination possible by opening up new possibilities for learning and exchange. Furthermore, the broker's role is essentially that of an interlocutor.

6 CONCLUSION

We have experienced, that the infrastructure of a non-profit music festival with an international brand is a great playground for implementing and testing engineering solutions. The DTU-RF partnership is in line with the current trend of establishing attractive learning environments where students, as part of their education can collaborate with external partners. We have identified some essential characteristics which are important for the collaboration to flourish. We think these findings can serve as pointers and inspiration for other institutions with similar interests.

7 ACKNOWLEDGMENTS

The authors would like to thank all partners of the collaboration for their continuous support and enthusiasm. Also a big thank must be given to all the enthusiastic, dedicated and creative students who have contributed over the years.

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Informational skills as one of the learning outcomes in education of engineers

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Conference Key Areas: Engineering Skills, Quality Assurance and Accreditation, Philosophy & Purpose of Engineering Education

Keywords: Information, skill, accreditation, fake news

INTRODUCTION

Evaluation and accreditation of Higher Education Institutions takes into account more and more criteria that were not considered 10 years ago, they are mostly arising from learning outcomes approaches. The institutions need to provide expected learning outcomes linked to programs in relation to the needs of society and must be also able to explain how they evaluate them in relation to their educational process.

In engineering education, it is the case for national agencies such as CTI (Commission des Titres d'Ingénieur) as well as for European labels such as EUR Ace, proposed by ENAEE, both agencies including professional members which ensures that those learning outcomes are linked to professional ones. Those agencies have proposed lists of skills that should be those of graduated students, among these skills, many soft skills are present besides technical ones.

When CTI revised its accreditation criteria in 2016, as all agencies accredited by ENQA, it had to consult stakeholders about its new standards. For this occasion, CDEFI (Conference des Directeurs des Ecoles Françaises d'Ingénieur) asked that among the 14 learning outcomes considered as mandatory for an engineer, one could be about Informational skills because the companies employing engineers were complaining on the fact that during

internships and projects, students were unable to choose pertinent information among the huge flow of information they had at disposal. Some students and teachers are always thinking that it is only a technical problem linked with computer science approach!

Finding the good information is not only a problem of librarians, it needs critical spirit too. At the time when "Fake news" become a real problem event in politics, how teach future engineers the good way to fetch and select information?

This will be discussed in the paper with reference to the work already done by several networks of institutions in France and abroad. This is a great issue for our engineers graduated at master level: critical spirit being a strong point in their education.

1 WHAT ARE INFORMATIONAL SKILLS

1.1 As defined by CTI and ABDU (Association of Deans of university libraries)

CTI [1] defines, among the 14 skills necessary for engineers, informational skills as the ability to find relevant information, evaluate and exploit it. This is a rather broad definition that can apply in many fields, not only scientific ones and that can be evaluated through many different activities.

The definition lies within the ideas developed by ABDU [2] for French "Conférence des Présidents d'Université" considering that information is a priority at the 21th century and that it will also play a strong role in long life learning. Its referential is based on 4 great principles allowing students to really master information, those are:

- capacity to identify a need for information and define its nature and its extend
- being able to access efficiently to the necessary information
- being able to evaluate in a critical way the information obtained (sources, demarches and results)
- being able to product and communicate from the result on the research of information

In both contexts the idea of engineering is not very present, so it is interesting to turn to the point of view of a French institution dedicated to education of engineers INSA (Institut National des Sciences Appliquées in Lyon) that has dedicated much energy on those subjects.

1.2 As considered by INSA

INSA took advantage of its association of alumni to define the skills needed in this domain [3] in 2015. It is interesting to notice that this investigation met a good success among engineers, concerning a large spectrum of jobs such as engineering study, project responsible, research engineers. 25% of the answering engineers declaring they have informational skill in their job description.

The difficulties encountered in front of information depend very much of the kind of job occupied:

- For engineering study, the difficulty is to know the fitted resources and to be sure to get exhaustively the results
- For research engineers, the difficulty was to be able to face the huge amount of information and to capitalise and memorise the results of the researches

- For responsible of production, the major difficulty was to face the huge amount of information
- For specialised engineers, the difficulty is to formulate the good questions and to capitalise and memorise the results
- For quality engineers, the problem was to know and access to fitted resources

We see that previous skills are formulated here in a more precise and applied way, but that the great challenges for information defined in 1.1 remain valid also for engineers.

1.3 As considered worldwide

Canadian and Belgium universities have worked since a long time on those subjects.

Canadian experts [4] define informational skills as the set of abilities allowing people to determine the times when they need information, and then to find, evaluate and use this information. This can be developed in 5 essential skills:

- Being able to distinguish the extent of information needed
- Being able to access this information in an effective and efficient way
- Being able to realise a critical evaluation of the information and of its sources, and to integrate it in its network of knowledge
- Being able to use information efficiently to reach a specific aim
- Being able to understand economic legal and social questions surrounding the use of information, so as to use information in an ethical and legal way

They constructed a norm on information skills in higher education and 22 indicators allow to measure the mastery of information that the student acquire. We notice than those fields are not significantly different from CTI's choices.

In Belgium and Australia [6] too, this field has also been widely studied and books have even been published. We must notice that Belgian people even think of a minimum level in this skill to enter higher education [5] because success of students in university reveals to be very in link with their level in informational skills.

2 WHAT ARE THE STAKES OF INFORMATIONAL SKILLS?

2.1 Fake news

Since the terrorist attacks of 2015, this word is very much used for political reasons, and in our everyday life especially through internet, we are invaded by those unverified information, that very often, young people take as true ones, because they are broadcasted.

So the interest of the world of engineering education for this phenomena is completely understandable because many engineering skills are in link with society and its bad understanding make students misunderstand the economic or politic context of their own work. Furthermore, on those fields that are highly delicate ones, the acquisition of reflex and methods got on scientific fields is easier and give rise to less debates than heuristic one.

It cannot be the only duty of higher education, but families must also prepare their children to this aspect of things, however, we want to diversify the social origins of our students, and this is not evident for all social classes: equality of chances also lies on this good apprehension of all kinds of information sources.

2.2 Scientific information

The French ministry is particularly preoccupied [7] on those aspects, there is a real need for citizen to come back to scientific facts, the link between science and society is a major challenge not only concerning public information on scientific matters but also for the access to science to define projects, politics without opinions or beliefs but on very factual elements.

There is a real need to inspire from a structured scientific demarche for questioning the “ready to think” and stimulate critical thinking

2.3 Information necessary for real life or companies

Since several years we have complaints from our industrial partners on the fact that students-engineers are not able to find the pertinent information any more, this is a real problem because companies have less time to innovate and very often, they take an internee to launch an innovation process. In this case it is very important that the information got be of good quality because the future work of the company can be based on that information.

Very often this skill is transdisciplinary and preparing our students to look besides their usual and comfortable field [8]; at the beginning this kind of teaching was given by librarian in specific teachings, nowadays those teachings are backed to technical apprentice ships with active pedagogies.

3 HOW TO TEACH INFORMATIONAL SKILLS SO AS TO EVALUATE THEM - ONE EXAMPLE

3.1 The work done in INSA Lyon

There are rather few indications on how get the informational skills in pedagogical books but INSA Lyon [9] realised a good work on informational skills, it can be considered as a basis for all education system.

This work lasted from 2014 to 2016, one of the major point that launched this demarche was the fact that technical teachers criticized the previous classical teachings on information, insured only by librarians, then it was decided to work in teams of teachers and librarians using opinions of students and engineers (see before). Students asked for a more contextualised teaching, and preferred teachings included in multidisciplinary projects.

A discovery trail has been launched in 2016, under the form of exercises; the principles underlying this creation were:

- limit information to basic informational skills so as not to make the exercise too dense
- autonomous work
- more interaction between students and teachers

This discovery trail has been successful; however, all students were not convinced of the importance to know the resources of the library.

3.2 The global training repository

The approach taken was a programme approach: expected learning outcomes of the graduates were used; 9 learning outcomes were used, the more important being:

- matching needs and resources,
- which includes: sort sources,
- use sources,
- sort results

This is fully consistent with both requirements of CTI and ABDU.

A progression of apprenticeship was necessary because informational skills must be evaluated all along the curriculum.

For the 3 first years (undergraduate students), first aims of apprenticeship were described, then evaluation criteria, followed by assessment and learning situations. Each year, students will work specifically on one of the skills and be evaluated on this skill. At the same time, the other skills will be only recalled.

-during the first year (after A level), students live the discovery trail: the skills aimed is then to be able to know and use the resources necessary for studies: the students can take them into account and criticise their previous uses. Those theoretical knowledge including critical one (Google, Wikipedia) are the module “numerical tools, documentary research”, it is an exercise sequence and gives rise to a multiple choice questionnaire. The pedagogy is an active one with teams of 4 students made at random.

-during the second year, the aim is to be able to find and evaluate the results of these information researches in relation with a project or a problematic, students learn to define external criteria for the validation of information; the theoretical contributions are: what is evaluation, which intents, which issues. The pedagogy is on the form of a multidisciplinary project; during the first part of the sequence, students use voting boxes for a formative evaluation with gaming elements, then the projects in small teams take place with documentary researches and methodological tutorials, then a practical work follow where student build a grid of criteria for the information concerning their project.

-during the third year, the aim is to be able to delimit precisely the needs for information for a project thanks to a mental card, to produce and communicate, to manage information, to create a toolbox “information management” and a bibliographic database. The theoretical knowledge are bibliography tools, mind mapping software, issues on plagiarism. During these exercise students are realising multidisciplinary projects in groups of 2 to 8 students, the evaluation is realised through a report where bibliographic references are evaluated.

In some cases, the evaluation is realised by disciplinary teachers, that are taught on information, on bibliographic norms and non-plagiarism in reports.

For the moments the modules for the 4th and 5th year (Master degree) are not completely defined, preliminary reflexion decided that the aim would be the ability to know and use

resources for research and for companies, it could be done within projects, with self-evaluations.

4 CONCLUSION

The debate concerning information skills has not yet convinced all institutions; though this new criterion appeared in 2016, we see very few information on those skills in the self-evaluation reports; the only example publicised in France is the one presented before.

The teachers of INSA themselves think that things could be improved for example by gamification [10] of some sequences but also being more creative for the evaluation of some sequences thanks to cooperation with other institutions.

Librarians had to get new skills for supervision, apprenticeship of new tools; but they had also to change their professional identities becoming much more a teacher that has to evaluate. This is sometimes difficult as for all changes but the dynamism of the team is to be kept!

We think that the central point is the constitution of multidisciplinary teams of teachers because disciplinary teachers do not know what librarians know and sharing knowledge could be a good help for them because teachers are also researchers and that knowledge on information could help in their own practice, on the contrary discussion between disciplinary scientist and librarians could make those discover new fields of activities.

It is very surprising for CTI that apart from INSA we have not in our evaluations discovered other institutions that had a reflection on this skill which is a fundamental one, moreover there is not one unique way to treat the problem, agile methods for example could be another way.

But, as what happened for sustainable development criteria, we know it takes time so that a new skill is taken into account especially in transdisciplinary fields so we hope that this kind of paper will make institutions reflect on the subject: too often this subject is considered by scientific teachers only as the problem of librarians alone!

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Lean accreditations

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Conference Key Areas: Quality Assurance and Accreditation

Keywords: Accreditation, lean process, periodic evaluation, quality assurance

INTRODUCTION

Quality assurance and accreditation agencies are developing for many years: in France engineering education institutions are accredited by Commission des Titres d'Ingénieur (CTI) since 1934, and many agencies have already done several cycles of their periodic evaluation in the institutions. Very often, the deans of those evaluated institutions say that it is not possible to continue because, together with their team, they spend huge amounts of time writing self-evaluation reports or preparing audits, instead of making their institutions evolve. These two activities are really very time consuming for institutions.

On the other hand, the human cost of evaluation is very high for auditors too, and much time is also spent by evaluators reading the same documents as in the previous audit or visiting institutions that have not really changed, and then writing and presenting the results of those investigations.

Everywhere in the world there are reflexions or attempts to make those accreditations lighter, some have not yet results such as in HFKG (Federal Council of Switzerland) [1]. We will limit our presentation to the French speaking countries that are Belgium and France where this new process is beginning in October 2018.

In 2017, it was decided to launch a reflexion on a leaner accreditation process; this took place in CTI nearly at the same time as Belgium AEQES (Agence pour l'évaluation de la qualité de l'enseignement supérieur) began to have ideas of the same kind. Nowadays HCERES (Haut Conseil de l'évaluation de la recherche et de l'enseignement) which is our generalist agency is also having a reflexion on those fields for private institutions, it is called "audit adaptés" which means fitted audits, this process changes only the duration of audits but not the SER of institutions.

It took many meetings in CTI to define what was really important to be observed and understood in institutions when they were accredited; this common reflexion, where external experts contributed, was in itself a result for the CTI. We first got to a common view on the necessary elements that make us think that a complete accreditation process is not necessary and then we established the documents necessary for this lean accreditation, the organisation of audit itself being also fitted to this new process. The paper presents the step and conclusions of this work done inside CTI as well as some elements of the work done on Belgium on the same subject, because it is interesting to compare these approaches for two reasons: first one is that AEQES is our French speaking neighbour but also because we have common accreditation procedures in Belgium institutions, so CTI's members will have to participate to a lean accreditation experimentation different from what has been decided in France. Concepts underlying the two démarches are different, which gives richness to this double participation, we present will this paper in a way that we discuss this point.

1 THE CONTEXT

1.1 The situation resulting from periodic accreditation

In France as well as in French speaking Belgium, periodic accreditation takes place each 5 years. In France, in most of engineering education institutions both HCERES which is the French generalist evaluation agency and CTI which is the engineering education agency come each five years because the contract that the ministry of higher education sign with those institutions is renewed every 5 years. For the time being HCERES and CTI are trying to synchronize their evaluation for some institutions (same self-evaluation report, same sequences shared during the audit), however it is impossible to do so for all institutions because of problems of synchronisms of annual agendas of agencies.

ENQA (European Association for Quality assurance in Higher Education) asks its agencies members to consult very regularly stakeholders and to take into account, if possible, their opinion on the evaluation processes and its criteria. Concerning French Deans it was clear from our discussions that several of them were fed up with all the time spent for preparing twice documents each 5 years, however, we saw in the afterward reactions that things are not so simple.

In Belgium, things were of the same nature, accreditation taking place each 5 years too, AEQES edits after each campaign on a specific field of education, a transversal analysis on this field; each institution can read it and this gives indications on the trend of the subjects more often questioned during evaluation, making them reflect on the subjects.

We do not realise this transversal analysis in France but each year CTI publishes the statistics on recommendations and on strengths of institutions accredited during that year [5], this document does not indicate which institution is concerned with each item but it gives a good global information to the schools that want to progress: we can notice that periodic accreditation made institutions really progress; the accreditation agency visiting the school

each 5 year, since 1997, with different experts which insures a different look, even on the same criteria, analysis of weaknesses shows that the main weakness of schools stays the quality system of the institution. This explains the importance given to quality system in the criteria for lean audits.

1.2 The vision of AEQES of follow up audits

AEQES at the contrary now makes a distinction in the aims between 2 consequent periodic evaluations [2] it is not the only agency to do so, but if we observe what ACEEU (Accreditation council for entrepreneurial and engaged universities) proposes [3] in its reaccreditation process, we can see that few changes occur (fig 1) while in AEQES all the process is completely revisited (fig 2).

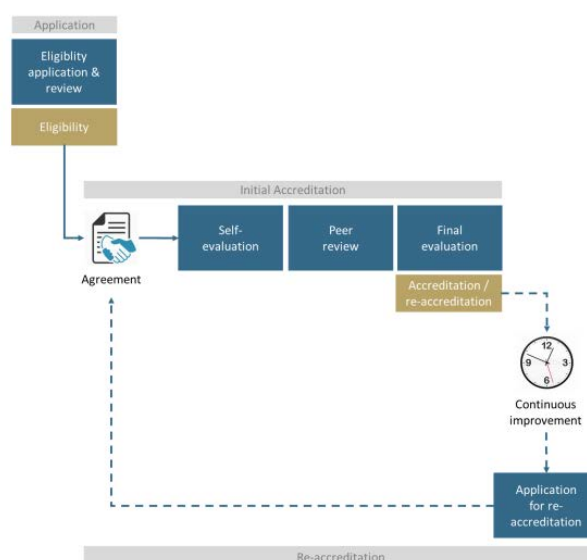


Figure 1

The first evaluation of AEQES is aimed at inviting the institution to have a look on itself and make a deep self-evaluation of its programmes, while the external experts make recommendations useful to improve their quality. Based on AEQES quality standards, this evaluation includes 3 steps:

- self-evaluation of the institution
- external evaluation realized through an expert committee, this step including a site visit and publication of the evaluation report
- publication of an action plan elaborated by the institution and its implementation

The agency then publishes a transversal analysis of the global quality of evaluated curricula.

The second one called “follow up evaluation”, is a lean evaluation and has the aim of supporting institutions in their continuous improvement dynamic, in the development of the actions presented in the action plan and in the construction of tools helping the governance.

So, a follow up evaluation considered as a consolidation evaluation, it is composed of 3 steps:

- a progress assessment of the actions already done
- an audit realised by a pool of experts, writing a public report
- the publication by the institution of an action plan and its implementation

AEQES thinks that evaluation cannot be limited to a diagnostic, it must also support the institutions for action: this explains and justifies the follow up phase. In this way it becomes much more than a strict external evaluation, because it becomes the concrete implementation of the quality policy of the institution. We can put this concept in parallel with the formative evaluation of our students because the same process is in action. While discussing with institutions we understood that more than the evaluation report it is self-evaluation that makes institutions progress [4]: the quality policy of the institution, leading to the construction of an actualised action plan, and its follow up is of the first importance.

The evaluation report itself allows the institution to confront the self-analysis of the institution to an external vision, thanks to the recommendations enunciated by the committee: so it can bring the institution a support to adjust the action plan that self-evaluation had helped to construct. ENQA in ESG 1.9 makes mandatory the publication of the action plan of the institution, so, AEQES asks that 6 months after the publication of the evaluation report of the experts, the institution publishes its actualised action plan on its website. The efforts made to really follow the plan, which are evaluated during the follow up evaluation, attest the wish of institution for continuous improvement inside a culture of integrated quality.

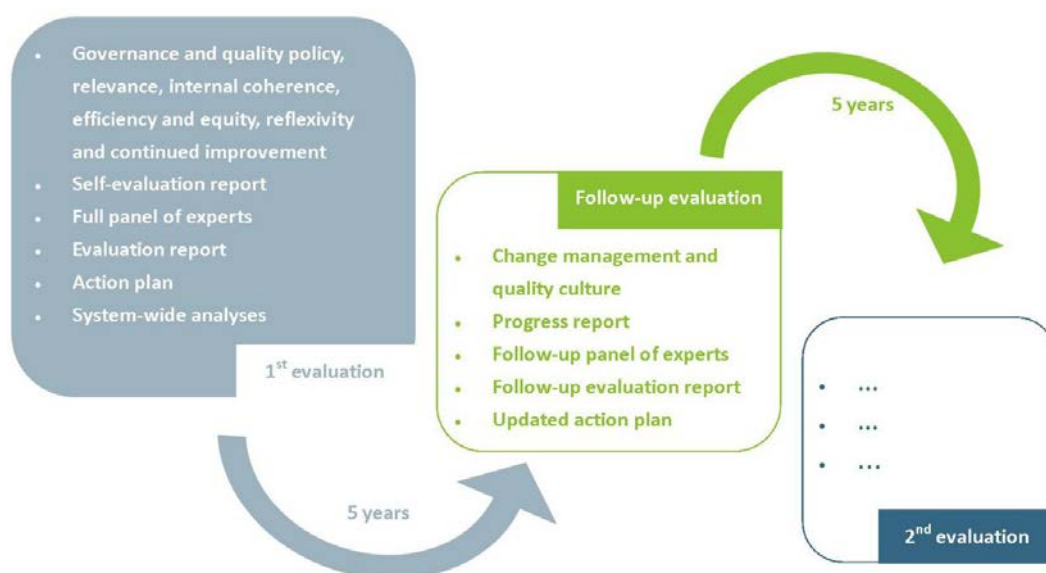


Figure 2

The aim of follow up audits is to support institutions in their dynamic for continuous improvement, in the pursuit of the actions already engaged and in the development of tools for quality. So, this audit at half course of a decadal cycle of evaluation maintains a true engagement towards quality because it intends to measure both the ability of the institution to change and the culture of quality.

The monitoring file elaborated by the institution for this follow up audit is not a complete self-evaluation report it only includes an introduction, a state of realizations with an analysis and annexes. In the introduction, the institution can explain the changes in the governance and in the program that happened since the previous evaluation. In the part where the institution presents the state of realisation of its initially planned actions, the institution also presents the actions it wishes to realize so as to improve the quality of its training offer. The questions raised in this part are:

-Since the previous evaluation, in the implementation of the action plan, which are the two or three more significant advances?

-Which are the two or three greatest difficulties encountered?

-Which is the retrospective look on the operating modes of the institution and how the stakeholders have been involved in the implementation of the action plan?

-Which are the two or three more priority actions for the next months or years?

In the annexes the institution gives the previous recommendations and their follow up, the initial action plan, a SWOT analysis, and an action plan actualized.

As a conclusion we can say that this vision of lean accreditation is very efficient in helping institutions in their approach of progress: as AEQES has not the mission of accreditation in its statute, this is a good way of proceeding for evaluation; on the contrary, CTI has an accreditation to decide each five years, so the way of operating is different, though the objective of improving the quality of the institutions is common to both agencies.

1.3 Vision of French accreditation agency on lean accreditation

The CTI is in a position where it is at the same time conscious of the weight of this accreditation for institutions and, as a representing of the French Minister and of the whole society (engineers, future engineers and employers) of the necessity of a control. Its position is then a mix between the evaluation of quality structures of the institution and the verification that CTI's criteria have really been taken into account.

Each 10 years, institutions have to go through a complete process of accreditation but the accreditation that institution has in between will not necessarily be a lean accreditation. So, a synchronisation will not exist between normal and lean accreditations of all institutions as in Belgium. The first thing necessary to elaborate were the conditions that the institution should meet so that a lean accreditation could take place: our first step was the definition of those criteria.

2 CRITERIA LEADING CTI TO THINK THAT A LEAN AUDIT IS POSSIBLE

At the beginning of the reflexion of CTI, the problem of audits arriving far in advance (3 years instead of 5) in the agenda, because of the synchronisation with the signature of the minister's contract, made us imagine a lighter audit than usual for those institutions; but, when we decided to extend this process to other institutions, it was necessary to describe the criteria that the institutions that would benefit from a leaner audit must meet.

The general information is that the institution must not have encountered major problems. It can be divided into two characteristics, one concerning the history of the institution: previous durations of the accreditation and previous recommendations and the other one concerning the quality system of the institution.

2.1 The quality of institution

Quality of institutions should be at the heart of the process of evaluation. However, in France, when we make the statistics of the recommendations given to institutions during the year, the

recommendation that arrives first in order in about half of the institutions is “to put in place a quality system” [5]

This shows that in France, for the time being, the culture of quality is not evident in institutions and that progresses have still to take place. CTI has a part to play for the development of those quality processes. This criterion is in a way very near to the AEQES one: if an institution is able to develop a good policy for its quality, CTI can trust it and let it have lighter accreditation, but the institution has also to be supported in this process through the leaner accreditation.

2.2 Level of satisfaction of the previous evaluation of the institution: duration and recommendations

At the end of each accreditation process, CTI gives or not an accreditation that can be either for 5 years (best result), 3 years (things that can be improved) or 1 year if CTI thinks that the program must be closed: it is possible to go to a lean accreditation only if the program has had a duration of 5 years' accreditation. This accreditation is given together with recommendations that the institution has to follow until the next accreditation time, so the second characteristic is the kind of recommendations given to this institution in the previous evaluation.

In CTI we have major criteria concerning several fields of the institution [6]. These fields are:

A Mission and organization of the institution in its context, B Partnerships of the institution, C The process of education of students, D Recruitment of students, E Employment of graduates, F Quality processes and continuous improvement

The recommendations after an audit can be given on any of these criteria. So CTI had to debate on the importance of these recommendations to decide if an institution can benefit from a lean audit.

As a conclusion, we see that the approach of lean audit is significantly different between France and Belgium: in one country all the institutions will benefit of a lean audit, at the contrary in France only “good pupils” can benefit from it: this difference is linked to two different dimensions: the culture of quality being more present in Belgium than in France for the time being, the second one being the fact that AEQES makes evaluation while CTI realises accreditation.

3 SELF ASSESSMENT DOCUMENT AND CRITERIA ASSOCIATED

When the institutions being relevant from a lean accreditation process have been stated by the Commission, they are advised that they will have to realise a shorter document (maximum 20 pages) based on elements decided by the CTI [7]. It is important to recall that even in those circumstances the frame of reference is always the same (R & O Volume 1) [6] but only the description of some parts is needed and the auditors will focus their observations on those parts.

3.1 The free part of the document

The institution knows its own contexts, it is important that it can express and explain positions concerning its evolutions. The institution has to develop in its document the internal evolution or the contextual evolutions that it had to live since the previous audit. So it can choose and develop these elements freely.

3.2 The mandatory items that must be developed in the SER

As CTI is an accreditation agency, some accreditation criteria have more importance than other, and some others can be new ones, so CTI asks the institution to develop on those points. First one is the complete description of the field of criteria that concerns its quality approach and its process of continuous improvement. CTI particularly asks to develop this field in reference to the ESG 2015 [8] edited by ENQA.

The criteria newly introduced (R &O changed in 2016) must be developed, they concern:

- the importance of fundamental and applied research in curricula
- the education to entrepreneurship and innovation
- the practice of another foreign language than English one
- the outgoing and ingoing mobility that must be followed by a return on experience with the students concerned
- the teaching and projects on sustainable development, social responsibility of companies, ethics and deontology: they have been introduced recently by CTI, some institutions have not been evaluated since this time
- the fundamental skill basis described for the program must be insured whatever the minors chosen by the student are
- there is a clear process established for the treatment of appeals in the institution
- any student can realize a one year break of study during at most one year but this must respect the terms of French law

The other elements are linked to institutional stakes, necessary check points on education, and new legal dispositions. They can concern as well site policy, pedagogic innovation, diversity, double diploma, contracts of professionalization, validation of the student commitment. It must be noticed that these two parts represent 15 on the 20 pages of the file (for an institution that has only a program to be accredited), the remaining of the file being constituted of mandatory parts such as data on the school or the note of strategic evolution of the institution.

4 THE FIRST RESULTS AND CONCLUSIONS

For the moment this new procedure has been presented and explained both to institutions and to auditors. As for each new process many questions arise and no doubt that some documents will have to be improved or more defined for the next campaign according to the quality policy of CTI (yearly surveys of institutions and auditors are realised)

However, the choice of this strategy for lean audit is perfectly assumed by CTI, it can give a model for other agencies that are having a reflexion at the same moment, either on their policy, either on the link between internal and external quality process, in this sense the comparison with the choice made by AEQES is interesting because this choice delegates to the institution a greater responsibility. Opportunities are also given to the institution to develop a portfolio [8] if they wish to, this new possibility can make our process evolve, but this supposes that the institution has an information system rather elaborated, which is not the case in all institutions for the moment.

All these changes are not so evident and many questions arise as well for schools as from auditors: CTI is in the process of changing and it is not evident for itself as well as for its stakeholders. For example, some drawbacks are possible because of lack of a complete vision of the commission on the institution and its historic. Our debates could be a bit different from what they are now, a strong recommendation to members to read the previous accreditation reports has to be made.

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Industrial impact on courses in software engineering

An empirical study on the contents of software engineering courses in 1990-2016.

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Conference Key Areas: Curriculum development, university-business cooperation

Keywords: Curriculum, thesis, courses

INTRODUCTION

Development of the curriculum is based on academic knowledge and research, but there are often topics where the industrial impact is clearly present. Developers of curricula should keep the contents up-to-date, both in the academic and professional points of view; especially in software engineering, where much of the experiences come from the companies. Institutions like ACM are making regular model curricula to help in the development process, but they are often a little bit delayed when compared with actively developed curricula.

In this paper, we have three points of view. The first one, based on material collected for paper [1], discusses the topics of master's theses, or how the topics have changed during the time. The second one studies the changes made for the offered courses, and we like to see if changes in the master's topics and courses have any connection. The third viewpoint is a short note how the ACM model curriculum of software engineering has changed at the same time.

1 MASTER'S THESES

The study of the theses is based on 540 master's theses made at the Tampere University of Technology (later TUT) on software engineering between 1990-2015. These were evaluated and examined by two professors, covering almost half of the total theses on software engineering of that time. We collected data from the topic,

company, type of the theses, language, orientation (research or constructive), and the gender of the author. Results have been published in [1].

In this study, we concentrate on the topics of theses. The topics were classified into six classes: embedded and operating systems, web, mobile, traditional computer science, communications and protocols (high level, “above sockets”), and information systems. In Figure 1, their share is given in per cent to make the comparison of years easier. After 2000, the number of students varies between 12 and 67 for years, the lowest numbers being 2002; for 2016 only four months is included (7 students). Before 2000, the yearly number of students is very small, from 1 to 6. The overall trend is increasing with a clear exception in the years 2010 and 2011. The last possibility to graduate with pre-Bologna curriculum was in 2010. Hence, the total of 67 students graduated. On the other hand, in the next year, only 24 students graduated.

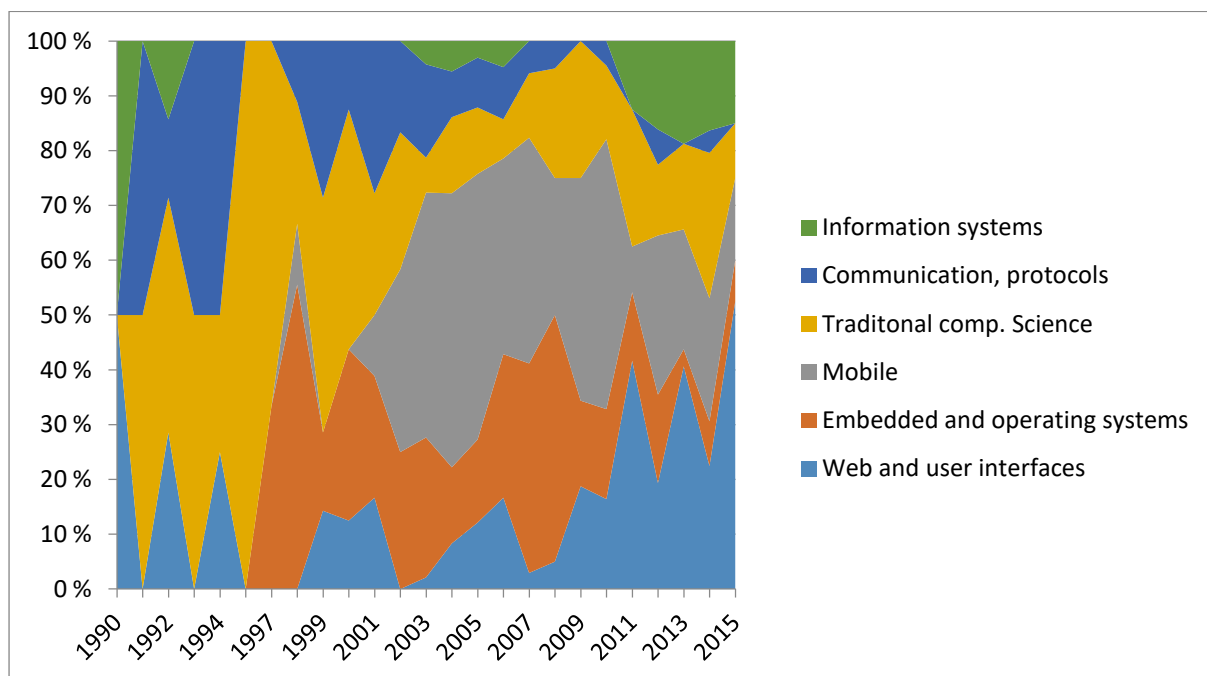


Figure 1. Topics of master's theses

There are some clear trends in Figure 1, even if yearly changes are big due to a small number of students per year, this affects especially years 1990–1999. Years 2008 and 2009 make the difference. Economic depression took place in 2008 and Nokia selected Windows for their phones instead of Symbian. Web and information systems became more and more popular. The number of theses in embedded and operating systems, and communications and protocols were decreasing, and computer science kept its share. Note that as so many theses were made on industrial topics, their topics were often constructive [1]. Hence, topics that are close to pure software engineering, are classified in "information systems".

2 STUDY OF COURSES

This study covers the courses on software engineering and related topics at TUT from 1990 to 2017 but concentrates on the years 2000–2017. After 2000, there have been two main curriculum reforms of the whole university; the first one in 2005 when the university adopted curricula that are compliant with Bologna agreement and B.Sc. level was introduced; prior to this, all students graduated directly as M.Sc. The second reform took place in 2013 when the faculties of the university were reorganised, B.Sc. studies were decided to be in Finnish, and M.Sc. level courses more and more in English.

Neither of these changes in curricula originated from faculty's needs to change the contents of the studies, but they forced us to redesign the curriculum and decide which are the courses needed in the new situation. The first change was a government decision, and the second one was made mostly because of financial reasons.

Figure 2 shows the relative share of courses classified by their topics. The topics used are the same as in Section 2 but there are no courses on information systems and software engineering is used as one topic.

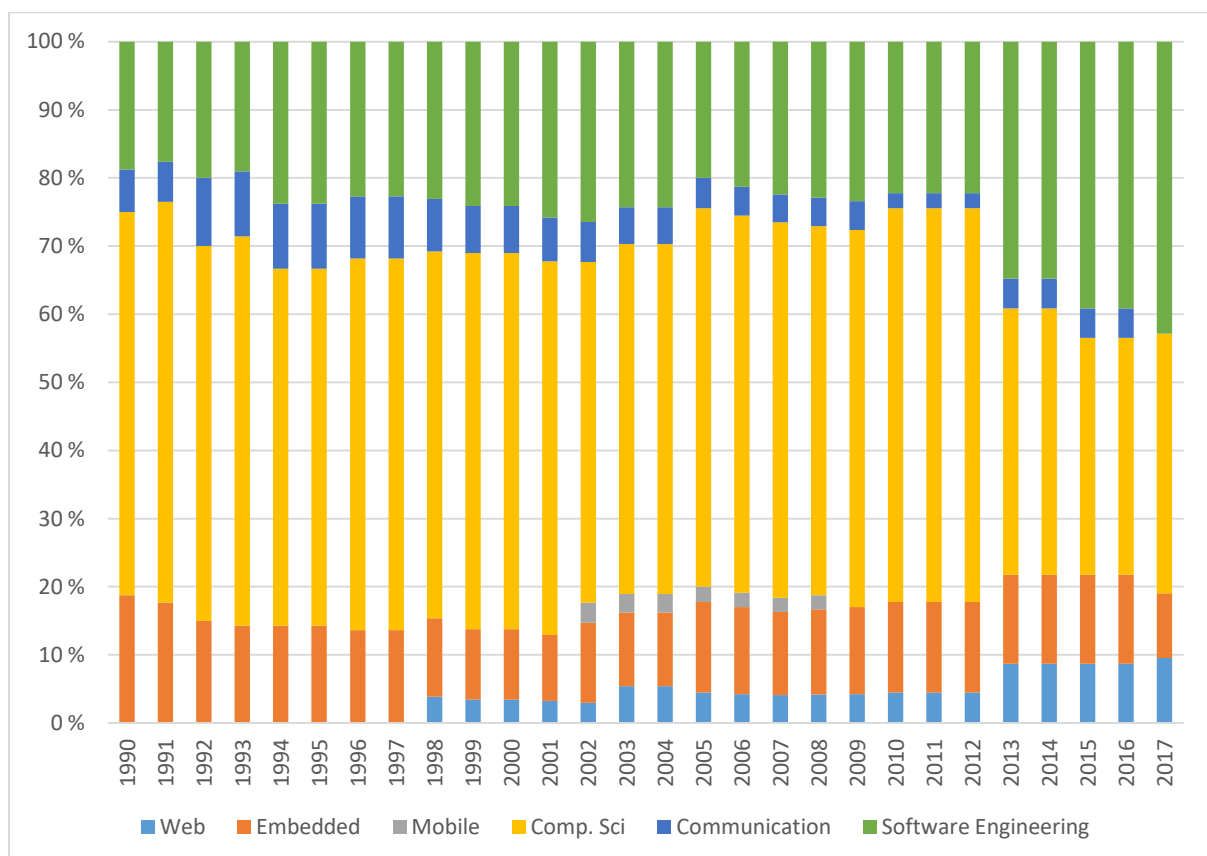


Figure 2. Topics of courses in six classes. Collected from [4].

In the viewpoint of IT, the changes can be divided into three phases: 1990-2001 was a growing phase (the growth is not shown in Figure 1, since it gives the share of each topic), 2002-2012 was quite stable (although it contains changes needed

because of Bologna agreement), and 2013-2017 was the shrinking phase. Before going to these phases, a quick look at courses that cover all these phases is taken.

2.1 Courses with a long lifespan

There are some courses that were in the curriculum in 1990 and are still there — or at least a corresponding course exists. The names of the courses may have changed, but their roles in the curriculum have been the same. These courses include mostly traditional computer science courses like "basic programming", "data structures and algorithms", and "the principles of programming languages", but there are also courses related to other topics like "operating systems", "introduction to software engineering", "software engineering methodologies", and "project work". Naturally, their contents have been updated several times over the years.

Of these courses, the basic programming course has been the most problematic one. In 1990, we assumed that new students have some idea of programming in advance. Since this was not the case in the real world, the course got quite early a companion; the courses were named programming 1 and 2. In 1997, IT students were given their own version of the courses, and in 2005 appeared their English equivalents. In Figure 2, courses that were offered both in English and Finnish are treated as one course.

The course of operating systems has had one major revision when concurrency was made a course of its own in 2005. The main reason was that multicore systems were becoming more and more popular, making concurrency issues important for the majority of the students; on the other hand, the need for deep understanding the operating systems was decreasing as a general skill.

Software engineering courses and project work have been the backbone of the curriculum, but there have been changes in their contents.

2.2 The first phase 1990-2001: Growing

In the years 1990–2002, the software industry in Finland was growing fast, Nokia being the leader. IT industry wanted to have more professionals and this message was heard. Intake of the curriculum of information technology at TUT was increasing rapidly being around 220 at the best years. The number of students increased and so increased also the number of courses. In 1990, there were 21 courses in software related topics, in 2002 there were 43 courses. Since some of the courses were also abandoned, this means that on average there were more than two new courses each year. In Figure 2, the relative share of different topics did not change meaning that all areas got new courses. The theses' topics in Figure 1 do not give any clear trend, mostly because of their small number.

Early in this phase, all kinds of skills were needed in companies, the goal was to educate as many masters as possible with quite versatile skills, but there was a growing trend of the companies' interest turning towards software engineering. This can be seen in the introduction of some new courses: "leading of a software project" (1992, intended for graduated people in companies), "testing" (1998) and "software

architectures" (1999). However, this was not seen in the topics of theses but several years later, software engineering was a skill that was needed, not yet clearly an academic topic.

Introduction of web-based systems can be clearly seen during this period. New courses on computer graphics, graphical user interfaces, web programming and usability were introduced. Some of them were short-lived before a proper set was formed. Also "databases" (1992) and "designing databases" (2001) were created. These two were not new courses in a sense that they were freely available for our students at the University of Tampere, but the increasing number of students and the increasing importance of databases also in technical applications caused their creation.

An interesting detail is that course "artificial intelligence" existed in 1990 but was cancelled in 1994. It was recreated 1999 with different contents, abandoned 2013 only to be recreated again shortly after that.

Some small courses were introduced for practical purposes: e.g. C language, Unix, and Fortran, but they were mostly short-lived and never essential part of the curriculum.

2.3 The second phase 2002-2012: Relatively stable but becoming International

The next phase from 2002-2012 starts with years where so-called "IT bubble" was broken. Interest in IT studies went down, but this is not seen in the courses. Instead, another phenomenon can be seen: more and more courses were lectured in English. This applies especially in the advanced courses on computer science, where lectures in Finnish almost disappear; in other areas, many courses were offered in two languages, Finnish and English. Still, the majority of the courses were offered in Finnish. One reason for computer science switching for English was the fact that at the beginning of this phase, the share of computer science theses decreased (as seen in Figure 1) and the number of students in courses was small. Hence, we did not afford to have them lectured in two languages.

In this phase, creating new courses was not so frequent as before; on average one per year; most of the new courses were created in 2005 when the Bologna system was adopted. In Figure 2, a small portion of courses is in grey to indicate mobile systems. Their topics were covered by several courses, but courses whose names indicate mobile systems were all Symbian-related. Hence, they disappear rapidly when Nokia published in 2008 that they will not develop their own operating systems (Symbian) any more.

2.4 The third phase 2013-2017: Shrinking

In 2013, there was a reorganisation of the faculties in the university, mostly motivated by financial problems. There were strict rules about curriculum development, which resulted in fewer courses. This was done by merging courses to bigger courses and dropping courses with a small importance and a small number of attendees out of the curriculum. This meant that parallel implementations for IT

students and other engineering students were cancelled. Computer literacy was also cancelled since students were expected to know more about computers in advance than before. From 47 courses in 2012, only 28 were left in 2013 (not counting parallel implementations in Finnish and English). During this period, only one new course has been introduced ("data-intensive programming", 2015) and two have been abandoned but of their contents were covered by other courses whose credit points were increased.

Most of the courses that were combined or abandoned were programming courses or traditional computer science courses. Since some of them had only a handful of students, they were removed from the curricula without having any corresponding course. Only two courses related to software engineering were removed from the curriculum: "maintaining software" and "the seminar of project management". This can be clearly seen in Figure 2, where the relative share of traditional computer science is dropping, but information systems have increased its share significantly. The share of web-related courses was doubled, too. This change was actually not as dramatic as how it appears, because the majority of students selected software engineering courses anyway.

2.5 Conclusion of courses

Until 2012, the number of courses increased, but the relative number of courses of different topic areas did not change. In spite of its popularity in theses, there were never many courses dedicated to mobile systems, but the topic was covered by other courses related to embedded and distributed systems. Basic knowledge of computer science courses is needed by all software engineers, explaining the number of courses on computer science compared with the number of theses.

Although software engineering courses were offered from the very beginning, theses that discussed improving the process were rare. Their amount has been increasing over the past few years. Switching for agile methods has been one of the reasons for this since they require new way leading projects and new tools for continuous integration, delivery, or automated testing to mention some. Anyway, this prevented the decrease in courses in software engineering, which can be seen in Figure 2 as an increase in their share.

3 ACM MODEL CURRICULA

There are two ACM model curricula available for undergraduate level software engineering during this period, the curriculum of 2005 [2] and later one in 2014 [3]. These reports do not represent their curricula in the same way, hence a detailed comparison is not easy. Since the above study concentrates actually on the master level of studies, the applicability of the ACM model is limited but it gives some hints to the trends.

If the "look and feel" of the reports is studied, a clear difference in describing software engineering is found. The tone of the 2005 version is to convince that software engineering is an important subject, but that tone is not found in the 2014

version. Clearly, the subject of software engineering had become mature by then. As expected, the curriculum still includes a lot of basic skills inherited from computer science, but there is a bigger emphasis on software processes, quality, large-scale programming related topics (e.g., architecture) and tools needed. Of course, most of these existed also in the 2005 version in some way, but there a clear difference in their relative importance.

4 SUMMARY

Compared with the development of the curriculum at TUT and our topics of theses, the same phenomenon as in ACM software engineering curriculum development can be seen: software engineering is clearly matured as a discipline. With maturity comes also the increasing need for professionals in the area, as our topics of theses indicate.

We were forced to make big changes in our curriculum in 2013, and it can be seen that they follow the spirit of the model curriculum of 2014. In the details, there are differences; we might have decreased the share of traditional computer science courses more than the model curriculum, but their absolute amount is above the minimum described by the model curriculum.

The conclusion is that the model curricula are excellent ways to check the direction of development. However, if the development is based on them, the curriculum is a little bit late. An actively updated curriculum should naturally lead to the same direction as the model one. At TUT, a close connection to the industry is formed with master's theses made of companies' topics. This connection helps to direct the courses and the content of the curriculum to correspond to the future needs of professionals.

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Research on the self-trust of engineering students

INTRODUCTION

Education should be able to train students with skills and competences that meet the expectations of the labour market during the study period.

Both higher education and recently graduated students are facing serious challenges presented by the 21st century labour market. Many competences are defined by employers as required, out of which *creativity*, *innovation* and *entrepreneurship* are key competences in most professional areas. This is especially true for the engineering profession since accelerated technical and technological progress in the 21st century presents a task to be solved for engineering education.

The purpose of the correlation research is to present, based on a pilot survey, the students' self-assessment of their own skills and achievements as key factors of self-trust, and compare these measurement results with those of senior business leaders in the same sector. The survey focuses on the existence of self-trust, one of the basic conditions for the key competences expected by the labour market.

The research is based on the hypothesis that engineering students on their way to enter the labour market are unaware of their own abilities and their self-trust needs improving. The significance of the subject is provided by the fact that students with higher self-trust can be more successful and are more consciously able to plan their professional goals and career. It is important to have long term goals in order to knowingly plan studies, optional subjects and competences to be improved. To do this, students need to have realistic self-assessment and self-image and as a result they must have a healthy self-trust.

In the framework of the current research which is the primary examination of an international research self-trust is made measurable and by applying the quantitative research method data are collected, anonymously among students based on a standardized questionnaire. People taking part in the survey are engineering students from various departments of BME Faculty of Economics and Social Sciences, who have enrolled for the optional subject of Learning and Lifelong Learning. The selection was aiming to include various engineering departments and it was assumed that the students who had enrolled for the subject were interested in the interaction between learning as an activity and the development of the career path.

The survey was conducted in two consecutive semesters.

In addition to questions relating to self-trust, students also answered questions about their needs for developing their competences and about their expectations with regard to the methodology of education. Alternative closed-ended questions on competency development were included in the online questionnaire, respondents were required to answer prioritizing multiple choice questions and open-ended questions.

On the one hand the survey results along with the comparative data from business were disclosed among the students concerned, and were evaluated with the tutor within the framework of the course. On the other hand, they are shared with business people, with the leaders of employers in the form of lectures and leadership training so that executives responsible for the integration of fresh graduates will see their own tasks and responsibility to develop the young workforce to meet their requirements. Last but not least the study intends to draw up key messages for higher education.

1. INNOVATION AND SELF-TRUST

A large-scale development of science and technology began in the twentieth century, which has further intensified in the 21st century, reinforcing the role of innovation and technological development both at the individual and organizational level.¹ The representatives of the engineering profession have a prominent role in this development, and higher education is facing a huge task in the education of engineers.

In the 21st century, not only the ability to develop is a requirement, technological advancement in different areas simultaneously creates competition and the need for co-operation between various actors. Creativity and innovation can result in novel methods, innovative or different ways of thinking, but at the same time, players in different industries are now forced to cooperate in certain areas of development, it is their well-understood interest to share the costs of development. The goal in every evolving industry is to find the state-of-the-art high-tech solution quickly and cost-effectively. In places where this works well - e.g. the Silicon Valley - a high degree of trust is a common characteristic both on the individual as on the organizational level.

Trust is a positive conviction that comes from the knowledge of the skills and values of another individual or organization. Trust can develop between two people when this conviction is reciprocal. Trust can accelerate processes; simplify collaboration thus resulting in lower costs. However, the ability to trust is based on self-trust. In order to be able to trust someone else, you have to be able to trust yourself first. The basis for our self-trust is to have a realistic self-image, based on which we can assess ourselves. To know our strengths and weaknesses, which ultimately result in our self-esteem that comes from our past experience and nourishes our self-trust with regard to challenges ahead in the present as well as in the future. This positive conviction nourishes our entrepreneurial spirit, our courage and our sense of responsibility.

2. TRUST AS A KEY COMPETENCE

Trust is a fundamental element of social capital – a key contributor to sustaining well-being outcomes, including economic development. (by Esteban Ortiz-Ospina and Max Roser) In a much cited article, Arrow (1972) says that "Virtually every commercial transaction has within itself an element of trust, certainly any transaction conducted over a period of time"².

Measures of trust from attitudinal survey questions remain the most common source of data on trust. Yet academic studies have shown that these measures of trust are generally weak predictors of actual trusting behaviour. Interestingly, however, questions about trusting attitudes do seem to predict

¹ Beszteri Béla: A 20. század mérlege és a 21. század esélyei

² Algan and Cahuc Trust, Institutions and Economic Development HANDBOOK OF ECONOMIC GROWTH 2013

trustworthiness. In other words, people who say they trust other people tend to be trustworthy themselves.³

OECD, the Organization for Economic Co-operation and Development started working out the project 'Defining and Selecting Key Competences: Theoretical and Conceptual Foundations with the participation of the Swiss Federal Bureau of Statistics and the United States Department of Education and the US Educational Statistics Center in 1997. International experts took part in the work, their analyses were arranged for publication⁴ by the organization and the compilation was simultaneously released in Canada, Germany, Switzerland and the United States.

The volume examines competences from a variety of perspectives and approaches. The theoretical approach of the concept of competence deals with general cognitive competences as intellectual abilities; special cognitive competencies, the existence of which offers the possibility to carry out an individual activity, such as driving a car. However, one of the various approaches and theories is the classification based on action competencies, which are at the same time the psychological conditions for a successful performance. The components of action competences are the general problem-solving ability, the ability to think critically, the possession of general and specific knowledge of a given situation, real and positive self-trust and social competences, which are often the outcome of school education. However their relevance exceeds formal education they are also important in everyday life. From the point of view of the subject of the study it is important to see that the theoretical approach classifies confidence as a constituent of action competences, which determine and influence our actions in different areas of work and private life. This theoretical approach also demonstrates that trust is not merely a feeling, but rather a measurable competence which can be established by behaviour frequency that basically affects efficiency in various fields of work and private life.

Education is at the heart of research at the Center of Educational Research and Innovation (CERI). They are seeking answers to indirect and direct questions related to future schools and universities in their comprehensive research which has been going on for many years.⁵

The aim of the project, which was developed in cooperation between OECD and CERI, "Learning Sciences and Brain Research", was to encourage cooperation between learning sciences and brain research, as well as between researchers and education policy.

Following the agreement with several research institutes, three conferences were held, focusing on "early learning", "young people's learning" and "adult learning". For the purposes of the present study it is worth highlighting and interpreting some statements included in the material of the three conferences.

The OECD study⁶ published in 2002 states that "successful learning is likely if a student has (a) high self-trust and self-esteem, (b) is strongly motivated for learning, and (c) his/her learning environment is characterized by "high challenge" and "low threat".

Learning fails when one (or more) of only four obstacles prevents success. The four learning obstacles are (i) lack of self-trust and self-esteem (the factor of well-being); (ii) poor motivation (does not "really want" to learn); (iii) real (or assumed) incomplete ability ("it is too difficult" or "I cannot do it"); (iv) lack of learning opportunities.

Referring to the opinions of a wide range of instructors, the publication states that the primary problem for students is self-trust and motivation. Self-trust and self-esteem are necessary but not sufficient conditions for motivation (the desire to really learn), the publication states.

3 Jones, E. (2013). Internationalization and employability: The role of intercultural experiences in the development of transferable skills. *Public Money & Management*, 33(2), 95-10

4 Defining and Selecting Key Competencies. Edited by Dominique Simone Rychen, Laura Hersch Salganik, 2001. Hogrefe and Huber Publishers (Seattle, Toronto, Bern, Göttingen).

5 <http://www.oecd.org/education/ceri/about/>

6 Understanding the Brain: Towards a New Learning Science OECD 2002

At the same time, in 2002, the OECD began examining good examples in eight countries (the UK, Australia, Denmark, Finland, Canada, Italy, Scotland and New Zealand) in terms of learning development methods which have proven successful in secondary education. The result of the inquiry in conjunction with the literature published in the various languages and the policy environment was published in several languages in 2005. In the chapter written by Janet Looney (Dylan William, King's College, London), the term "metacognition" is used to indicate that the learner is aware of how to think over and learn a subject. Learners having this ability can better target goals and develop their own learning strategy more consciously. This is supported by the results of the PISA Survey conducted in 2000, one of the most important conclusions of which was that in the absence of motivation and self-trust, students are unlikely to be able to develop such regulatory strategies.

In the 2005 study, several school teachers reported that cooperative learning, learning from each other in small groups, self-assessment, and feedback to each other not only increases learning efficiency but also promotes self-trust.

3. SELF-TRUST OF ENGINEERING STUDENTS

The survey related to the topic of the paper was conducted among engineering students at the Budapest University of Technology and Economics (BME) Faculty of Economic and Social Sciences (GTK) in September 2017 and later in February 2018. The questions of the survey were the same as the online survey questions listed by the New York based global adult training company, FranklinCovey in order to allow for comparison between students' data and those of active players in the labour market.

As a pilot of an ongoing research, over the two consecutive semesters 20 and 14 students completed the questionnaires. When providing the average and variance values in the answers of the two groups we follow the chronological order, so the first number is always the result of the autumn group, and the second is of the spring group.

The online questionnaire, consisting of 12 questions, asks about key elements of **personal credibility** and **self-trust**, such as **integrity**, **intent**, **capabilities**, and **results**. The engineering students formed an opinion about themselves on the online site, anonymously. In relation to each key factor, they had to indicate by a value between 1 and 5 which of the two statements most expresses their own attitude and behaviour. Values 1 and 5 were expressed by 1 statement respectively. The results of the two groups were very similar with respect to each key factor.

With respect to *integrity* the questionnaire asked about trustworthy behaviour, respect for one's own and others' promises, behaviour according to their own values and principles. On a scale of five the average of the two groups is 3.48 and 3.62. For comparison, the average of the 150 respondents working in the competitive sector in Hungary is 4.41.

Students responded by giving a value from 1 to 5, where the highest average was given to the question where value (1) meant the statement, "*I often act differently from what I say*" while value (5) denoted the statement "*I act according to my values and my principles*". The average of the two groups was 4.00 and 3.92, with a coefficient of variation of 0.79 and 0.62 respectively. Response 1 was not marked by any respondent, while 25% and 14% of the respondents marked 5, acting according to his or her own values and principles.

Among the questions related to integrity, the students gave the lowest rate answers to the question where (1) meant that "*It is hard for me to admit that others might be right*", while the value (5) meant that "*I'm honestly open to consider new thoughts*". The average response rate for the two groups is 2.9 and 3.6, with a coefficient of variation of 1.16 and 1.09. Three of the larger group responded that they had difficulty in admitting that someone else might be right, which accounted for 15% of the respondents. There was no such student in the other group.

Undergraduate students are thus consistent in tracking their own values and principles, but it is difficult for them to admit that others may be right or have valuable new ideas. This phenomenon can be a barrier to collective creation. It is quite clear that responses of managers who are at the highest level in a hierarchy in a given organization represent a value higher by 0.86, averaging the value of the two groups, for integrity.

The questions asked about the second key factor of credibility, i.e. intent, investigated the students' attitudes in looking for balance between their individual goals and the consideration of the goals and interests of others. Here the average value of the two groups is 3.37 and 3.36, while the business leaders' average is 4.19.

Concerning questions relating to individual intent both groups are the strongest in their ability to care for others. With regard to the two statements, (1) "*I pretend to care about others*", (5) "*I sincerely care about others*" - the average of the two groups is 3.80 and 3.43. Generation researchers claim that the Y generation desire to belong to a team, are willing to become members of a team. This average result supports this claim and the coefficient of variation of 1.02 and 1.10 shows this generation's aspiration for independence and freedom. It is important to note that no respondent marked the value of 1, students do not pretend any other intentions than what they feel about others

The lowest average value among questions relating to the research of intentions, 3.1 was attributed to the statements on abundance at the autumn group, where statement (1) meant "*I behave as if there was not plenty of everything*" (money, opportunity, resource), while (5) meant "*I behave as if there was plenty of everything*" (money, opportunity, resource). The abundance mentality is relevant in cooperation with others and entrepreneurial skills. If one can believe that there are enough resources and everyone can get enough, then he or she is able to enter a win-win cooperation. The lack of this attitude leads to a feeling of threat by scarcity, it undermines self-esteem and results in an urge to compete and defeat others.

The lowest average of the spring group, 3.29, relates to the two statements (1) "*I tend to consider only my own interests*", and (5) "*I take into account the interests of others*". This result is interesting because this group is also strong in the care of others concerning their response to questions of intent, but based on their responses taking into account the interests of others is not their strength.

As a result of responses to questions related to intent as a key element of personal credibility, it is apparent that, as with the survey results of research conducted on the behaviour of the millennials, the students participating in the survey have a strong intention to pursue their own goals and needs, and they turn to others in the intent of caring for them with the same attitude.

In our interactions with others, we judge others based on their behaviour, while we judge ourselves based on our intentions. Intention is not loud in itself if we do not communicate it, or if we do not express it correctly and consciously, others will only judge us based on our behaviour. For this reason, students participating in engineering education can benefit from work in small groups, from project tasks requiring co-operation, where they have to match their own goals to others' goals. The knowledge gained in these tasks gives them an opportunity to acquire useful self-knowledge and self-assessment experiences.

The first two key factors of self-trust, *integrity* and *intent* derive from the character, while the next two key factors, *abilities* and *results* are related to competence. In assessing a person's trustworthiness, the higher level of self-knowledge the students are at for the first two factors, the more they can realistically judge themselves. Self-knowledge can be most efficiently developed by experience. Students receive less feedback from higher education in this field, as opposed to the other two key factors, in particular the results. This is also supported by research findings.

Within the field of responses to competency questions, obtained results reflect on the attitudes required to achieve results as a measure of one of the key factors of self-trust, and these are the best average results obtained in the survey. The average result of the two consecutive groups is 3.75 and 3.57 on a scale of 1-5, while that of business leaders is 4.61. This tendency can also be observed among the participants working in high ranking leading positions in businesses. responses around the topic of results show the highest scores comparing responses related to the four key factors.

The autumn group response to two statements provided the same average score of 3.85 as the highest value; the spring group also estimated themselves with the highest average of 3.93 with their answers to the same statements. One of these statement pairs is (1) *"I cannot always be counted on"* and (5) *"I'm totally trustworthy"* with the coefficient of variation of 1.09 in the autumn group and 0.997 in the spring group. The other set of high average values for the spring group is (1) *"I set the benchmark at a low level"* and (5) *"I aim at success"* with an average of 3.71.

In the light of the a.m. data, it can be concluded that according to their own assessment the students' self-trust is based on their reliability and result orientation. In higher education, it is worth paying attention to and giving feedback on this positive conviction and the manifestations of these two skills so that the students are aware of their strengths. If students receive more positive feedback, it increases not just their self-trust, but also their trust in their teachers and higher education.

As a last factor, students are required to interpret their own answers related to their own skills. Both groups evaluated themselves lower in relation to the statement pairs related to their skills than in the case of statements about result orientation and the same trend can be observed in the responses of business leaders as well. The average of the responses of the two groups is 3.13 and 3.12 respectively compared to the average of 4.42 for business executives.

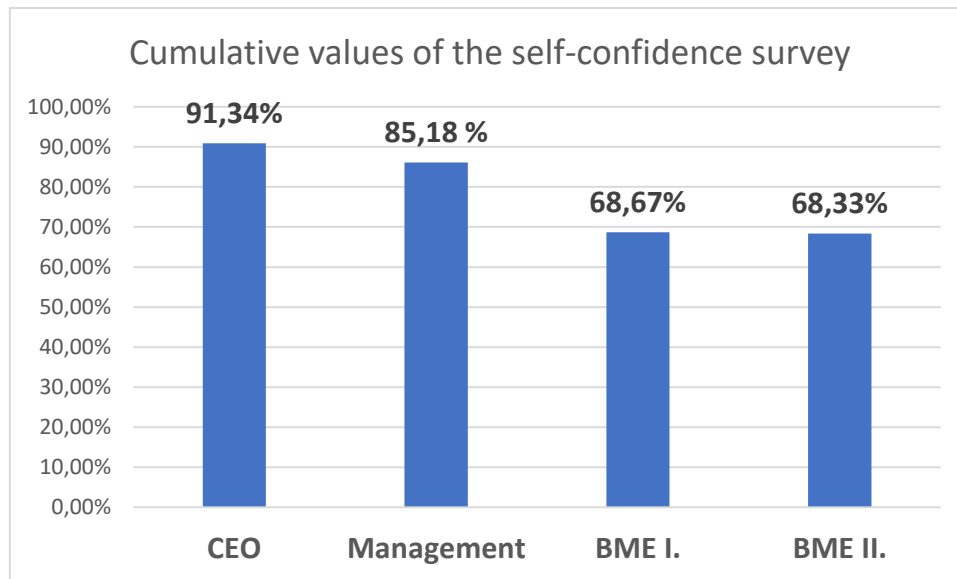
In this group of questions, the lowest value (2.55 and 2.93) with the highest coefficient of variation (1.317 and 1.328) is achieved by the responses to the statements (1) *"I do not know where I'm heading in life"* (5) *"I know exactly where I want to get"*. Within this group of questions the highest scores (3.55 and 3.21) are reached by the responses to the statements (1) *"I lack the abilities necessary to perform my duties."* (5) *"I have all the necessary abilities to accomplish my tasks"* with a coefficient of variation of 1.19 and 1.12 respectively.

In the 21st century scopes of activities, jobs disappear and are restructured, digitalisation is expected to further shape the labour market. Students' parents who are employees do not work in the same workplace or job during a lifetime. Students have very few examples around themselves, in virtual or real life, which are helpful in planning their life career. During classroom discussions with the students, it turned out that their acquaintances who graduated as engineers have an unimaginable variety of jobs: they are executives in their own ventures working in various fields, or make a living as actors and other occupations not requiring engineering competencies. This variety of patterns is more alarming for students than inspirational.

One must not ignore the fact that in comparing the attitudes needed to achieve the results - *"I believe in myself, I am trustworthy"* - and the assessment of ability - *"I have all the necessary abilities to accomplish my tasks"* - the answers of the people at the top of the hierarchy showed similar tendencies.

In examining our competencies, we are most subjective when we assess our own abilities; it is most difficult to assess our own capabilities realistically.

Finally, when examining the self-trust values calculated as the aggregate result of the four key factors, it is apparent that for the 11 executives at the top of their career participating in the survey, their positive convictions about their own selves were the strongest. The value of their responses converted gives a result of 91.34%. Their direct reports, the 139 top-ranking leaders' self-trust index is 85.18%, whereas those of the two groups of engineering students participating in the survey are almost the same, 68.67% and 68.33% respectively.



All in all, we can say that our achievements and our success at work strengthen our self-trust. If the labour market confirms our knowledge and abilities by offering the potential to be promoted to a high ranking position, it strengthens our self-esteem. However, not every fresh graduate can expect to have a leadership position, so it is very important that the self-image and self-assessment of newly graduated students just entering the labour market does not depend on the feedback of the outside world, they should rather be aware of their abilities, strengths and weaknesses.

4. CONCLUSION

OECD studies and the various studies carried out by the pedagogical profession emphasize the importance of self-trust in the efficiency of learning. Higher education can start educating students who have been studying for 12 years, who already have a learning experience, more or less good self-image and self-esteem, and have a vision of their own future, or are expecting it from university years.

Engineering education faces these challenges and tries to meet the expectations of the labour market as best as they can by designing the best training content and methodology. The present study aims to contribute to this by providing a non-exhaustive summary of the research related to the subject and by presenting specific research results.

It can be established that, in academic education, in addition to theoretical education, work in small groups, project tasks and cooperative research work have to play an increasingly important role. As part of this cooperative work, students need to get the most feedback possible from their instructors and from each other. This not only improves their self-assessment, it not only helps to raise awareness of their strengths and competencies to be developed, but also enhances the ability to give and receive feedback, which will become one of their most valuable assets in the world of work.

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Active Learning in University: An Approach to a Freshman Science Course

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Conference Key Areas: Innovative Teaching and Learning Methods

Keywords: Integrated Science, Active Learning

INTRODUCTION

Student-centred active learning approach in undergraduate science education has increasingly been adopted by a number of universities world-wide during the past few decades, and mounting evidence indicates positive impacts of the active learning approach on students' learning outcomes [1,2]. Some notable active-learning models such as *Student-Centred Active Learning Environment with Upside-down Pedagogies* (SCALE-UP) at North Carolina State University [3] or *Technology-Enabled Active Learning* (TEAL) classes at MIT [4], have successfully been applied especially to large enrolment classes. Moreover, real-life challenges faced by tomorrow's engineers in this ever-changing world demand a strong interdisciplinary foundation applicable to real-life situations. To that end some universities have designed their own integrated science courses such as the *Integrated Quantitative Science* at University of Richmond [5], *Frontiers of Science* at Columbia University [6], and *What is Life* at Harvard University [7].

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As a pioneer university in Turkey in implementing a liberal-arts based educational model, Sabanci University envisions its graduates (~70% engineering majors) to be able to thrive in an interdisciplinary environment and to be able to tackle real-life problems from different angles. We also expect our students to contribute to the development of science and technology on a global level through participatory teamwork, as well as disseminate the gained knowledge to the benefit of the community. The pillar of the unique educational model of our University is the first-year core curriculum, taken by all incoming freshman students (~1000 students per semester) regardless of their background knowledge and their prospective majors, which aims at helping students develop the skills for accomplishing these goals and expectations, starting from the very beginning of their university life.

Conforming to the visions of the University, the core curriculum team have also joined the global initiative to place students' learning at the focus and reconsider the roles of instructors in higher education. In particular, our two-semester introductory science course, "Science of Nature" (NS course; 6 ECTS credits per semester), is now offered in active, collaborative learning format in specially-designed classrooms similar to those used in SCALE-UP and TEAL. The NS course was originally custom-designed and has been offered since the beginning of our relatively-young University. The course aims to initiate curiosity and desire for learning "scientific thinking" in students, and at the same time introduces some of the basic concepts of natural sciences. At the same time, in the NS course we place high priority in skills such as critical thinking, systematic problem-solving strategy, scientific literacy and teamwork, all of which are quite essential and valuable skills for all professionals including engineers. However, over the years the course had lost its interdisciplinary nature and more importantly, all the components of the course were given with traditional pedagogy, which had become outdated and ineffective for the student profiles that changed over these years. The profile change is due to i) the decrease in the ratio of students on full scholarships from ~80% to ~40%, ii) the changes in the secondary education system and in the central university entrance exam mechanism in our country, and iii) the increase in the number of freshmen students from ~200 to ~700 in over 10 years. These factors resulted in the drop in the level of academic performance of students (see *Fig. 1.*), more diverse background of the freshman students and drop in attendance rates. Necessitated by the profile change, as well as to stay up to date in "Scholarship of Teaching and Learning" (SoTL) [8] and to preserve our University's leading position in the education scene of Turkey, we thoroughly reviewed and revised the NS course in 2013.

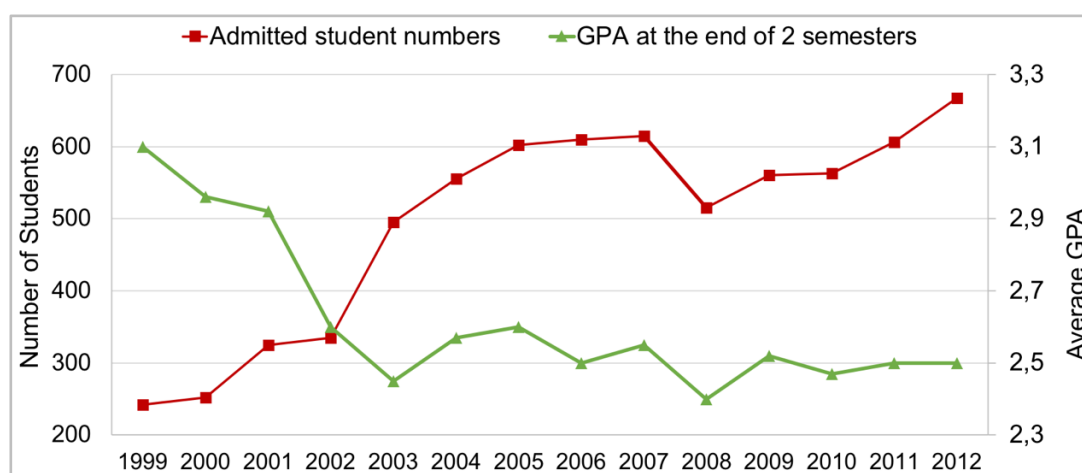


Fig. 1. Average GPA (green, right axis) at the end of the 2nd semester and number of admitted students (red, left axis) since 1999

Throughout the revision and implementation process, the key question we pursued was “How can an introductory science course more effectively help prepare our engineering students to cope with real-life challenges?” In response to that, the methods we chose were active, collaborative learning with student-centred course design, using integrated science contents that are relevant to students’ daily life and interests.

1 THE NS REVISION AND COURSE DESIGN

1.1 Pre-Revision Course Format

The NS course consists of NS101 and NS102 taken in sequence. Before the revision, physics topics were taught in NS101, followed by chemistry and biology in NS102, all with rather classical contents. The weekly structure of the original version consisted of two two-hour lectures given in a large auditorium (~350 students) and one two-hour recitation (problem solving session) in a classroom with ~25 students. The lectures were taught in a non-interactive, traditional manner and students were mostly passive listeners throughout the course. The recitations were taught by graduate teaching assistants (TAs) who solve conceptual and numerical problems related to the weekly content, on the board. Additionally, there were three lab sessions per semester, where students performed basic physics, chemistry, or biology experiments as a group and wrote reports. The exams (two midterms and one final) were the major assessment tools used to evaluate students’ performances in the course, constituting 50–70% of their course grades, depending on the semester. The rest of their grades were obtained from weekly quizzes taken in the recitations and from the lab reports. These assessments were all summative. By 2012, the attendance rates had dropped significantly; on average, the rates were ~40% in the lectures and ~60–70% in the recitations, and the course failure rate had soared to as high as ~40%.

1.2 The Revision Approach: The Structure and Contents

The revision process was initiated in 2012 by a team of faculty members who had taught the NS course with classical contents in the traditional format. The team first analysed pedagogical approaches, curricula, and designs of similar science courses offered by the leading universities in engineering education (including those listed in Introduction) and determined the framework of the revision: the student-centred “backward course design” model [9], with all learning activities and assessments aligned with students’ learning objectives.

In addition, we adopted a modular structure around four major open questions in science, concerning Nature and relevant to our daily life:

1. Are we alone in the Universe?
2. Is antibiotic resistance a big threat for the humankind?
3. Are humans causing climate change?
4. Can we ever comprehend the workings of the brain?

Within each of these four modules, the basic concepts of physics, chemistry and biology and their interconnections are emphasized to bring back the interdisciplinary aspect of the course. We note that while the format of the course is disruptively revised, there is ~70% overlap in topics with what were previously taught. The new courses additionally provide materials that serve to bridge the topics in different disciplines. With this revised model, we aim to strike a balance among development of higher order thinking and learning skills, learning of fundamental facts specific to the three disciplines and personal development for the students.

1.3 Revised Course Format

Each module is 7-week long (2 modules per semester), and all students must take all four modules in sequence. The weekly course structure of the revised NS course begins with a pre-lecture worksheet, aiming to prepare them for the main concepts of the upcoming week. The lectures are still given in the same large auditorium; however, a classroom response system with peer discussions, online simulations, and “muddiest point” feedback are incorporated in the lectures, to change the role of students from passive listeners to active learners. The recitations are now held in specially-designed classrooms with round tables and whiteboards all around to promote collaborative learning, where students work on problem sets in small groups. The recitation sections are led by “Master TAs” (MTAs), who are TAs specifically trained in pedagogy and classroom management in the active-learning environment. The MTAs coordinate a team of fellow TAs and undergraduate learning assistants (LAs), who facilitate collaboration among the student groups, assess the students’ conceptual understanding, and provide timely feedback to the students during recitations. An online quiz closely related to the recitation problems is administered at the end of each recitation session. Finally, students work on an online homework set to reflect on the weekly contents and concepts and self-assess their learning level. Students’ performances are evaluated through all of these weekly components: pre-lecture worksheet (10%, formative assessment), lecture participation by answering questions (5%, formative), recitation quiz (20%, summative assessment), and homework (15%, summative but multiple submissions allowed), in addition to two midterm exams, one for each module (25%, summative). NS101 and NS102 have been given in the new format starting from the Spring and the Fall semesters of 2014, respectively, and about 4000 students have taken the NS courses in the new format.

1.4 Pedagogical Training Programs

Another noteworthy component of this NS course revision is the establishment of two professional development programs for students interested in teaching. The programs are designed to train the NS course assistants (both graduate TAs and undergraduate LAs) to become effective facilitators in the student-centred learning environment, and at the same time inform them on the current advances in SoTL. Through these programs, we have trained and worked with ~150 LAs mostly from Faculty of Engineering and Natural Sciences (FENS) and 55 TAs (all FENS) who subsequently worked as MTAs. These programs benefit not only the freshman students taking the NS course but also the assistants themselves to become better educators, leaders, and learners. Many of the LAs go on to contribute to upper level courses as LAs and are also positively changing the learning culture on campus.

2 OUTCOME OF THE REVISED NS COURSE

To evaluate the effects of the revised NS course, we compared NS101 Fall semester data of two years before (2012, 2013) and two years after the revision (2014, 2015) in various aspects. Every year, more than 50% of freshman students are enrolled with the intention of majoring in engineering (FENS) programs and even higher rate of students (~70%) actually graduate from FENS programs at our University. The NS101 enrolment numbers were 652 (2012), 695 (2013), 724 (2014), and 804 (2015).

After the implementation of the revised contents and the active-learning pedagogical structure, a change that we observed immediately was the persistent increase in attendance rates (by two folds for FENS students), both in lectures and recitations (see *Fig. 2*). The increase was much more prominent in the lectures due mainly to the lecture participation (through clicker questions) now being a solid part of the course

grade. In the old NS101, the incentive for lecture attendance was 12 questionnaires randomly given throughout the semester and counted towards the course grade as bonus points. The recitation attendance rate increased to 80% on average with the active-learning format. For the rest of the outcome analysis presented here, we focus only on FENS students.

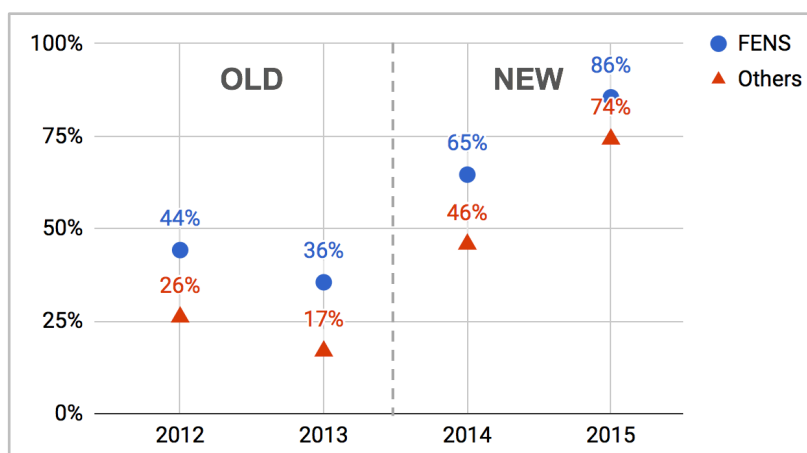


Fig. 2. Rates of students who attended >70% of both lectures and recitations in NS101 Fall semesters sorted by their faculties before (OLD) and after (NEW) the revision

2.1 Skills and Attitudes Surveys

Prior to the implementation, we anticipated some changes in students' perception of their own scientific literacy level as well as general attitudes towards science, with the new NS contents and approach. Therefore, during the semester immediately before the implementation (Fall 2013; F13) and two semesters afterwards (Spring and Fall 2014; S14 and F14), we administered to NS101 students pre- and post-semester surveys to measure students' perception of learning in terms of skills and attitudes, as well as scientific concepts relevant to the NS course. The survey questions were adapted from a validated assessment tool, *Student Assessment of their Learning Gains* (SALG) [10]. The adapted questions were grouped into four categories: A) understanding science, B) skills gained, C) attitude change, and D) learning habit development, encompassing 8, 24, 15, and 18 questions, respectively. We analysed the data obtained from 58 (F13), 62 (S14), and 134 (F14) FENS students who self-claimed in the post-survey that they attended at least half (>50%) of lectures and recitations, and took both pre and post surveys.

To analyse these data, we first quantified the choices in each question (i.e., "a great deal" = 4, "a lot" = 3, "somewhat" = 2, "just a little" = 1, "not at all" = 0), summed each student's responses within each category, and compared the quantified data of pre and post surveys within a given semester (including S14+F14 combined) using paired *t*-test (unpaired data were discarded). We found significant difference ($P < 0.05$) in category A in both F13 and S14+F14, $t(46) = 4.1$, $P < 0.001$ and $t(167) = 3.1$, $P = 0.002$, and in category C in S14, $t(53) = 2.1$, $P = 0.04$. When all the categories are combined, only in F13 a change between pre and post was found at $t(169) = 2.9$, $P = 0.005$.

We also compared the category data between the semesters before and after the course revision using analysis of variance (ANOVA). A significant difference was found only in the category A between F13 and S14 at $F(1,103) = 4.5$, $P = 0.04$. In summary, the results indicated a change in the students' perception of understanding science and a temporary change in their attitude after the revision. On the other hand, their perception on skills and learning habits were not affected by the delivery of the new

course. A further, more detailed analysis at question level is needed to understand how these data are different, and such in-depth analysis of the differences is ongoing.

2.2 Grade Distribution Comparison

Due to the different course contents, diversity of student profiles in any given semester and the large enrolment size, which in turn translates to the diversity of the teaching team members, we did not expect to see a significant change in overall grade distributions at least immediately after the revision. Nonetheless, we compared NS101 grade distributions of two semesters before the revision (2012–2013) and two semesters after (2014–2015), in particular the first midterm exam grades, overall course grades and their first-year GPAs. Here, we only compare Fall semesters since the student profiles differ considerably between Fall and Spring semesters. In *Fig. 3*, we show the course grade distributions of the four semesters, for all FENS students registered in each semester. Since the grading scheme of the old and new NS are different, we normalized the course grades to the highest grade of that semester (i.e., the highest = 100) in this comparison. We also present in *Fig. 3* the means and the standard deviation of the distributions. When comparing the combined grade distributions of the old (2012+2013) and new (2014+2015) format using one-way ANOVA, we find $F(1,1503) = 7.79$, $P = 0.005$, indicating a significant difference with a slightly higher mean value.

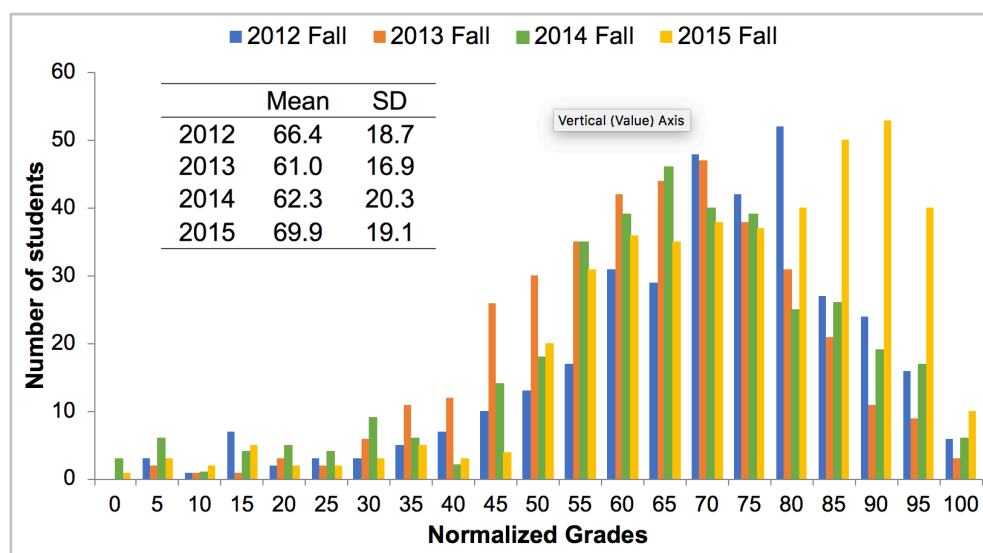


Fig. 3. NS101 Fall semester grade distributions of all FENS students over the four years (2012–2015) before and after the course revision. The mean and standard deviation (SD) values of the distributions are also shown as an insert.

In addition, when we compare sub-groups of students with grades >75 in old and new semesters, the difference is even more statistically significant whereas no difference is found in the distributions of those with grade below 75. In fact, the rate of students with course grades >75 increased by from 29% (old) to 38% (new) and continues to remain above 35% every year up to now. On the other hand, despite the increase in the attendance rate, we observe that students with a certain profile who usually would not come to the classes now attend lectures and recitations in the new format, but do not actively participate in the learning activities. Students in general find the integrated contents more challenging, and conceptual questions and interpretation of numerical results weigh more in the assessments in the new format. Therefore, it is crucial in the new system that the students take responsibility in their own learning and actively participate in the discussions in the student-centred learning environment, to further

their conceptual understanding of the course topics and eventually to succeed in the course.

2.3 Student Feedback

Among our students, the NS course is generally perceived to be the most challenging and demanding course during the first year, even for future engineering students. In order to assess if this perception changed and to collect general feedback on the modules, we ask students to fill a short questionnaire on how they liked the four modules and why, at the end of NS102 each semester. Their qualitative responses collected since 2015 do not clearly indicate the change in their perception of the challenging/demanding aspect of the course. However, majority of the students expressed their NS course experience as interesting, attractive, interactive, enjoyable, exciting, educative, and beneficial. The students' feedback was mostly focused on interdisciplinary content, their perspective about natural sciences, relation of the course content to real life, and learning environment rather than difficulties of the course. Some example comments taken from the questionnaires are as follows:

- *"All these modules can give students new point of view" (2017 Fall)*
- *"All of the NS course gains me a huge perspective about natural sciences and current problems – especially the ones which involve antibiotic resistance, brain, and climate change" (2016 Spring)*
- *"Interesting and must know subjects for consciousness and get ideas about different disciplines and how connected they can be" (2016 Spring)*
- *"Unlike other schools' science lessons, our modules are very closely connected to the situations in real life (eg: connecting electricity and magnetic fields to the brain and mri scans...) thus it makes it easier and more enjoyable to study on the lesson." (2015 Spring)*

3. CONTINUING REVISION AND PROSPECTS

Although the lectures given in large auditoriums became more interactive, they still remained largely passive compared to other course components. The increase in the attendance rate was a positive outcome but it also brought new challenges for us in terms of sustaining student engagement, student-teacher interaction and managing peer discussions. To address these issues, the NS course went through further revision in its delivery format in 2016, and the course has been offered in a "flipped" format since, in which students work on a preparation set that includes video lectures, readings and quizzes before coming to the class. This allows for more in-class activities and instructor-student interaction time in smaller classrooms (<100 students per section), benefiting both parties. According to the qualitative surveys administered to both students and instructors after the first year of the flipped version, the students' perception of their own learning in this format is mixed while all of the instructors who have taught in this format so far provided positive feedback and deemed the flipped approach largely beneficial for the students.

Here we investigated the impact of the student-centred, interdisciplinary approach on students' learning, attitudes, and perception in our introductory science course given at a large scale. To this aim, we compared the attendance rates and analysed the grade distributions (Fall 2012-Fall 2015), the skills and attitudes survey data (2013-2014), and the student feedback (Spring 2015-Fall 2017). We observed a considerable increase in attendance rates and a statistically-significant difference in the course grade distributions between the traditional and student-centred approaches. To fully understand the nature of the grade difference we found, we are conducting in-depth analyses as well as a comparison analysis of physics concept inventory data collected

in 2011 and 2018. Furthermore, the skills and attitudes surveys revealed that students' perception towards "understanding science" is significantly different in the new format compared with the traditional format. Changes in their attitudes were also apparent from the students' end-of-the-course qualitative feedback. The skills and attitudes survey data are being further analysed at the question level to assess the change.

Finally, we note that we have overcome many unique challenges when implementing active-learning pedagogy for such a large class with very broad student background. Transformation from traditional to student-centred learning environment prompts the change of students' role from passive to active learners. This is a rather radical change especially for our students who are, prior to the university, educated to use only the basic level cognitive skills rather than application, analysis, or synthesis skills. Such a change in learning habits develops slowly and a long-term study of the course outcome is needed to show the full impact of the student-centred approach.

We thank Didem Varder-Ulu for consultation and guidance provided throughout the revision process of the NS course.

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Transdisciplinary approach to sustainable innovation and entrepreneurship education

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Conference Key Areas: Sustainable development

Keywords: Transdisciplinary case study, Sustainable development education, Innovation and entrepreneurship education

INTRODUCTION

In France, there is a noticeable and continually growing interest in sustainable development education strongly supported by the legislation (from the “Loi Barnier” introduced in 1995 and later the “Lois Grenelle” in 2009 and 2010) and by civil organisations (CPU, CIRSES, etc.). As it was outlined in the latest annual report of CGE [1] (Conférence des Grandes Ecoles – a French national organisation gathering together directors and leaders of engineering, management and business schools), sustainable innovation and entrepreneurship education became a central question for higher educational institutions (HEIs) despite the existing discrepancies on regional level. According to Prevost and Jouffray [2] this interest to integrate sustainable development in their educational activities is particularly strong in engineering schools. The introduction of sustainable development education in the accreditation criteria's in 2014 by the French commission of accreditation (CTI - Commission de Titre des Ingénieurs) generated a real change not only in the way of thinking about the importance and place of sustainable development education in engineering education but also in the practice of French engineering schools [3].

Despite this keen interest, there are few available open-access teaching materials for sustainable development education focusing on entrepreneurship and innovation subjects. For this reason, the main purpose of our work was to create a highly adaptable new teaching material to raise students' awareness about sustainable entrepreneurship and innovation issues. This objective is in line with the CGE's Sustainable Development Chart [4] encouraging their members to integrate the challenges of sustainable development in the educational program progressively. Moreover, this is among the main priorities of HEIs in France [5] in coherence with the European Commission entrepreneurship 2020 action plan [6]. This new and innovative teaching material will be open-access and widely spread in France between all HEIs members of the CGE (not only for engineering students but for other students feeling interest in this subject).

In this paper, we aim to provide guidelines for the design of teaching materials for sustainable development education based on the Transdisciplinary Case Study (TCS) approach. This work is based on our experience in the CGE's Sustainable Entrepreneurship and Innovation Working Group in France. The members of our multidisciplinary working group are teachers and researchers in divers HEI's (engineering, agriculture, management, etc.) who have a specific interest to make a contribution to sustainable development education. We consider sustainable development as one of the major issues of our modern society, and our work is motivated and founded on this common interest.

TRANSDISCIPLINARY FRAMEWORK

Transdisciplinary is a relatively recent construct developed by Piaget in 1970 with the evolution of disciplinarity in order to help a better understanding of the modern world with growing complexity. He defined transdisciplinary as a 'superior stage' of interdisciplinarity 'which will not be limited to recognise the interactions and/or reciprocities between the specialised researches, but which will locate these links inside a total system without stable boundaries between the disciplines' [7:144]. For Edgar Morin, transdisciplinary represented the liberty of thinking 'between disciplines' (or go-between disciplines) that allows an exchange by creating a link between them. According to his definition, all 'knowledge is relevant only if it can fit into a context and the most sophisticated knowledge, if it is completely isolated ceases to be relevant' [8:3]. In 1985, Nicolescu involved the meaning of 'beyond disciplines' in the definition, for the reason that in our modern world 'disciplinary knowledge has reached its own limitations with far-reaching consequences not only for science but also for culture and social life' [9:21]. From this perspective, disciplines are considered in their social context in a holistic way, not separately from the real world and taking into consideration their interdependence [10].

The relevance of the transdisciplinary research and sustainability is widely recognised, almost considered as mainstream today. Besides, it is evidence that there is a close link between the transdisciplinary approach and sustainability issues to find a solution to a problem in a complex societal context [11]. In this case, transdisciplinary learning allows us taking sustainability issues from their starting points and exploring them from the angle of various disciplines applying an integrative perspective to find an effective solution [12]. Consequently, transdisciplinary learning is a well-adapted form of learning in sustainability education to tackle with real, complex and socially relevant problems. As it was highlighted by Merck and Beermann [13:24] 'transdisciplinary teaching can have a positive influence on the motivation of graduates, especially in sustainability programs, and allows an active imparting of practice-based knowledge'. Also, the application of transdisciplinary teaching is particularly relevant in the situations when there is a high level of discrepancy between the logic of sciences as it is the case between engineering and social sciences.

In engineering education, transdisciplinary teaching and learning is broadly recognised and viewed as an excellent way to develop engineering students' capacity to apply a holistic view and not to be limited only to their technical disciplines. As it was pointed out by Jeder [14:130] transdisciplinary teaching has numerous advantages for students' sustainability skills and competencies development as 'opportunity for motivation, inspiration and stimulation of the interest in knowledge and exercise of critical thinking and creativity...diversity in the way of thinking, feeling and living and opens decks to a modern understanding of the world and life which school should prepare'. For Nicolescu [15] each discipline should devote approximately 10% of teaching time for transdisciplinary so as to develop a larger perspective. According to Tejedor and Segalàs [16:7088], the integration of transdisciplinary teaching and learning in engineering curriculum allows for training a 'new brand of an engineer' who 'thinks critically about the co-construction of public welfare and the technological systems'.

From the beginning of the '90s, the 'Transdisciplinary Case Study - TCS' is viewed as a powerful and particularly well-suited method to conduct sustainability learning

using unstructured cases with qualitative data in a real-world context for complex and socially relevant sustainability issues [17]. For Steiner and Posch [18] this appropriate method for sustainable development involves learning not only for the students but also for the teachers and participating practitioners as it is based on a mutual learning process between them.

TEACHING MATERIAL DESIGN

For the teaching material design, we developed a five step iterative process based on the process for TSC defined by Scholz and Tietje [19] from the goal definition until the final validation.

1.1 Goal definition

This first step of our teaching material design aimed to develop the mutual understanding of the issue, including the formation of guiding question, in order to define our objective. Despite our common interest in sustainable entrepreneurship and innovation education, our multidisciplinary working group had a very different vision about the possible objectives depending on our disciplines and professional culture. After several sessions of discussion, we were able to create a collective perspective and a new meaning for all of us with the application of a transdisciplinary approach. Consequently, the goal definition was based on valuable mutual learning process between us, as it was indicated by Steiner and Posch [18]. We decided not to focus on a specific question of sustainable entrepreneurship and innovation but rather to offer a broad vision to the students. We thus defined a future-oriented objective: stimulating and inspiring students' motivation and raising their awareness for future investigations and actions.

1.2 System building

Based on the recommendations of Scholz et al. [17], we opted to the application of multiple case studies with unstructured cases that is better adapted to the transdisciplinarity approach than the application of single case study. From an epistemological point of view, our new teaching material has an exploratory nature that is compatible with this choice. For the problems' structuration, we were based on the widespread Sustainable Development Goals (SDGs) defined by the United Nations. As our main objective is to offer a broad vision for students, we defined as our imperative to address the maximum possible of these goals but at least one of them for each case study. For the system building, as an innovative solution, we defined a structural matrix with treated goals, in the face of various contextual situations and disciplinary perspectives as the third dimension.

1.3 Scenario construction

For the scenario creation, we selected complex and multi-faceted real-world problems occurring in our modern society generating a significant social or societal impact. In order to provide a broad transdisciplinary vision, each member of our multidisciplinary project team participated in the scenario construction allowing us to integrate into the scenarios the vision of various disciplines (e.g., engineering, management, agriculture, marketing, social sciences, etc.). For the scenario description, we followed the guidelines defined by do Prado Leite [20:49] and tried to avoid the main weakness as the minor semantic problems or the lack of homogeneity or perspectives. Also, we aimed to follow the structure of our matrix system and develop scenarios in order to fill it in a most optimised and relevant way.

1.4 Assessment questions

In the framework of the assessment process, we defined multi-criteria assessment questions based on the four following issues: general definition, perceived values, stakeholders' role and applied strategy. For the development of assessment questions, we implemented a multi-logic thinking approach requiring students to combine the knowledge of different disciplines and using multifaceted reasoning inciting them not to give the immediately obvious answer to the questions. The application of multi-logic thinking approach was guided by our intention to avoid a simplified assessment including traditional step-by-step logic considered as less adapted in the case of transdisciplinary approach toward sustainability learning.

1.5 Validation process

For the validation of our new teaching material, we applied a two-step, intern and extern validation process. At first, we carried out an internal validation with the participation of our working group members to discuss the areas of consensus or divergences in each case study and provide a first impact description with future orientations. Secondly, the external validation by academic teachers, researchers and practitioners in the framework of a workshop dedicated to investigating their opinion as independent experts [21]. This external validation step is particularly challenging as it gives a first external vision of our work judging his diver's facets.

RECOMMENDATIONS

Despite their high interest and willingness, engineering HEIs have several difficulties to introduce sustainable development education effectively. As the experimental study of Prevost and Jouffray [2] questioning institutions, teachers and students revealed one of these major difficulties is linked to the definition of the sustainable development education. Teachers in diverse technical disciplines feel not really legitimate and competent to teach sustainable development issues which they do not manage the whole understanding. For this reason, applying transdisciplinary approach in the design of pedagogical dispositive is essential in order to allow a holistic understanding of sustainable development issues. However, our experience pointed out the difficulties of the application of transdisciplinary approach in the development of teaching materials.

The first obstacle could be for engineering schools to work out new transdisciplinary teaching materials is to get together a multidisciplinary team. In our case, the initiative and support of CGE was a critical condition of our work as we had the opportunity completing it in the framework of a well-organised working group with membership from very different HEIs from various French regions and all of us specialised in diverse disciplines. As our case shows, an existing and well-established multidisciplinary professional network could greatly facilitate the application of the transdisciplinary approach.

Secondly, at the beginning of the work process, our working group had very divergent ideas and perspectives about the meaning of education for sustainable entrepreneurship and innovation. For creating a mutual understanding and finding the way how to work together, we needed to take our time to discuss and understand each other views. We wanted to achieve not only a 'cross-disciplinary borrowing' [16:7086] but removing the limitation between our fields to thinking 'beyond disciplines' [9]. It was evident that the application of transdisciplinary approach requires close collaboration between our working group members, but we widely

underestimated the difficulty and time needed for this first step of conceptual definition. However, this major difficulty at the beginning of the work could decline the group dynamic or in certain cases causes the dissolution of the working group. To avoid this situation it could be useful to consider this difficulty of multidisciplinary collaboration in advance to be able to provide communication and coordination support [22].

We have to highlight that the interface has a significant role in the whole system design process. We used the platform SULITEST having a special mission to support sustainable development education and in particularly sustainability literacy. The vision and assignment of this platform are perfectly in line with our mission and could allow us to widespread our work not only on the national but also on the international level. The features and constraints of this platform were taken into consideration from the beginning of our work for achieving good system adaptability.

In the scenario construction, the selection of real-world cases was a real dilemma of our design process. We raised the question about the adequate complexity level and broached SDGs goals of our selected cases. As noted by Steiner and Posch [18], too high complexity level could cause the frustration and demotivation of students while too low complexity level could be perceived as unrealistic and demotivating for acquiring additional knowledge. Accordingly, the most adequate solution seems to be selecting real-world cases in line with our objectives. For example, our main objective was to give a broad multidisciplinary perspective for our students, so we tried to select heterogeneous cases with limited complexity but giving sources of complementary information. In this case, they have the possibility to enhance the complexity level of their case studies if they want to gain added knowledge.

CONCLUSION

Sustainable entrepreneurship and innovation education for engineering students is a very complex subject that includes not only technical but environmental, ecologic, economic, social or societal dimensions. Consequently, the application of transdisciplinary approach for the development of innovative teaching materials is highly relevant to train modern holistic engineers. However, to put into practice a transdisciplinary teaching materials design process for a multidisciplinary team involves several difficulties. Our experience shows that close collaboration between our working group members and high level of commitment in the same way at the personal and institutional level were essential for this work.

At this time, we are at the end of the internal validation process and preparing our national workshop for the external validation. Following the validation, we intend to implement our new teaching materials on the French national level with the help of the CGE's network. As a future perspective, we would like to explore the perception of engineering students and their teachers about the efficiency of these new teaching materials. More specifically, to investigate engineering students about their perception: What kind of sustainability skills and competencies could they develop with it? What are their motivations? What is the real effect of this transdisciplinary pedagogical approach?

ACKNOWLEDMENT

The authors would like to acknowledge their colleagues from the project A-STEP 2030, co-funded by the Erasmus+ programme of the European Union. The European

Commission support for the production of this publication does not constitute an endorsement of the contents which reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

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Blended Learning and Continuous Assessment as Tools to Promote Active Learning in an Electronics Product Design Course

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Conference Key Areas: Continuing Engineering Education and Lifelong Learning, Engineering Skills, Innovative Teaching and Learning Methods

Keywords: Blended learning, continuous assessment, active learning

INTRODUCTION

Multiply skilled professionals is what the modern working life is seeking for. Mastering the theoretical skills of one's own field is not enough, but several other skills, such as social, presentation, teamwork, problem-solving and time management skills are expected from the new engineers. In addition, the students should finish their studies in a reasonable time to master the time-related pressures for their studies from the government and from the financial point-of-view.

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In order to answer the above-mentioned challenges it is important that students are actively engaged in the learning process. This paper introduces a teaching experiment in which elements of blended learning and continuous assessment were used as tools to activate students in their learning process. The aim of using the blended learning and continuous assessment was also to offer students versatile and flexible learning opportunities. The framework of this experiment was a bachelor level university course of electronics product design at Tampere University of Technology (TUT) at the department of Electronics and Communications Engineering during autumn 2017. The course duration was 14 weeks and the extent was 4 credits (ECTS). Thirty-three students participated and passed the course. At the end of the course, student feedback was collected and the results of the feedback are summarized in this paper.

1 BLENDED LEARNING AND CONTINUOUS ASSESSMENT

Blended learning can be defined in several ways, but a simple form of definition defines it as a combination of face-to-face instruction with computer-mediated instruction [1]. This seems easy and natural way of learning as information and communication technology is such an integral part of new university students. It is however important to notice that at its best the blended learning integrates the strengths of the face-to-face and online learning environments and avoids their weaknesses [1]. A careful design is thus needed, so that the blended model is not just an add on to the existing dominant method, but the face-to-face interaction and the asynchronous online interaction are merged in a manner that the students are offered learning experiences not conceivable via either modes separately [2,3]. In this way, blended learning can facilitate a community of inquiry, in which all three elements: cognitive, social and teaching, are present and thus a meaningful learning can occur [3]. The advances of combining these two teaching methods include, among others, pedagogical richness, access to knowledge, social interaction, cost-effectiveness and flexibility [1]. It has also been indicated that the implementation of blended learning can result in higher degree of utility, motivation and satisfaction among the participants and thus a positive attitude towards learning can occur [4].

The possibilities to combine these two learning environments are limitless and several different forms and levels of blended learning exist. Blending can occur at activity level, course level, program level, or institutional level [1]. Course-level blending, the most common way to blend, consists of a combination of distinct face-to-face and online activities used as part of a course [1]. These activities can overlap in time or be sequenced chronologically [1]. The teaching experiment presented in this paper is considered a course-level blending as the course consists of different activities some of which occur in a classroom while others are realized in a Moodle learning environment.

1.1 Continuous Assessment

Assessment is often used for grading purposes and such an assessment is generally referred to as summative assessment. Formative assessment on the other hand usually involves feedback so students can improve their performance.

Continuous assessment often has both summative and formative function by grading students' achievements and by supporting their learning process [5]. In the teaching experiment described in this paper the continuous assessment has both these functions. Firstly, all the different assignments and the three electronic exams that were distributed along the course were compulsory requirements for completing the course. Thus, students needed to work continuously during the course. As some of the assignments and all the electronic exams were graded, they had the summative

function. Feedback, either individual or group level, was given from all the assignments and exams so they had the formative function of supporting the learning process as well. Overall, continuous assessment can have a positive effect on learning as it has been indicated that continuous assessment can make the students to adopt a more continuous learning style and motivate them to study [6]. The most traditional structure of many engineering courses with lectures, exercises and a final pen-and-paper exam that determines the course grade does not necessarily activate students' learning process evenly throughout the course nor does it offer students much flexibility of scheduling their studying.

2 COURSE IMPLEMENTATION

Electronics product design is a third-year bachelor level course and its main target is to provide students with basic knowledge on the different hierarchical levels, production processes and design perspectives of an electronic product. To complete the course students had to gather 19 points out of 38 points. Points were given from the two group works, one calculation exam and from the three electronic exams. Grade three required 27 points and grade five 35 points. The evaluation was performed on a scale of Excellent (5), Very good (4), Good (3), Very satisfactory (2), Satisfactory (1) and Fail (0).

As the amount of information in this course is quite high, the course was divided into five blocks. Each block reflects a major theme of the course and consists of several smaller topics. One block lasts 2 - 5 weeks depending on the extent of the theme. The amount and form of learning events and assignment included in each block were designed so that they support learning of the theme topics, offer versatile learning experiences as well as flexibility to students and distribute workload evenly throughout the course. The detailed course content is presented in Table 1.

Table 1. Electronics Product Design Implementation in Autumn 2017

Block	Weeks	Main topics	Learning events	Learning assignments
1	1-2	Introduction to the course Wafer manufacturing Integrated circuit manufacturing	2 lecture events 1 group work presentation event	Group work Electronic exam
2	3-5	Electronic package, through-hole and surface mount technology Wire bonding and flip chip Soldering (wave and reflow)	3 lecture events 1 wiki assignment wrap-up event	Wiki assignment Electronic exam
3	6-7	Basics of printed circuit boards Flexible printed circuit boards	2 lecture events	Group work Laboratory work
4	8-9	Basics of thermal management and heat transfer mechanisms Thermal design	2 lecture events 1 calculation exercise event 1 calculation exam	-
5	10-14	Basics of reliability and reliability testing Basics of testing and testing strategy Quality and Six sigma Environmental aspects Wrap-up	5 lecture events 1 group work wrap-up event 1 calculation exercise event	Group work Forum discussion Electronic exam Voluntary individual assignment

2.1 Learning events

The twenty face-to-face learning events consisted of lectures, calculation exercises, one calculation exam and different wrap-ups of the learning assignments.

The lecture events of the course were designed so that they introduce students to each topic. The learning assignments then complemented these lectures and enabled students to deepen their knowledge on the topic. All lectures were also designed to be interactive and activating meaning that they included teacher's questions, Kahoot-quizzes, group and pair discussions and small exercises. The Kahoot-quizzes were used in the beginning of lectures to revise the core contents of the previous lecture and to have a fun and activating start to the lecture. Teacher's questions, discussions and small exercises were applied during the lectures to encourage students own thinking and to practise discussion and argumentation skills.

The purpose of the group presentation and wrap-up learning events was to offer students the possibility to present their work; how the group realized the assignment, what was the outcome of the assignment, did the group work go as planned and was the distribution of work even. In these events, students were also able to see how other groups realized the assignments. By presenting their assignments students learned presentation and communication skills, which are important future career skills. Other important career skills – calculation and problem-solving skills – were learned in the calculation exercises and in the calculation exam. In the exercises, students were able to work together, thus share their knowledge, and jointly come up with a solution. The calculation exam then consisted of two problems and students had two hours time to give answers. The maximum points of each problem was four.

All these different face-to-face learning events had an important social aspect in the blended course model. In the learning events students had the possibility to group, strengthen their belonging to the group, interact with themselves and with the teacher and share opinions and understanding. It has been indicated that such face-to-face events can support team development, commitment and accountability to team members [7]. In addition, among learners these face-to-face events give a sense of community and thus students do not feel isolated and have a higher risk of dropouts. Fully online courses would lack such sense of community. [8]

2.2 Learning assignments

The aim of the nine compulsory learning assignments was to enable students to continue their learning process after the introductory lectures and thus to deepen their knowledge on the topic.

For the group works students formed groups of four to five people. In the first group work the target was to study the basic process steps of making an integrated circuit. Each group had one topic and they prepared a 10-minute learning session from this topic. The topic of the second group work was applications of flexible printed circuit boards and in the third group work the students needed to do an operating condition and reliability testing specification for a coolant temperature sensor. In each group work, the students wrote a report and presented their outcomes. Each group realized their work as they wished meaning that some groups preferred to meet face-to-face while other group realized their group work mainly online. The group works were designed to promote collaborative learning and to increase students' teamwork, information retrieval, communication, interaction, design and documentation skills. Teacher wrote feedback for each group regarding their work. The first and the third group work were graded on a scale of 1 – 6 points and the second group work was scaled passed/failed.

With the laboratory work, which was done in pairs, the students gained hand-on experience with printed circuit board manufacturing process. The students made a double-sided printed circuit board and soldered the components. Each group were able to choose between making a decibel meter or a FM transmitter. The laboratory work included also preliminary and follow-up reporting and it was graded passed/failed.

The wiki assignment and the forum discussion were fully online assignments. These were also done in the same groups of four to five people. In the wiki assignment the students wrote a wiki about surface mount technology in the Moodle learning environment. Each group was responsible of a certain topic in the wiki. In the wrap-up learning event each group then presented their work and explained how they realized the assignment. This wiki assignment was graded passed/failed. For the forum discussion each member of the group were given a role: a thermal design engineer, an electrical design engineer, a production/test design engineer and a printed circuit board design engineer. The group then had to discuss and select one component out of predetermined components to be used in a smart phone. Each student had to write at least three messages in the Moodle by giving one's reasons for the component, making questions and arguing for other components. Group also had to write a short summary that was then gone through in the wrap-up learning event. This assignment was also graded passed/failed. Teacher wrote feedback for every group from both these assignments.

The electronic exams were individual and they were realized with the EXAM electronic exam system. The students had 50 minutes time to answer each exam and the exams were graded on a scale of 1 – 6 points. Teacher wrote feedback for each student.

3 STUDENT FEEDBACK

At the end of the course, a student feedback was gathered with an online feedback system. The questionnaire consisted of multiple choice questions and open questions. The total number of respondents during the academic year 2017 – 2018 was 30.

Table 2. shows the overall rating of the course and its implementation during academic years 2015 – 2018. In the 2015 – 2016 implementation, the only compulsory requirements of the course were the similar laboratory work as described in the chapter 2.2 and a final electronic exam. The lectures and exercises were arranged in a certain time and place, but they were optional. During the academic year 2016 – 2017, the course consisted of various activating lecture and exercise learning events. Students had to gather a certain amount of points by taking part in the learning events or by completing separate written exercises in order to pass to course. In addition, the same laboratory work and the calculation exam as described earlier were compulsory requirements in the course. The final electronic exam was optional, but it was possible to raise the course grade by taking it.

Table 2. Overall rating of the course and its implementation

Academic year	Number of respondents	Mean	Mode	Median	Standard deviation
2017 – 2018	30	4.27	4.0	4.0	0.63
2016 – 2017	21	4.05	4.0	4.0	0.58
2015 – 2016	35	4.21	4.0	4.0	0.63

As the Table 2. shows the mean of the overall rating during 2017 – 2018 was 4.27. This is slightly more than in the previous years as during 2016 – 2017 the mean was 4.05 and during 2015 – 2016 it was 4.21.

In Fig. 1 the overall rating of the course and its implementation is further compared during academic years 2015 – 2018. As the Fig 1. indicates, 90 % of students found the course during academic year 2017 – 2018 very good or excellent. This is also slightly more than in the previous implementations of the course. It seems that the course structure that was implemented during the academic year 2017 – 2018 was successful as the overall rating of the course increased.

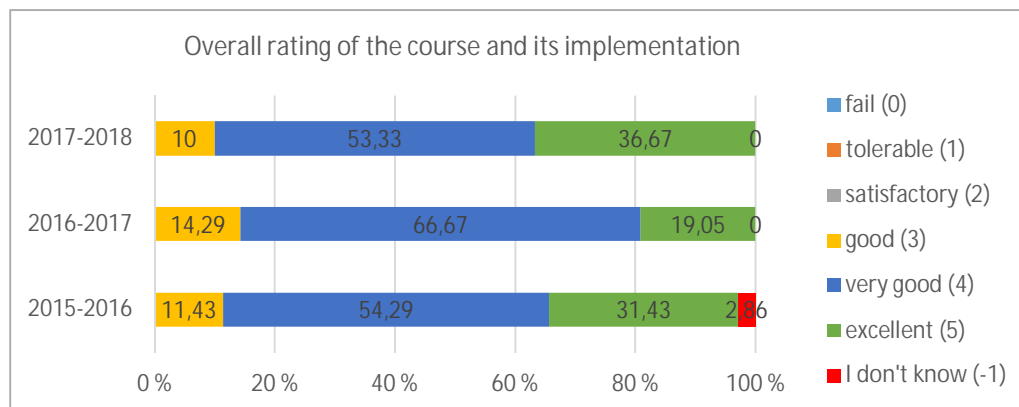


Fig 1. Overall rating of the course and it implementation

Many students found that the working methods used in the course made the course versatile, deepened learning, made it more meaningful and developed group work skills. This is indicated in the following quotations regarding the question “How did the working methods used during the course affected your learning?”:

“Working methods were the best part of the course and helped, as it were by accident, with getting familiar with the topic, and they brought nice variation. I recommend also in future.”

“By thinking yourself or in a group issues stick in one's mind very well, which lowered the need to read for an exam. Revision before the EXAM was enough. The flexibility of the EXAMS was also convenient for me.”

“The working methods deepened learning and developed group work skills.”

“Learning was more meaningful compared to the traditional course structure.”

Many students also found the continuous assessment positive. It seems that the continuous assessment divided the workload evenly throughout the course, made learning easier and made at least some students to adopt a more continuous working style. The following quotations regarding the question “How did the calculation of the final grade based on the sum of learning exercises and the EXAM exams affect your learning?” indicate this:

“Very nice as a whole, splitting up the topics made learning easier.”

“One had to study evenly throughout the entire course”

“Throughout the course one made and kept in mind the course things. EXAM exams split the topics up to good entities. - > improved my learning.

“Positively as the workload was divided evenly throughout the course.”

“One stressed less for an exam. Studying one block at a time is easy.”

“One revised the learned topics right away so I believe they stick better in one’s mind.”

Few students felt that the workload was too heavy and that there were too many assignments. However, 91.67 % of students found that the course workload corresponded to the number of credits.

4 CONCLUSIONS

The teaching experiment presented in this paper has shown that blended learning and continuous assessment elements can help in activating students in their learning process. The results of the experiment indicate that such a course structure offers students versatile learning experiences, which can make students feel positively towards learning and thus make it more meaningful. Blended learning methods can furthermore make learning deeper and develop group work skills. Continuous assessment on the other hand can make students to adopt a more continuous working style. These results support other findings, which indicate that by blending the face-to-face and online learning environments students still get the important social aspect of learning, which is then supported by the online learning experiences offering students time to ponder, process and have online conversations independent of time and place [2, 7]. This can lead to a positive attitude towards learning and facilitate a higher learning experience [3, 4]. Continuous assessment can also affect positively on learning and thus students may learn in a more continuous manner [6].

Another important aspect of such a course structure is the flexibility it offers compared to the traditional face-to-face course structure. As part of the learning assignments in the course are independent of time and place students have more possibilities to complete the course, if they e.g. work along studies or have overlapping learning events. Finland’s Ministry of Education and Culture has recognized in their development plan that work along studies, inflexible teaching arrangements and problems with study skills and motivation are factors slowing down studies [9]. A course structure implementing blended learning elements can help students in their time management and thus make studies more efficient.

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Assessing transversal skills in an interdisciplinary programme

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Conference Key Areas: Curriculum Development, Teaching Creativity & Innovation, Innovative Teaching and Learning Methods

Keywords: assessment, interdisciplinary, transversal skills, reflexivity

INTRODUCTION

The paper discusses the assessment of transversal skills in the framework of a 9-month interdisciplinary programme – the China Hardware Innovation Camp (CHIC) – that runs across 3 institutions in Switzerland and includes a short-term study abroad (STSA) in China. The programme has the particularity of having teams composed of engineering students (3), design students (2) and business students (1) affiliated with one of the 3 institutions and working together to develop an Internet of Things (IoT) device. The pedagogical scenario builds on a “learn-practice-reflect” framework. While limited to one-sixth of the project’s assessment, significant emphasis is placed on the development of transversal skills for engineering students. The assessment strategy makes heavy use of reflexive notes.

The paper presents the pedagogical scenario underlying the programme as well as the protocol to assess the transversal learning outcomes for the engineering students involved in the programme. It discusses a sub-set of the transversal skills assessment strategy, namely reflexivity. It suggests that reflexivity needs to be trained and maintained throughout the programme through different formats. It raises a number of questions related to the use of reflexivity as an assessment strategy for transversal skills in the context of an interdisciplinary programme.

1 PROGRAMME OVERVIEW

1.1 Brief description of the programme

The CHIC programme proposes to go “from idea to functional prototype in 30 working days”. Teams receive a blank sheet of A3 paper at the beginning of the programme and have 3 semesters to conceive, develop and prototype an IoT device.

1.2 Architecture of the programme

The programme is offered as an interdisciplinary Minor (30 ECTS) at the Master level at EPFL¹. It runs through the first three semesters of the Master. It takes place mainly in Switzerland but includes a 16-days prototyping sprint in a Chinese factory.

Credits for the programme are divided in two categories:

- Project-related (18 ECTS); each student works on a project within an interdisciplinary team; 3 out of the 18 ECTS are devoted to transversal skills;
- Technology-related (12 ECTS); students have to choose courses from a pre-established list; they can propose additional courses that are necessary to the completion of their project; courses can be taken during any of the three semesters.

In addition, students are to follow a 2-semester long humanities-related course ("Global perspectives, local realities") aimed at contextualizing their techno-scientific project.

1.3 Underlying pedagogical aspects

The programme has been crafted with a number of pedagogical dimensions in mind:

- Bottom-up: projects are proposed by the students themselves; in essence, teams are given total liberty as to the problem their device aims to solve;
- Double-interdisciplinarity; engineering students originate from different sections and faculties (e.g., computer science, mechanical engineering and micro-engineering); in addition they work in a team with one business school from a neighbouring university and with one industrial designer and one media interaction designer from a neighbouring design school;
- Real world, real learning: while not aimed at being commercialized, projects must demonstrate a commercial potential and economic feasibility; teams simulate most of the aspects involved in developing a hardware device (e.g., business models, industrialisation, pitching to investors, etc.);
- Immersion; the initial development of the device's prototype takes place in Switzerland; the teams are flown to Southern China (Shenzhen and Hong Kong) to improve their prototype and run a small-batch production at the end of the second semester; the STSA allows to extend the learning experience from cross-boundary to cross-cultural;
- Reflexivity; students are asked to reflect on different aspects of their learning throughout the programme both in terms of process and result.

In short, the programme is project-based, interdisciplinary, multi-site and student-driven. Immersion aside, it can be assimilated to new product development project-based programmes [1]. While being asked to step outside of their comfort zone, students seem to particularly appreciate owning a project from beginning to end, working in interdisciplinary teams and looking at a theme from different perspectives.

1.4 Mixed learning outcomes

The high-level learning outcomes of the programme have been divided into:

- Disciplinary: define functional requirements of a connected device, apply a structured approach to product development and realize a functional prototype;

¹ It is offered at the Master level in the neighbouring business school (HEC Lausanne) and at the Bachelor level at the design school (ECAL).

- Transversal: communicate effectively with professionals from other disciplines, write a scientific or technical report, identify the different roles that are involved in well-functioning teams and assume different roles, including leadership roles, apply fast prototyping techniques and technologies, pitch a product in front of different audiences, communicate effectively across different languages and cultures.

The nature of the programme implies that students are exposed to various management issues, including project management, teamwork, meeting management and cross-cultural management. Put differently, the development of the device becomes a vehicle to apply technical skills already or in the process of being mastered and to acquire new transversal skills.

1.5 Teaching strategies

Material related to transversal skills is taught exclusively through workshops. Their length varies from 3 hours (e.g., for pitching) to 2 days (e.g., for teamwork).

Teams are given significant autonomy to organize their work within a structured framework. For instance, the monthly milestones are built round a detailed set of deliverables; the latter are decomposed in weekly tasks. In addition to the provided “development roadmap”, teams can access resources related to the tasks – a resource can be related to a scientific/technical or to a transversal dimension. Faculty members initially created these resources. At the end of each edition, students work in pairs to either improve an existing resource or create a new resource they felt was missing in their project.

1.6 Motivation of the paper

In a sense the paper aims to answer a question raised by a colleague in a working group on open-ended projects. His question was the following: “how to make sure that students really learn transversal skills in multidisciplinary projects?” My initial answer to the question was “you can’t but I’ll will show you the assessment mechanism I put in place”. A number of deeper reasons are driving the paper:

- Transversal skills were defined as central learning outcomes in the programme and must therefore be assessed;
- The weight given to the transversal skills in the programme's overall architecture remains limited (3 ECTS) but students tend to perceive them as one of the key benefit of the programme;
- Transversal skills and more specifically reflexivity about transversal skills are at times a scarce resource in the training of engineers;
- Interdisciplinarity is not a given; in other words, putting students from different disciplines around a table does not make an interdisciplinary team, nor does it ensure that students have benefitted from their exposure to different disciplines;
- In light of the resource-intensive nature of the programme, a valid question to ask is whether one can demonstrate “significant” learning in terms of transversal skills or if these could be achieved differently than through an interdisciplinary programme [2].

Questioning the acquisition of transversal skills in the framework of an interdisciplinary programme (and the associated assessment) is therefore at the core of the paper. As such it aims to build on the question of transferability enunciated in Ivanitskaya et al. with a focus on transversal skills in the context of an interdisciplinary programme [3].

2 ASSESSMENT OF TRANSVERSAL SKILLS

2.1 General protocol

Given the limited number of students participating in the programme each year (10-12 engineers and 10-12 non-engineers), emphasis is put on a qualitative assessment of the learning outcomes related to transversal skills. The transversal skills are evaluated through various means (see Table 1) including oral presentations at the time of milestones, individual reflexive notes at the end of the second and third semester and documentation of activities during the whole programme (e.g., blog posts of project progress).

Table 1. Overall assessment scheme

	MA1	MA2	MA3
Disciplinary skills (5/6)	Project preparation	Project realisation	Project finalisation
Transversal skills (1/6)	Oral presentation and reflexive note on group work	Oral presentations, reflexive note on group work and project management, documentation of activities	Oral presentations, reflexive note on group work, cross-cultural management, mentoring and documentation of activities

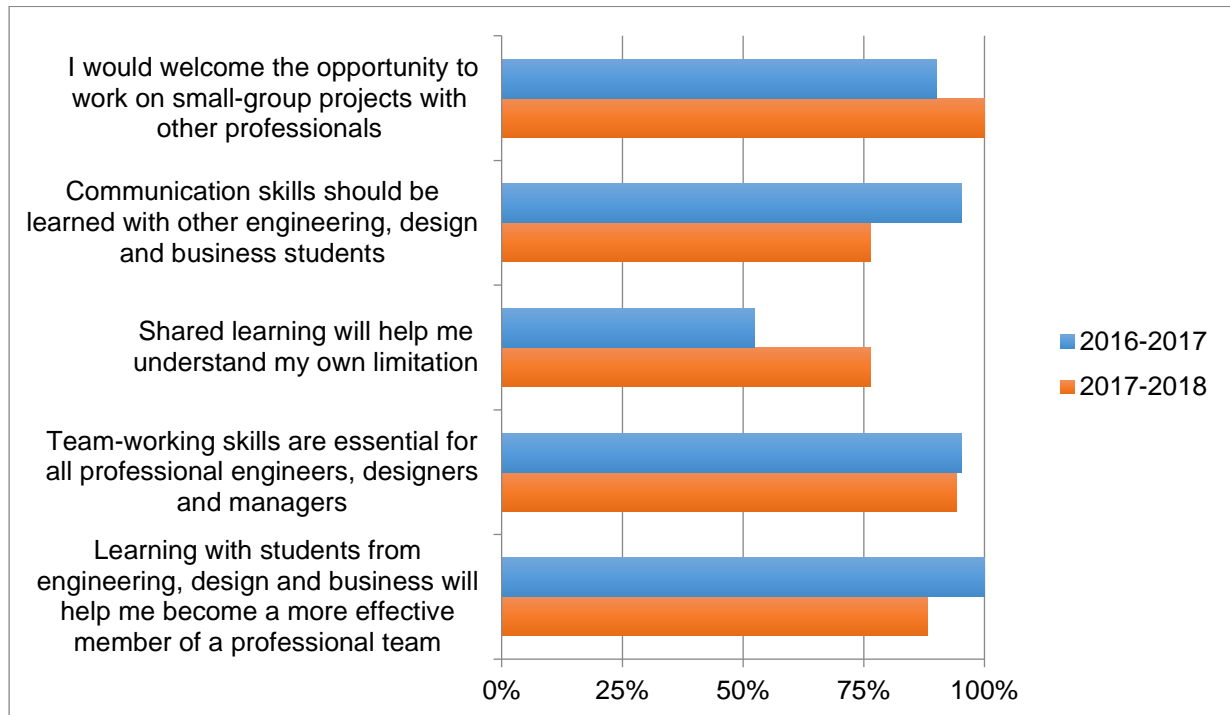
At each milestone (MS) students are to fill a spreadsheet, documenting what they learned so far regarding their own discipline, other disciplines, group work, project management and themselves. The spreadsheet is common to all team members and accompanies them throughout the programme.

Table 2. Selected comments from an engineer (MS 2 and 3, 2017-2018)

	My discipline	Other disciplines	Group work	Project management	Myself
MS2	Starting to discuss the electronics is exciting as it forces us to decide which will be the limits of our product	Having good visuals of the product doesn't only nicely illustrate our idea, it is also a way to get a more precise and relevant feedback	Discussions within the team were not necessarily easy with the distance / during the break	It might take some time for some ideas to mature in other persons' minds. Patience can be rewarding!	I was awed at the fact that working (meaning sleep deprivation before deadline) with the group sometimes felt very natural and fun
MS3	I realized how little flexibility Apple gave us to work. The 3D printing went very well and it is good to know that we have this option but it definitely won't resolve most of our prototyping issues	I learnt that the design and the creative process was sometimes a lot longer than I first thought	I feel that we start to really know how we work with each other and we did a good job separating the tasks and preparing for the presentation	I feel like we are a little bit stuck with some of the perspectives in the project but it will be easy to catch up the delay later on	Milestones are really a good way to make us realise the state of advancement of the project

A cross-cultural dimension is added for the milestone at the end of the China trip. This dimension is further explored as students work in pairs to document one theme on both sides of the Hong Kong-Shenzhen border (1'000 words). Themes include makerspaces, mass transit, the sharing economy, social media, innovation parks, migrant workers, etc. For this activity, engineering students can only pair with non-engineering students and work with someone outside of their project team. In addition a slightly adapted version of the Readiness for Interprofessional Learning Scale (RIPLS) questionnaire has been administered to all students at the very beginning of the programme during the past 2 editions (see Figure 1).

Figure 1. Adapted RIPLS questionnaire (agree/strongly agree)



2.2 Reflexive notes

Reflexive notes are required at the end of the second and third semester. Both are meant to link the workshops and the work conducted on the project. The final assignment consists in writing a short essay (1'000 words) on:

- The student's personal reflections on their own team experience;
- The mentor-mentee relationship, and how the student could draw from their own experience in order to guide their mentee;
- How this mentoring relationship helped the student understand one's team dynamics or how it might be beneficial in the future.

Given the structure of the programme, students from 2 consecutive editions "overlap" during one semester. This provides the opportunity to put to use the skills acquired by the first batch of the students to "accompany" the second batch. This has been operationalized through a peer-mentoring mechanism. Instead of asking engineering students to mentor their next-in-line students on engineering dimensions, they were asked to do so on transversal skills. Students were asked to integrate a section in their reflexive note regarding mentoring. For instance, "To conclude my reflective note, I will explain the advice I would give to my mentee through my own CHIC experience", follows a list of advice related to teamwork and social skills. In a similar vein, "during the first meeting of our mentee, I quickly realized that the main problem they faced was totally different from ours, so was the group dynamic, but its

resolution may come from our experience.” A couple of engineering students nonetheless struggled with finding use in the mentoring exercise because of the timing (i.e., early in the programme).

Table 2. Assessment scheme of the final reflexive note

	Default Grade = 4		
	+1/2 point	0	-1/2 point
The length of the essay is adequate.		yes	too short/long (±50%)
Personal reflections on team work:	at least one example for what worked well/not well each.	some parts of their own team experience mentioned	own team experience not mentioned
One aspect related to interdisciplinarity OR team/individual values/goals was outlined in a concrete example	yes, and a specific "lesson learned" for a similar situation was stated	yes	no
One aspect related to team-internal communication OR meeting structure/organization was outlined in a concrete example	yes, and a specific "lesson learned" for a similar situation was stated	yes	-
The student described that (s)he interacted with their group of mentees.	-	yes / no because the mentees did not wish to be mentored	no, without reason given
Student used his/her own experience to guide the mentee	yes, and it was useful for them	yes, but it did not apply to the group/no, because it would not have applied to the group (with justification)	no, the student did not try to draw any parallels
The student's mentoring approach helped their mentee to "do differently by asking reflective questions"	yes	no, because only a directive approach worked OR aspect not visible in the essay	the mentoring approach was too directive and mentor simply told the mentee what to do
Student discovered a feature/team mechanism in the group of mentees which worked particularly well and came to a generalizing conclusion OR Student could draw personal benefit from mentoring relationship for the future (was able to generalize a situation)	yes	no/unknown	-

Whereas all engineering students comply with the assignment, one can identify differences in terms of the depth and breadth of insights in terms of disciplinary grounding, advancement through integration, and critical awareness [4]. Such differences can be attributed to the different learning experience that students went through during the programme. Interestingly enough, the level of functionality achieved by the device is not so much correlated with the quality of the reflexive dimension. One student who worked on a project achieving very limited functionalities produced a note with deep insights. The same can be said from a student who worked on a project that has the potential to be deployed in the field.

2.3 Peer-reviewing as an additional reflexive tool

Another reflexive tool has been introduced recently. Team presentations at the time of milestones are peer-reviewed. The mechanism has been introduced for two reasons: 1) keep students engaged during their peers' presentations and 2) give and gain feedback from additional persons than the faculty members. Each team is attributed another team and reviews are individual which means that each team receives 6 individual feedback sheets. Feedback touches upon form and substance with wording like "what I liked, what could be improved". Students are also asked to synthesize the most important comments and inputs from the discussion between team and faculty members following the presentation. The feedback sheets are collected, compiled and made available to teams after the milestone.

2.4 Discussion

At EPFL reflexivity towards transversal skills is not the most common assessment tool. Neither students, faculty members or administrators are accustomed to it [5]. This in turn raises a number of questions:

- Means to train reflexivity among engineering students. Setting reflexivity as an explicit learning outcome implies that students are given the opportunity to learn about and/or practice reflexivity. Whereas engineering students are often required to reflect on the engineering dimension of their projects, it much less the case on the transversal skills acquired and practiced in their projects; this is even more true in the case of an interdisciplinary project in which students are to collaborate across disciplines;
- Means to ensure the legitimacy of such an assessment mechanism among faculty members and, more broadly, academic affairs. This question can be particularly acute in an academic environment with a tradition of formal assessment methods
- Necessity to balance more "traditional" assessment methods with reflexivity;
- Timing of reflexive assessments throughout the curricula. This raises both the question of timing and frequency (e.g., less can be more);
- Means to motivate students to take a reflexive posture beyond the formal assessment requirement;
- Type of feedback to provide to the students regarding their reflexive note;
- Adequacy of reflexive notes as the mean to capture the learning attached to cross-boundary collaboration.

3 REFLEXIVITY AS AN ASSESSMENT TOOL

3.1 Lessons learnt

Akin to Heikkinen and Isomöttönen [6] we find that students generally have a positive view of multidisciplinary, that multidisciplinary teams enable students to better identify their own expertise and that very different team dynamics emerge from the tensions emerging from interdisciplinary project-based learning. This can at times lead to comments such as "it is easier to work only among engineers". As mentioned, students from different disciplines working in a team don't make an interdisciplinary team. In fact students placed in an interdisciplinary setting are usually well-aware of the different values, norms and ways of looking at problem-solving around the table. Not orchestrating the encounter runs the risk of re-enforcing some stereotypes and "inherited" disciplinary approaches. In the case of the CHIC programme, a lot of the learning activity takes places outside the classroom (e.g., when students have team meetings). Structured reflexive notes are one among several assessment methods. Combining it with peer-teaching allows students to reflect both on their own learning and on the application of their learning to a different situation.

3.2 Levers for improvement

One of the interesting recommendations by Carr et al. lies in the joint supervision of the students enrolled in an interdisciplinary doctoral programme [7]. At this stage, participants of the CHIC programme are only supervised by faculty members from their discipline. Engineering students are nonetheless encouraged to attend the “critiques” that design students undergo during the semester. All students are encouraged to attend the meetings that their team members have with their supervisors. One could imagine to include a section in the reflexive note covering these interdisciplinary “encounters”. Hoegl and Parboteeah find that among professional product development teams, team reflexivity is positively related to team effectiveness but not efficiency [8]. Social skills and project management skills are positively related to team reflexivity. One could therefore from the outset raise the students’ awareness as to the upside and downside of interdisciplinarity work using the answers to the RIPLS questionnaire as a basis. One could also introduce team reflexivity instead of individual reflexivity.

So far, transversal skills are not assessed by the engineering faculty members. One could imagine integrating a reflexive note in the final engineering report asking students to reflect on how their design choices regarding engineering have been influenced (or not) by working in an interdisciplinary team. Assessment of this part of the report could be conducted by faculty members representing the 3 institutions involved in the programme [9]. This raises the most vexing question, namely the level of involvement of faculty members in such interdisciplinary programmes, both welcomed but also seen as a distraction from their research imperatives.

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Does gender-sensitive teacher training have a place in Engineering Education?

Assessing pedagogical training as a step towards gender-inclusive curricula

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Conference Key Areas: teacher advisors, teacher training, STEM, gender-sensitive pedagogy, implicit gender bias.

INTRODUCTION

Inclusive teaching strategies aim to foster learning for all students. Traditionally, in the literature on gender and teaching, a special focus is given to strategies that may lead to include or to exclude female and male students.

Teaching advisors seek to sensitize teachers to use inclusive teaching pedagogies because they facilitate learning to all students. Being aware of gender-sensitive pedagogies may potentially lead

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teachers to consider how to manage better the gender composition of a class with respect to teaching strategies and interactions. A failure to do so has been shown to create learning environments which can hamper female students' learning and their decision to continue to pursue a career in Engineering.

This paper presents the results of a self-assessment of our teacher education activities. These are mostly short workshops and some longer courses. Four teaching advisors were involved in this project.

The aims of the study was to identify how the teaching training offered by our unit sets the example for gender sensitive teaching to its participants. In order to reach this aim, we assessed the materials and the learning activities used in our workshops from a gender approach.

A checklist for self-assessing our practice was developed by our team. This checklist was inspired on two research-based tools for gender in teaching. The checklist made the team reflect on things we perhaps did not normally consider. Because of responding to it, we identified what further research needs to be done in order to address some gender related issues. This checklist is presented here as a useful reflective tool for trainers.

Our results show that as a team, we have a clear intention to challenge gender bias in teaching and in responding to the checklist opened a discussion on our views and practices towards gender-sensitive teacher education. This discussion is now a baseline towards the gender-inclusive teacher training we aspire to offer teachers in Engineering Sciences.

1 GENDER AND ENGINEERING EDUCATION

1.1 Background

Studying Engineering and Science seems a constant fight for women, since their first day on campus.

Institutional efforts to value women in science and engineering abound, but they can have an adverse effect to their noble intention to help. A longitudinal study on students' intake of Women in Engineering Programs (WIE) reports that women shy away from studies after feeling 'spotlighted' for being women, instead of feeling encouraged for their competencies and knowledge like the rest of students. They conclude that in singling out female students a feeling of discomfort arises, either by promoting studies in engineering to young girls or by integrating female students to mentoring programs once at university. This is called spotlighting [1] and, in terms of gender inclusion for learning, spotlighting could be avoided with other strategies such as the pedagogy in the classroom.

Some learning strategies that that can be gender inclusive are design thinking and problem-based learning, notably because in engineering education studies have shown that the distribution of tasks within working groups have a gender dimension which can be addressed. For instance, a panel of experts in 2015 [2] discussed how women's' persistence to stay in engineering is associated to group work performance where girls often do the scheduling of meetings and organizing of final reports and are often excluded from the mathematical problem solving tasks.

Likewise, accounts of interactivity during team projects report that women are interrupted more frequently when they speak and have their design proposals underplayed [3]. A similar qualitative study also found that within student groups, the academic and seniority status of students affected group dynamics more directly than gender biases [4]. Both of these studies argue that despite other factors affecting group dynamics more negatively than gender, the cumulative, long-term effect of undervaluing women becomes a serious obstacle for women in developing a sense of engineering expertise.

Because male and female scientists carry gender biases into their professional practice, it is important to encourage gender sensitive epistemology to future scientist. For instance, Handley

etals, (2015) [5] concluded that what affects scientists' reactions to research on gender in science is not the quality of science that is reported but the reference to gender in the scientific papers.

The evidence presented above raises the question of finding what Karen Tonso proposes as 'insightful pedagogical practices' [in 3, pp.247] which would help to evaporate a learned indifference to gender inequalities instilled in the early years of studies, enforced throughout the academic years and later reproduced in professional practice.

1.2 Gender-sensitive pedagogies

Gender sensitive pedagogies are those instructional methods which allow students to participate equally and enables them to learn, regardless their gender. An example is peer instruction: Zhang, Ding and Mazur [6] showed that when taught with peer-instruction, first year students shift attitudes towards learning physics, they also found that female students speak more during peer-instruction than during bigger group unstructured discussion, typical of a lecture.

We adhere to the principle that gender sensitive pedagogies foster better learning because they boost constructive interaction between students. The research done by Chi, M. (2009) [7] shows how interactive instruction increases student learning by stimulating constructive dialogue and equal participation.

Therefore we will discuss some of the instructional methods that we consider adequate when training Science and Engineering instructors to teach. The paper also discusses the challenges that this initiative imposes on educational developers.

1.3 The challenge for teacher training

Studies on gender in teacher education argue that because teachers and scientists' are exposed to implicit gender biases during their pedagogical training, teachers later on reproduce them in their professional practice.

These studies raise the question of whether teaching education in Engineering promotes gender-sensitivity or reinforces gender biases.

It is believed that implicit gender biases in the materials used for teacher training reinforce the masculine culture of Engineering Education. For example, Zittleman & Sadker, [8] took a close look at teacher education textbooks and identified a series of sources for gender biases. The list highlights a superficial presentation of gender prejudice as well as of homophobia and harassment in the textbooks. Other sources of biases include the choice of textbook images and the choice of cited authors of which three out of four are male. Their main concern is that once in the classroom, teachers would implicitly reproduce such biases.

According John Hattie's meta-analysis, exemplary teacher education underlines good teaching that boosts learning. He identified three main characteristics of good teaching in Higher Education: having clear goals, using different interactive and inclusive teaching strategies and giving and getting feedback on teaching, all of which can be taught to pre-service teachers [9]. As described by Darling-Hammond, what makes teacher education exemplary is: a coherent vision of good teaching, an accountability to standards of good practice and, most importantly to this paper, an education which confronts teachers with their prior beliefs and assumptions about learning (in [10], page 113). Following this line of argument, teacher training opportunities that challenge teachers' prior beliefs, about gender and learning, would require the use of gender-sensitive pedagogies.

Therefore, the motivation of our study was to identify the gender-sensitive pedagogies used in our teacher training workshops and alternatively adjust the workshops in order to include gender sensitive teaching strategies in their delivery.

1.4 Aim of this paper

The main question of this paper was to identify *what* gender-sensitive pedagogies are used in our teaching training opportunities targeted to teachers in Higher Education science, technology engineering and mathematics (STEM).

Other questions that became relevant are: Do we identify implicit gender biases in the planning, organising and delivery of our workshops, and if yes, what can we do to eliminate these? Which areas of the training activities at our unit are more prone to use gender-sensitive pedagogies? What changes to make in support of our initiative but without spotlighting the underrepresented?

In order to respond to these questions, the paper draws on previous research and on European initiatives to structure gender-inclusive curricula.

2 METHODOLOGY

2.1 A checklist

A first step was to define an instrument to help assess our approach to gender in teaching training. The GARCIA project toolkit for Developing Gender gender-sensitive curricula [11] and the self-evaluation checklist built by the e-equal project, University of Fribourg [12] were our sources of inspiration. Both tools are evidence-based and built to support trainers in designing program and courses from a gender-inclusive perspective. The GARCIA project gives recommendations such as reflecting on how many female/ male academics one invites for visiting lectures. It also suggest finding examples that are renowned for their gender-sensitive approaches. These checklists are a first step to a reflection and analysis of text and images, course content and examples but also of the type of learning activities and student evaluation methods.

In addition, our checklist has sections that we found would help us contextualise our training in Science and Engineering education; such developing the critical thinking of the participants with regards to gender in teaching. We also found it important to include a possibility for peer assessment, and therefore the checklist also includes an observation grid.

The self-assessment checklist is divided in two parts. The questions are fully presented later on in the results tables. Part I, with 6 questions the intentions and aims of the workshop, of which an extract is presented in Table 1 below. Part II, with 8 questions asks for the content of the material and the learning activities used in the workshops. An observation for peer-assessment completes the checklist but is not reported here.

Table 1. An extract of Part I of the checklist.

Intentions and objectives Before the workshop	yes	No	Get info.	Irrele vant	Evidence / comment
1. Do you prepare your participants to be gender-sensitive teachers?					
2. Have you included in the readings gender-sensitive publications?					
3. Have you devoted at least some time to gender dimension of the workshop subject?					

4. Do you plan to make your participants more aware about gender stereotypes connected to the topic of the workshop?					
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2.2 Self-assessment

Each teaching advisor completed a self-assessment for each workshop they already facilitate. After each trainer responded, they were invited to discuss their reflections of doing the self-assessment with the project leader and later all together in a seminar-type session.

3. RESULTS AND ANALYSIS

Four Teaching Advisors self-evaluated 14 workshops of which 9 are offered exclusively to Professors (Full, tenured and tenure-track), 4 to PhD Assistants and 2 to Bachelor and Master students. Post-Docs are welcome to attend any workshop. The total of 17 answers show that we take turns in facilitating the PhD workshops throughout the year. The quantitative data is shown below.

The tables below show the frequency analysis for the responses per question and it groups all workshops. Five replies were possible: 'yes', 'no', 'irrelevant' and 'get information' it was also possible to leave the space without an answer. Fig 1. shows the results for Part I of the checklist: the intentions and preparation of the workshop including the design and planning of each workshop asking about the content, the material and the teaching strategies planned for the event. Fig. 2 below shows the results for the self-assessment of the content (concepts, examples illustrations) and materials (images, slides, objects) for the workshops and courses.

The histograms shown below shows the results for self-assessing the design and planning of workshops. Questions ask for the content, the material and the teaching strategies planned for the event.

Figure 1: Self-assessment of planning (i.e. intentions, aims, choice of material)
14 responses

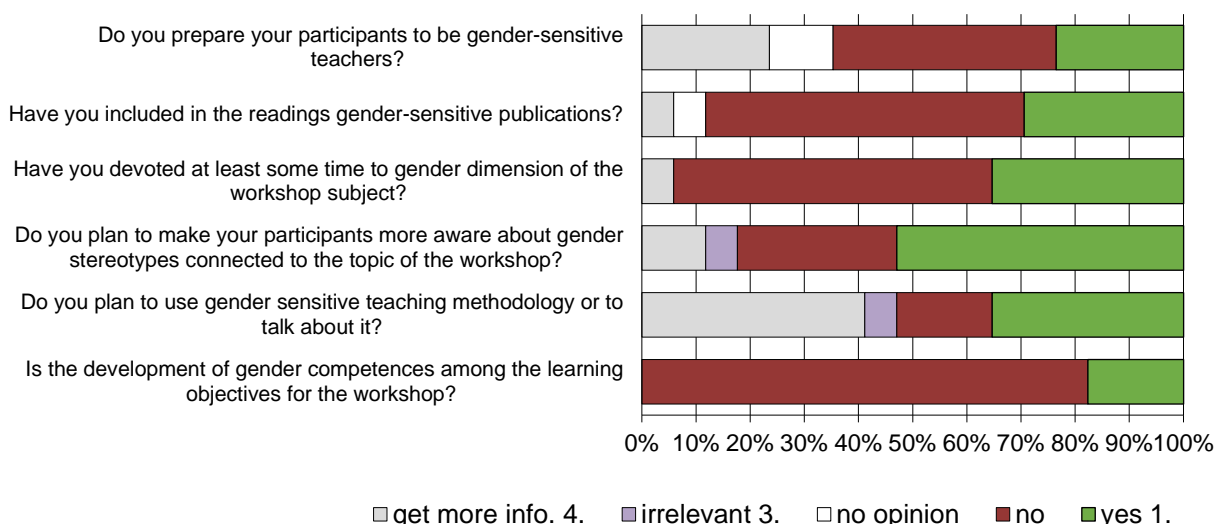
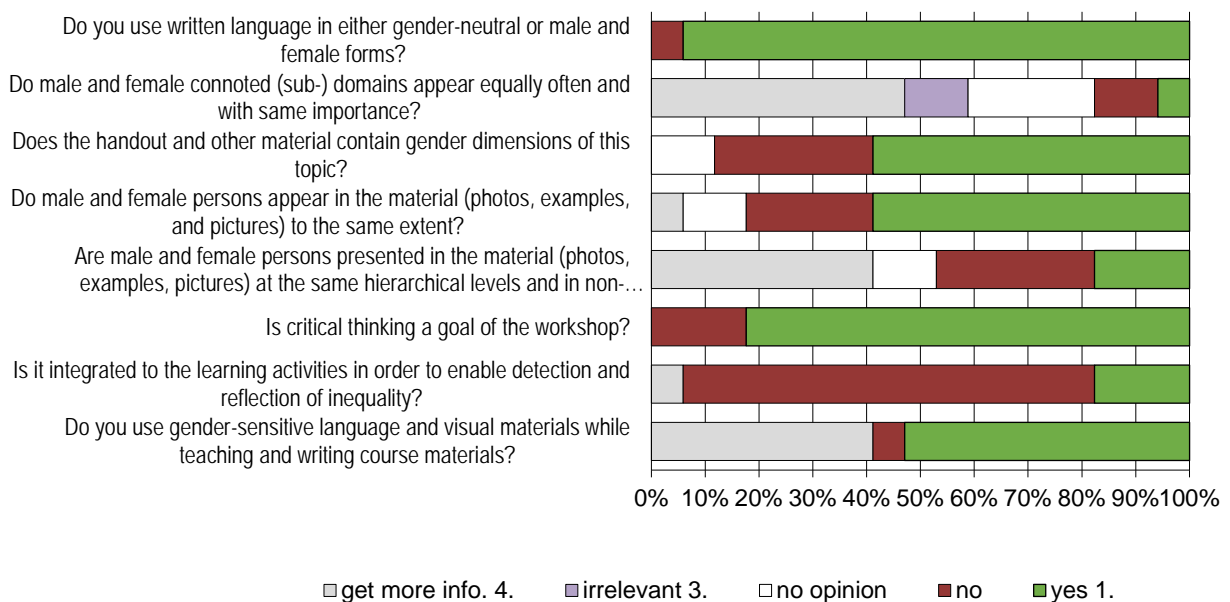


Figure 2: Self-assessment of material (text, theory, images)
14 responses



Results show that the material used for training teachers is gender neutral in text and images, using the English gender-neutral 'it / the', or taking images and pictures respective of gender equality or by not using human images. Almost all workshops aim for critical thinking but only in three of them, the workshop activities intend for discussing gender biases or reflect on inequality.

In general, teacher training is organised thinking to be gender-inclusive. Our results show the use of gender-sensitive pedagogy for certain workshops that can potentially be used in other workshops. These were the think-pair-share, jigsaw activities and electronic voting.

Some content addresses gender in learning such as in problem solving, where differences between girls and boys are shown as well as of gender stereotypes in study habits. Gender and fairness is presented when speaking about evaluating student learning, as reliability can contain gender bias.

Our results showed a positive predisposition to learn more about gender assumptions in solving engineering-type problems, carrying out group work as well as in avoiding spotlighting and gender stereotypes in workshops practicing presentations skills in teaching. More research is needed on information on gender stereotypes and hierarchies in relevant domains of teaching.

Trainers know something about gender-sensitive teaching methodology but still wish to know more. Generally we are all willing to prepare teachers to be gender sensitive instructors. While the highest positive response is on the intention to raise awareness of gender stereotypes, the lowest positive response is about including the development of gender competencies as an objective of workshops. Five workshops include material with reference to gender. Six workshops deal with the gender dimension of certain subjects linked to teaching and learning.

Concisely, the results confirm a systematic use of gender neutral written and audio-visual supports. We found an overall positive attitude to learn more about the gender dimensions of teaching and of gender sensitive pedagogies. This shared intention to educate teachers to become gender sensitive teachers has led to apply more widely think-pair-share and the electronic voting as gender-sensitive teaching methods.

4. DISCUSSION, CONCLUSION AND NEXT STEPS

The answer to our main question is: mostly yes. Yes, we are preparing teachers to be gender-sensitive teachers by carefully planning our workshops and choosing relevant research and examples in the content and the material. However, the self-evaluation showed that we needed to take a closer look at our individual insights to gender-sensitive pedagogies in order to share them and use them.

Did we identify implicit gender biases in our practices as teacher trainers? Mostly no, but if some were identified in the choice of images have already undergone revision. Nevertheless, this point deserves to dig deeper into our choice of content, examples that may build bridges between gender and teaching the in STEM disciplines.

Do we use gender-sensitive pedagogies, and are these more adequate to some trainings? Yes, we use gender-sensitive pedagogies, and they might apply to all workshops. Our results confirm that we use interactive teaching strategies such as the think-pair-share consequently we, as a team, have discussed how to balance classroom participation. We have since identified research relevant to our aspirations and teaching practices, such as electronic voting for peer-instruction looking at gender [13].

We feel we have learnt from this project and are enthusiastic about the next steps. There is still some way to go: for example, when presenting these approaches to teachers do we call them gender-sensitive or just 'good teaching'? How do we raise awareness of gender issues in classrooms but avoid spotlighting? These are questions that we will want to address.

A few last words on the checklist, which we built based on existent ones: we found it extremely useful as a reflective tool. Let me explain; the individual questioning of our practices and the common sharing of results opened a space for us to discuss the experience as respondents to the checklist and it got conversation going on sensitive issues and teacher training. This has been unanimously a rewarding learning experience. The reflexivity ignited by this exercises is still alive. We find it would be a positive result to apply it in other contexts and training programs.

We expect to keep the enthusiasm in training teachers and we shall insist on the importance of gender-sensitive teaching in an Engineering and Science curricula.

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Using Digital Tools for Enhanced Student Learning and Engagement in Particle Technology Courses at Graz University of Technology

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Conference Key Areas: Innovative Teaching and Learning Methods

Keywords: digital tools, eLearning, student engagement

Introduction

Digital-based approaches to enhance student learning and engagement have seen much attention during the past ten years. These approaches have included online learning management systems, MOOCs, student response feedback systems, among others. At Graz University of Technology (TU Graz), there has been a significant emphasis on using digital tools, which have been previously reported¹⁻². Digital tools and adaptive learning have posed a challenge to the academic community, in that new assessment methods and data analytics are necessary to quantitatively determine enhanced student learning and engagement. Both quantitative and qualitative approaches have been studied, though many are dependent on the learning habits and preferences of a particular student³.

At TU Graz, multiple digital tools were used to enhance the student learning and engagement in the Particle Technology sequence of courses. The three main tools that were used were: (i) Perusall, (ii) Feedbackr, and (iii) TeachCenter. The three primary goals in using these digital tools were (i) to enhance student learning, (ii) improve student engagement in the classroom, and (iii) to obtain rapid feedback regarding student understanding of the course materials.

Our present concept paper will highlight how these digital tools were introduced in the course sequence, as well as some best-practice recommendations for classroom and course implementation.

The Particle Technology sequence at TU Graz consists of two courses: Particle Technology I (a lecture), which primarily focuses on more introductory material, and Particle Technology II (a combined lecture and practical), which focuses on more advanced topics, such as gas-particle separation processes. All three digital tools were used in the Particle Technology sequence. The following section describes each digital tool in more detail.

1. Digital Tools

1.1 Perusall

Perusall is a digital platform that allows students to collaboratively annotate textbooks, papers, and other similar classroom reading assignments⁴. It is a web-based tool that allows for commenting on otherwise static content. Students can essentially “crowd source” comments, questions, and answers on text-based course materials using this digital platform. The students’ asynchronous responses, comments, questions are recorded (these records include student names and timestamps), and shown to the class and instructor. Additionally, if wanted, the student comments can be scored by a machine learning algorithm. Previous uses of Perusall in physics courses found that the students who engage in high-level discussion online make more gains in conceptual understanding than students who do not⁵. Another use of Perusall, in a chemical engineering course, found that at least 80-90% of the students believed it was a useful educational tool and that they learned new material by responding to other students’ comments⁶.

In order to introduce Perusall to the Particle Technology courses, five different papers were assigned to the classes to read as supplemental material⁷⁻¹¹. Although class attendance is not mandatory for these courses at TU Graz by law, the instructors decided to consider an outside-the-classroom method to help engage students in studying the material. The assigned papers brought additional depth and introduced contemporary concepts to the course material. Students were asked to provide approximately three annotations per paper.

Fig 1 shows an example of what a paper digitally highlighted in Perusall looks like. The yellow highlighted text has been annotated by students, either using comments or questions. These comments and questions are called a “conversation” in Perusall. It is essentially a thread of comments for a paper. Fig 2 shows a list of conversations for the material highlighted on page 1 of the paper (Fig 1). Fig 3 shows an example of a single conversation between two students and a particular topic found within the paper.

Characterization of Lunar Dust for Toxicological Studies. I: Particle Size Distribution

Jaesung Park¹; Yang Liu²; Kenneth D. Kihm³; and Lawrence A. Taylor⁴

Abstract: The particle size distribution (PSD) of lunar dust, the <20 μm portion of the regolith, was determined as an initial step in the study of the possible toxicological effects it may have on the human respiratory and pulmonary systems. Utilizing scanning electron microscopy, PSDs were determined for Apollo 11 (10084) and 17 (70051) dust samples, as well as lunar dust simulant JSC-1Avf. The novel methodology employed is described in detail. All measured PSDs feature a log-normal distribution having a single mode in a range 100–300 nm for lunar dust samples, but the lunar simulant has a mode at ~ 600 nm.

DOI: 10.1061/(ASCE)0893-1321(2008)21:4(266)

CE Database subject headings: Dust; Moon; Particle size; Toxicity.

Introduction

NASA has recently announced major space missions to return human beings to the Moon, and then to Mars, and beyond. Immediate plans are to use the Moon as a test bed for Mars and for a propellant fueling station, with the in situ resource utilization of lunar materials providing for the establishment of a permanent lunar outpost. Regolith and soil on the Moon will be used to construct a base, but also will be processed to produce oxygen and hydrogen for rocket fuel, and helium (^3He) for possible nuclear energy (Taylor 1992a, b; Taylor and Carrier 1993; Taylor and Kulcinski 1999). All activities on the Moon, be they regolith handling and processing or simply moving on the lunar surface, have one factor in common—involvement with lunar dust, with its numerous deleterious effects. Lunar dust is the <20 μm portion of the lunar soil, makes up $\sim 20\%$ by weight, and consists mostly of sharp, irregular-shaped, abrasive, impact-produced glass. Because of the unique environment prevailing on the lunar surface, the soil and its dust contain myriads of nanophase metallic Fe particles that impart the soil with unexpected properties of ferromagnetism (Taylor et al. 2005) and extreme coupling to microwave energy (Taylor and Meek 2005).

During the Apollo missions, the astronauts experienced unanticipated problems due to the ubiquitous lunar dust. Many of the

astronauts experienced problems including eye, nose, and throat irritation, to different degrees. With plans of returning humans to the Moon for prolonged stays (e.g., 15–90 days), it is imperative that the possible physiologic effects of lunar dust on respiratory systems be thoroughly investigated (Park et al. 2006a,b; Taylor et al. 2005). The detrimental and adverse effects of the lunar dust must be carefully examined. In particular, it is the <2 μm particles that can readily remain in human lungs, where they can cause fibrosis or even enter directly into the blood stream, particularly when <100 nm. As a first step in the understanding of lunar dust and its deleterious effects, studies have been undertaken on the particle size distribution (PSD) and morphology of some Apollo lunar dust samples.

After each Apollo mission, the various lunar soil samples collected had their PSDs determined by wet/dry sieving. Largely because of sieving limitations, such size distributions were measured primarily from millimeters down to 20 μm (Morris et al. 1983; Graf 1993). Several studies measured size distributions of lunar soil down to 1 μm (Duke et al. 1970; Heywood 1971; Carrier 1973; Butler et al. 1973; Butler and King 1974; McKay et al. 1974; Greene et al. 1975). However, the submicron grain sizes have not been well examined to date. One reason for the scarcity of submicron size data was their perceived lack of importance for lunar soil science (i.e., origin and evolution). Until now, the possible toxicology of lunar dust was not an important subject. In

Fig 1. Example of highlighted annotated text in Perusall.

? In my point of view its interesting that the authors are... 3

To my mind this could be avoided or at least minimized by a...

? How can the phsysiologic effects of lunar dust be tested ...

? Is this similar to the effect of asbestos? 3

? Do I have to be affraid of dust particles on earth, or a... 2

? How is this possible? Wouldn't we need other conditi... 2

Don't breath this

There are already measurments an astronaut can take to av...

? Shouldn't their space suits be impervious against suc... 3

? Does these techniques used in the pharmaceutica... 2

? How does this apparatus work?

Fig 2. "Conversation" topics in Perusall based on content in Fig 1.

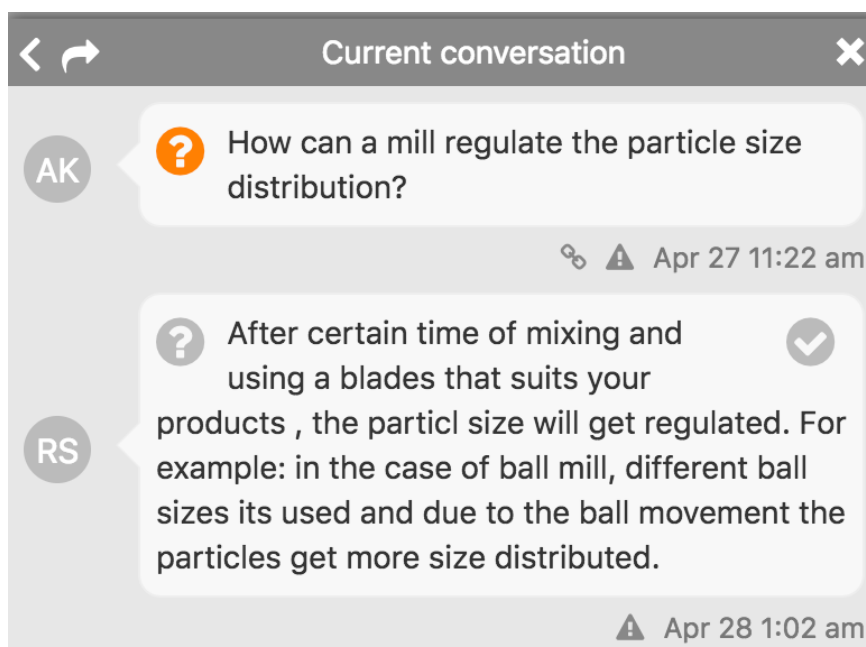


Fig 3. Example of a single conversation within the paper. The initials refer to students and timestamps are provided for when the comments occurred.

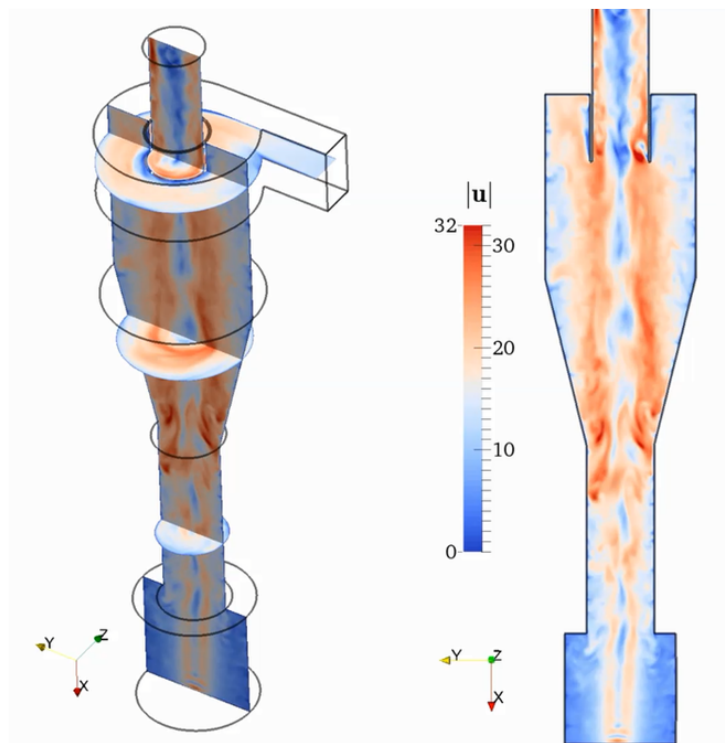
1.2 Feedbackr

Feedbackr is a digital student response tool that can be used for immediate feedback in the classroom. It is a web-based tool which collects feedback anonymously. Questions consisting of text, equations, computer code, or figures can be sent directly to the students. The students then respond, and the feedback data is immediately sent back to the instructor. The main reasons for using Feedbackr in the Particle Technology courses were to (i) engage students and initiate discussion, (ii) identify “weak spots” in the student’s perception of a certain topic, and (iii) identify topics that need further discussion. Fig 4 is an example of a (figure) question that was administered to the class.

1.3 TeachCenter

TeachCenter is an online resource management tool for students to use for a particular course. It is similar to *Moodle*, in that it serves as a “hub” for course content and online student engagement for a particular course. However, also non-*Moodle*-based resources were hosted on TeachCenter: most important, links to etherpads were provided that acted as “virtual blackboards” for (i) feedback collection, and (ii) group formation. Also, a database of multiple-choice and calculation-based questions, which can be used for formative assessments, were hosted on TeachCenter. Since such applications of a *Moodle*-like environment are fairly standard nowadays, details related to TeachCenter are not further elaborated below.

Which statements are correct about the figure below:



- ☐ ...this is a typical result of a traditional cyclone design calculation.
- ☐ ...this is a typical result of a LES-based flow simulation used to design cyclones.
- ☐ ...this is a typical results of a 4-way coupled multiphase flow simulation that can be used to design cyclones.
- ☐ ...this is a typical result of a modern cyclone design calculation

Fig 4. Example of a Feedbackr question used in the Particle Technology courses.

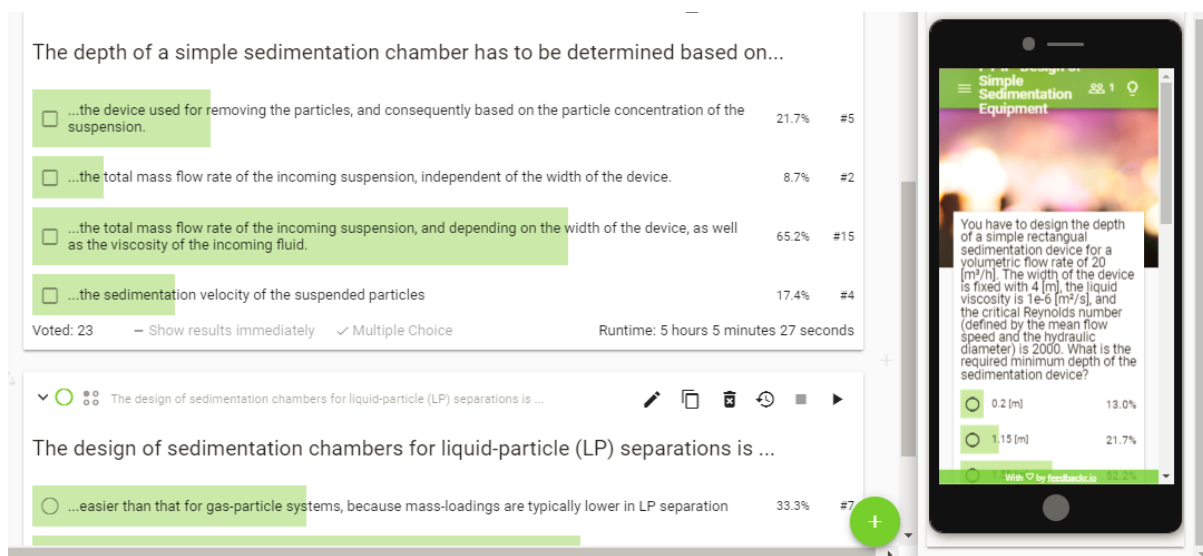


Fig 5. Example of a Feedbackr response session.

3. Preliminary Results

Since this was the first time Perusall was introduced in these courses, the instructors were in the preliminary stages of collecting data on how the readings enhanced student learning. In order to help encourage students to do the readings, extra-credit questions based on the readings were included in the final exam. Students who were annotating the assigned papers using Perusall were able to answer the extra-credit questions. Informal feedback from students inferred that they felt the readings complementing the course materials. One approach that was used to measure student engagement was to study “heat maps” of student activity. Specifically, these maps were used to measure the students’ activity and time used to read the papers. Fig 6 is an example of a “heat map” of student activity for one of the papers assigned.

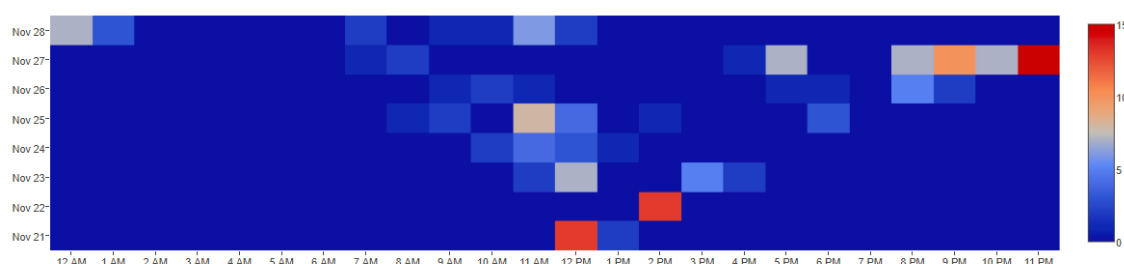


Fig 6. Example of a heat map of student activity in Perusall

For the use of Feedbackr, the participation in the lecture classes fluctuated on a moderate level. Based on a Feedback questions, it was found that 19-25 students participated in these questionnaires, thus indicating that 38-50% of the students participate in the lecture units. This is significantly above average participation in previous editions of the particle technology sequence of lectures that did not use these digital tools.

4. Conclusions

Perusall, Feedbackr, and TeachCenter were used for the first time as digital tools to engage students in the Particle Technology course material, and to enhance their learning and understanding of core topics. In this “concept paper”, the authors describe the various digital tools employed in these courses. Although thorough assessment of student learning and engagement was not obtainable for the initial implementation, the authors concluded that a significant step to enhance student learning was achieved by attempting to use all three digital tools. The authors recommend that other instructors consider adopting one or more of these digital tools as a way to engage students both inside, and outside the classroom.

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With focus on non-technical engineering skills

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Conference Key Areas: Engineering Skills, Continuing EE & Lifelong Learning, Ethics in EE

Keywords: Non-technical engineering skills, professional role, active learning

INTRODUCTION AND RELATED WORK

How can we prepare engineering students for their professional life? To have a successful career in engineering, the engineer needs both technical engineering skills and non-technical engineering skills. To systematically address non-technical engineering skills six mandatory Engineering days have been introduced at the Bachelor programs in Computer Engineering and in Electrical Engineering with automation at Lund University's campus in Helsingborg.

The ability to communicate, to work in teams, reason about ethical questions, have an understanding of entrepreneurship and economy are some of the non-technical engineering skills of interest. This has been recognised by certification bodies that have included such non-technical engineering skills in their demands on engineers. For example, to be accredited by the Accreditation Board for Engineering in the US, an engineering education program must show that their students can collaborate in multidisciplinary teams and can communicate effectively [1]. Also The European Union has stressed the importance of non-technical engineering skills and the inclusion of them in the curriculum of engineering education programs in the EU. The Dublin descriptors in the framework for qualifications of the European Higher Education Area include ethical and social issues. On a national level, several countries demand that non-technical engineering skills should be included in

engineering programs. For example, in 2012 the Swedish National Agency for Higher Education evaluated all Swedish engineering education programs. In that evaluation the non-technical engineering skills played an important role, and some programs were highly criticised and threatened with losing their right to graduate engineers because they failed to fulfil demands on non-technical engineering skills. Employers also underline that non-technical engineering skills are important [2]. The authors of this paper have similar experiences from focus group meetings held together with nine different companies situated in the south of Sweden. They all stressed out the importance of non-technical engineering skills in the employment process. Larsen et al. [3] have observed that it is not only technical knowledge that is needed for a successful career in engineering, but also non-technical engineering skills, for example being able to co-operate in multidisciplinary/multicultural teams, justify the value of new technical solutions and present an analysis to people with different background. A summer course developed at Aarhus University in Denmark in cooperation with the company Bang & Olufsen, was surveyed 2-6 years after the course and the result showed that the students experienced that the course gave them a more holistic view of product development and also improved their ability to work in heterogeneous groups.

Non-technical engineering skills such as oral and written communication, ethics, the impact of technology on society and group dynamics are introduced in engineering programs as compulsory courses used to cover non-technical engineering skills. The main contents of a course are either non-technical engineering skills as such or engineering with non-technical engineering skills as an integrated part. Some engineering programs offer their students non-technical engineering skills in non-compulsory activities like summer courses or other types of non-curricular activities. Knobbs and Grayson [4] describe how self-awareness, empathy, relationships, communication, group dynamics and conflict handling are introduced in a course in the third year of a mining engineering program. Reading assignments, peer interaction, coaching, psychometric tests, and work in heterogeneous groups were used during the course and the authors of the article claim that the papers the students write during the course and the course evaluations show that the students' non-technical engineering skills were increased. A concern, according to Cech [5] is that engineering students during their studies tend to become less concerned with public welfare, a claim that is backed by surveys from four American universities. Since engineering plays an increasingly larger role in our society, that may lead to serious problems the author emphasises. It is also noted by Herkert [6] that in 80 % of all engineering education programs in the USA, the students do not have to take any ethics-related courses. The author also surveys the ethics education for engineers in the USA and the most common way of introducing ethics is case studies, sometimes supplemented with ethical theories. There are two common approaches, a required course with elements of ethics or a cross-the-curriculum approach, where ethics are spread through the curriculum during the years.

Six mandatory Engineering days, called "Ing-dagar" have been developed in a project and introduced at the Bachelor programs. Approximately 80 new students are admitted to the two programs each year. The programs first year are very similar in content but year two and three differ significantly. This paper describes the project and ideas behind the concept "Ing-dagar" in section 1, the organisation and content of the concept in section 2 and in section 3 the observations and lessons learned. Some thoughts about future work will be given in section 4.

1 THE PROJECT AND IDEAS BEHIND

The project with four members (three teachers and one Coach ACC and Educational Coordinator) started out with thoughts about ethics, since in the Higher Education Ordinance (1993:100) there is a demand that the students must show the ability to make judgments with respect to relevant ethical issues. When different ways of implementing ethics were discussed, new ideas on other non-technical engineering skills started to grow. The knowledge and skills the students need to have as an engineer related to the Higher Education Ordinance and also what is required by industry were surveyed and the project was enlarged to embrace further non-technical engineering skills (described in section 2).

The members in the project defined four guiding principals for the concept “Ing-dagarna”:

- Active learning
- The professional role as an engineer
- Collaboration with industry
- Progression

According to the project members it is important to activate, motivate and engage students in order to stimulate students in their own learning process. In the development of the concept “Ing-dagar” the Kolb circle [7] and the four different ways of learning: concrete experience, reflective observation, abstract thinking and active experimentation influenced the work. For the project members, it is important to create the conditions for active learning because active learning creates motivation, interest in the subject, increases understanding of concepts and even more effective work [8]. Active participation, thus contributes to a learning outcome that corresponds to the higher levels of the SOLO taxonomy [9]. Lecturing has a tendency to result in passive listening and less effective learning compared to situations where the students are more active and engaged [10]. The project members use, for example teamwork, casework and reflections in the active learning process. Another active approach can be reached by introducing blended learning. The literature presents different definitions of blended learning and there is still no clear definition of the term according to Kuhn et al. [11]. However, a presented definition is that blended learning is a combination of different learning techniques, technologies and delivery procedures [12, 13], and another definition focuses on online teaching integrated with classroom education [14]. To integrate digital tools with classroom education has a positive impact on the students’ experience of their studies, their experienced control over their own learning, on throughput and on the achievements [15,16,17]. This is also supported by results by Parson et al. [18] showing that overall students indicate that podcasts and vodcasts were a beneficial additional resource for learning, especially used together with lecturers’ slides and when used for assessment.

One way of introducing blended learning is to use Flipped Classroom where the basic idea is to replace traditional lectures with active in-class activities and pre-/post-classwork [19]. Often the students are given an assignment before class to prepare and the time in the classroom is used for active learning under the teacher’s guidance. This is for example used in Ing 1b. When using blended learning it is important to map the teaching methods and monitor the learning. The monitoring serves three purposes; identify that the students learnt what was taught, see that students prepare for class and to identify parts where many students have problems [20]. The use of Flipped Classroom gives “better relationships, greater student engagement, and higher levels of motivation” [21]. The professional role as an engineer and collaboration with industry are also key components for the project. It is

agreed on by representatives from higher education institutions that industry related activities give pedagogical values and makes the graduates more employable [22], and collaboration seems to inspire and motivate students to work more efficiently [23]. A main concern for the project members is also to design learning activities, which encourage students to adopt an active approach to learning and also a progression over time. A “deep learning approach” described by Biggs [9] allows students to connect new knowledge to existing ideas and build an understanding. For example, create activities that increase in complexity and run as a red thread throughout the three years of education.

2 THE ORGANISATION AND CONTENT

To have ongoing themes regarding non-technical engineering skills throughout the three years of education is the idea of “Ing-dagar”. All activities such as group dynamics, ethical discussions, engineering writing are mandatory and will take place within the framework of existing courses. The activities are included in the six “Ing-dagar” presented in figure 1 and relate to six different themes, ethics, communication, the engineering profession, teamwork, entrepreneurship and international and intercultural aspects. Three of the days (Ing 0, Ing 1a and Ing 1b) are linked to courses in year one, two of the days (Ing 2a and Ing 2b) are linked to courses during spring in year two and the last day (Ing 3) to courses in the autumn in year three. Students are also given the opportunity to supplement the compulsory activities with voluntary activities and are then able to be certified in non-technical engineering competence (CITIK) and receive a diploma that can be attached to the student's CV.

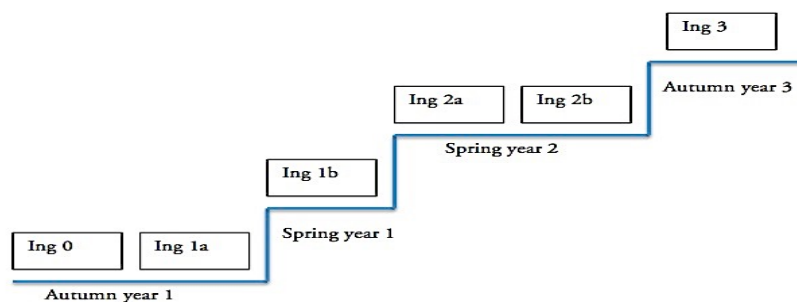


Figure 1

Ing 0 is held one of the first days of the students' education and focuses on teamwork, ethics and the engineering profession. The day begins with teambuilding activities with the aim of getting the students to know each other and to encourage cooperation and social interaction among the new students. According to the theme ethics they are given a lecture on basic values, the discrimination act and master suppression techniques. The lecture is then followed by group discussions. Regarding the theme the engineering profession, the students are encouraged to bring a picture that illustrates the professional role of an engineer and/or how engineers affect society. In class they then gather in groups presenting their pictures to each other and each group agrees on one of the pictures. The selected pictures are then later presented on the day Ing 1a, where the students can vote for the “Engineering picture of the year”. The activity is intended to create discussion about what an engineer is and the students' future professional role. In order to address the role of the engineer further, films are shown where alumnus describes their work. They also provide advice to the students for their ongoing studies.

Ing 1a, with a focus on written communication is also the starting point of “Writing for engineers”, part of the introductory course. The students practice information search, reading scientific articles, writing summaries and reflections based on the articles. They also peer review each other’s text. During Ing 1a, the students are introduced to the non-technical skills included in the Ing-days and the skills are put into context and the importance of these skills for their professional life is stressed out. The activity “Writing for engineers” is also presented, and it is emphasised that writing skills are important both during the education and during a professional career as an engineer. To prepare the students for the writing assignment, experts on language and writing from The Academic Support Centre of Lund University give a lecture on good writing style and on how to write a review of an article. Many students “borrow” pictures and other material they find on the Internet without checking if it is free to use or without asking for permission. To make the students aware of the dangers of that, basic facts about intellectual property and especially about copyright is presented to the students. Traditional copyright and new concepts like Creative Commons are described. The main message is that if they are not sure that they have permission to use material they have found, they shouldn’t do it. Also, plagiarism and what it may lead to are discussed. The last part of the day focuses on group dynamics, teamwork and working in project groups, especially how to handle conflicts. This part concludes with a group exercise for the students, where they shall abolish five civic rights in a country. They get a list with civic rights and the task is to agree on what rights that should be abolished. Finally the students vote for the best engineering picture from Ing 0, and the winner receives a small prize.

Ing 1b includes ethics in the form of digital traces, teamwork and group dynamics. To randomly group the students they are given a piece of paper with a picture of a well-known person, real or fictitious. In the room there are paperboard figures picturing the persons in the pieces of paper and the students find the matching paperboard figure. There will be about five students per paperboard figure. A short lecture on digital traces is given, about the history of information acquisition by governments and companies and the possibilities of today are described and exemplified. Examples include the use of cookies in targeted advertising and how criminals have been found just by using their digital traces. The students have prepared themselves before the lecture by reading a number of articles on the subject. After the lecture the students carry out a number of tasks, 1-3 as a group and 4 as individuals:

1. They read a story about a day in the life of their figure (1-2 pages long). The group of students shall find the digital traces left by the figure during that day. Most groups find about a dozen traces.
2. They chose three of the traces and analyse them more closely. They shall answer questions like: Who collects the data? How is data used? What’s good with collecting this data? What’s bad with collecting this data? What is the worst that could happen if the data is used in a malicious way?
3. They chose one of the traces from assignment 2 and make a poster about that trace.
4. They vote for the best poster. The winning group gets a small, symbolic prize.

Ing 2a is part of project courses and therefore closely linked to teamwork, but the day also relates to ethics and intercultural aspects. After an introduction the students work in their project groups with establishing ground rules, a set of expected behaviours within the group. The ground rules and consequences for non-compliance are then documented in the

different project groups' project plan. In class the students then get a short presentation of sequential and synchronous time perception and how this differs over the world. They gather in their project groups again and discuss what affect sequential and synchronous time perception has on project plans and agreements on how to work regarding time planning and meetings in multicultural teams or with companies in other countries. The final group discussion is about the Code of Honour (The Swedish Association Of Graduate Engineers) where the students try to agree on the three most important principles. The individual assignment at the end of the project courses includes parts where the student reflects on his/her own commitment in the group, the ground rules and what activities in the project would be affected if the project members come from other countries. The individual assignment is designed as a personal letter for a job application and is a continuing training of writing skills from "Ing 1a" but focusing on another target group as well as training in applying for work. Students receive support in their writing from the Academic support centre and they also receive a guest lecture on how to write a personal letter from the Human Resources Department of a company.

Ing 2b continuous from "Ing 2a" with intercultural aspects, an invited guest lecture from a global company share experiences of working in multicultural teams, how the experience is to live and work in Sweden, differences, similarities and things to think about when working with people from other countries. After the guest lecture group discussions are held and written summarised reflections are handed in. Since many of the students will work in multicultural teams or work abroad in the future, these aspects are important to highlight during the education. Ethics is also included in "Ing 2b" through a guest lecture and group discussions about the new law General Data Protection Regulation (GDPR), which will affect students both as individuals and professionals.

Ing 3 will be introduced in the autumn of 2018 and will focus on the students' beginning career with career coaching, CV review, negotiation techniques and entrepreneurship. The specific activities are still at the planning stage.

3 OBSERVATIONS AND LESSONS LEARNED

The concept "Ing-dagarna" has not fully been implemented yet, Ing 0, Ing 1a and Ing 1b have been given two times, Ing 2a and Ing 2b just once and Ing 3 is in the planning phase. The activities are still changing based on observations and lesson learned. The observations and lessons learned so far will be presented in this section.

The students are introduced to written communication during Ing 1a and there are indications that the students' writing skills have improved according to statements from teachers who meet the students' writing in later courses, when they write reports, reflections and thesis. It has been noticed that the structure of the written texts and the language has improved. Coping with copyright issues, for example regarding the use of other people's pictures and figures has also improved, showing that the students take into account the ethical aspects presented in class. However, since this is a work in progress at an early stage, no systematic evaluation has been done yet. A more comprehensive evaluation of progression regarding the writing is planned in cooperation with The Academic Support Centre of Lund University.

A lesson learnt during the first year when the evaluation showed that some students did not understand the purpose of the writing activities. To address this and improve motivation, the second year the writing was put into context and it was described in detail what the students are going to write during their education and in their professional working life.

The student work in teams from the first day (Ing 0) with team building activities were the main goal for the students is to getting to know each other and start to communicate. They also start to reflect on their professional role by choosing a picture that they think illustrates the professional role of an engineer and/or how engineers affect society. The students choose a picture freely, they don't get a number of pictures to choose from. The pictures illustrate what the students think are the most important aspects of the engineering profession. The three most common aspects in decreasing order have been:

- Problem solving (many different kinds of pictures)
- Entrepreneurship and the engineer as a hero (many with a portray of Elon Musk)
- The impact of engineering on society (many different kinds of pictures)

The results for 2016 and 2017 were similar. When the students voted for the "Engineering picture of the year" during Ing 1a, a flowchart won in 2016 and the Eiffel tower in 2017. The intention is to do the same activity during Ing 3 to investigate whether the students' views on an engineer have changed during their studies.

The students further work in teams during Ing 1a with ethical aspects where the students were given 15 civil rights granted to the citizens of a fictive country. As described, the students' task, chose five rights they thought could be abolished. This has been done in 2016 and 2017, and the results were very similar. The rights most groups wanted to abolish were related to physical mobility and freedom in everyday life, for example the right to swim and camp anywhere, the right to park anywhere and the right to walk the dog anywhere. The rights most groups wanted to keep were related to communication, media and professional life for example the right to choose telephone operator freely, the right to criticize your boss without reprisals and the right not to be contacted by telemarketing companies without permission. Perhaps there is a trend that students do not chose rights related to physical activity and politics and consider the most important rights to communication and media but this is to soon to conclude.

Ethics, teamwork and group dynamics are in focus during Ing 1b and the students work in groups with finding the digital traces left by a fictitious person during the person's day. Almost all the student groups discover about a dozen traces, a very good result. The winner in the poster content was a poster about the use of cookies in 2017 and about the use and misuse of assault alarms in 2018, both very relevant traces. Most of the posters can be classified into the categories, economic transactions (paying or ordering by electronic transactions) or surveillance and tracking services. In the first category the students identifies the problems with fraud and systematically map of users in the second integrity problems. Most students seem to fear that individuals or companies can misuse information, not that authorities or the state can do it. The reason for that is probably that Swedish people usually trust the state and local authorities. The students also see the advantages of technology that leaves digital traces, so their view is quite balanced.

To get progression regarding teamwork and also include intercultural aspects, more ethics and connections to industry during the students' year two, the students work in project

groups and during Ing 2a the students discuss project plans and ground rules. The most common ground rules agreed on by the project groups are rules regarding attendance at meetings, working hours, treating each others with respect and being active and contribute to the project. The students also discuss the effect on project plans and agreements on how to work in multicultural teams or with companies in other countries. The discussions and reflections written individually later in the connected project course shows that the students were well aware about the problems that may arise and how to handle them. During Ing 2b the students are presented to intercultural aspects again from another perspective by meeting an invited guest lecture from a global company sharing experiences of working in multicultural teams, and work in Sweden when you come from another country. After the lecture the students discuss in groups and a written reflections are handed in. A summary of the reflections shows that the main lessons for the students are that people are not 0:s or 1:s, there is a endless spectrum of personalities, there is always something that people have in common, what I look like does not define who I am, we have prejudices we are not aware of, it is important with respect and understanding, and business cultures differ between countries.

At first we had concerns that the students would not perceive "Ing-dagarna" to be interesting, but experiencing the different subjects as "dopey", but based on teachers' observations during the "Ing-dagarna", it seems to be the opposite. The students are interested and engage in the various tasks. Based on previous experience of using external resources that worked with students in for example group dynamics, we have avoided external resources because the students responded negatively. They experienced the activities as diffuse and irrelevant. This has led us to link the activities explicitly to current courses, and for example ethical aspects are related to contexts like digital traces.

4 FUTURE WORK

To complete the concept "Ing-dagarna", the last building block in the concept Ing 3 will be launched during autumn 2018.

Since this is an ongoing work, the students have evaluated different parts separately, such as guest lectures and written communication, never the entire "Ing-dagar" concept. The students have been mostly positive in their evaluations. However, the whole concept will be continuously evaluated and updated. The objective is to develop an overall plan for systematic evaluation and data collection in order to be able to follow the various activities over time and get more feedback from the students.

To make the students even more active during "Ing-dagarna", concepts and tools for blended learning will be introduced. Digital tools will be used where it is appropriate. The use of Flipped classroom will be further developed. Today it is used in conjunction with Ing 1 b where the students prepare by reading articles, but this need to be developed further.

We in the group who are developing and working with "Ing-dagarna", experience that we get to know our students better, and they contact us also regarding other matters. We as a group have strengthened our collaboration, we have become better at utilize each other's skills and strengths and our goal is to maintain this and further develop.

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Serious Game Development - Entrepreneurship as the context for Engineering Education

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Conference Key Areas: Fostering Entrepreneurship; Innovative Teaching and Learning Methods; Teaching Creativity and Innovation; Innovation as the context for Engineering Education

Keywords: Serious Educational Game, Entrepreneurship

INTRODUCTION

In this paper, we conceptualize an innovative and sustainable teaching way that motivates and engages to study engineering by providing an entrepreneurial context. More specifically, we describe the development of a serious educational game that combines educational learning theory with existing frameworks for game development into one coherent framework. We specify this framework with regard to teaching engineers by letting them take on the role of an entrepreneur.

1 SERIOUS EDUCATIONAL GAMES

A serious educational game (SEG) is a computer-based game with the primary purpose of education. SEG allow the educator to connect real-world scenarios with specific learning objectives [1]. These games have been shown to address both the cognitive and affective dimensions of learning [7], and hence, enable players to adapt learning to their cognitive needs, and provide a higher intrinsic motivation for learning. They have further shown to provoke active player involvement and deep learning through hands-on exploration and experimentation and increased visualisation [9]. Particularly for a generation that is more digitally sophisticated than any generation previously, SEGs provide a learning method that suits the students'

personal preferences for learning at a pace that they chose themselves. Therefore it is not surprising that SEGs have become widely adopted by a new generation of learners, who has grown up immersed in new communication technologies [8].

However, whereas educators and games share the idea that participants have to achieve some goal, the goals of a SEG and the learning objectives often do not match. When designing a SEG, a dedicated framework for educational games is lacking [8]. Among the available frameworks, most are rather technical and hence, provide advice for how to bridge game design, game criticism and technical game research [2]. Yet, frameworks that specifically link game development with educational objectives are rare [5]. Those that deal with learning objectives typically address physical classroom games or massive multi-user online games but leave out critical elements of SEGs such as game complexity. In what follows, we hence develop a coherent framework based on models for SEG development and educational learning theory and specify this framework with regard to the topic of our educational game: entrepreneurship as the context for engineering education.

1.1 The Developing Perspective – Subsystems of SEGs

When developing SEGs, three levels have to be taken into account: the conceptual level, the technical level, and the practical level. The conceptual level comprises a set of interrelated elements and specifies how they interact with each other and develop over time. The conceptual level creates the dynamic in the game. It needs to be a closed self-contained environment, which can be reached with a decision tree that incorporates all possible paths a player, can take. The technical level describes the tooling system for the system architecture. This concerns the management of the game when in use later. The practical level provides principles for how to reduce complexity (e.g. by providing relevant information in form of a tutorial). Yet, these subsystems do not take into account the learning experience.

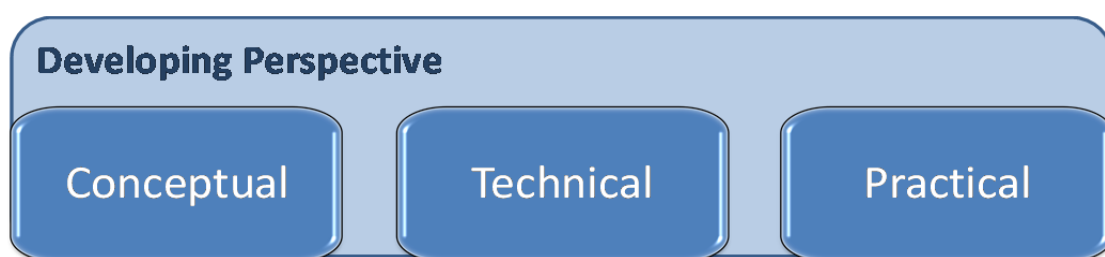


Fig. 1. Developing Perspective

1.2 The Learning Perspective – Bloom's taxonomy

To determine how effective SEGs are, the quality of learning should be assessed with regard to the extent the game helps players to reach the learning objectives of the course/class. To guide such an assessment, researchers have developed taxonomies on the basis of learning objectives. In this regard, Bloom's taxonomy and its revised version [2] became most popular. The revised taxonomy is a hierarchical model that includes six major categories in cognitive processing: *Remembering*,

Understanding, Applying, Analyzing, Creating, and Evaluating (cf. Fig 2). The taxonomy helps classifying educational system goals to support educators to achieve learning at a deep level in their students. Such deep learning occurs on the higher levels of the taxonomy (i.e., analyzing, creating and evaluating). Hence, for our SEG development, the learning objectives should focus on these higher levels and guide the game structure and design. They also serve as a control for curriculum alignment once the game is finished.

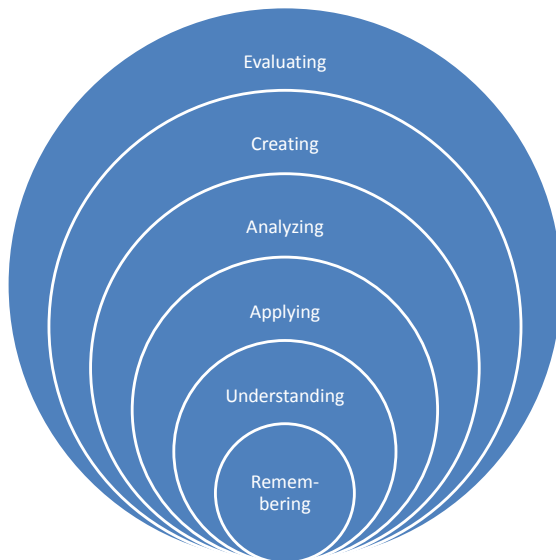


Fig. 2. Bloom's revised Taxonomy

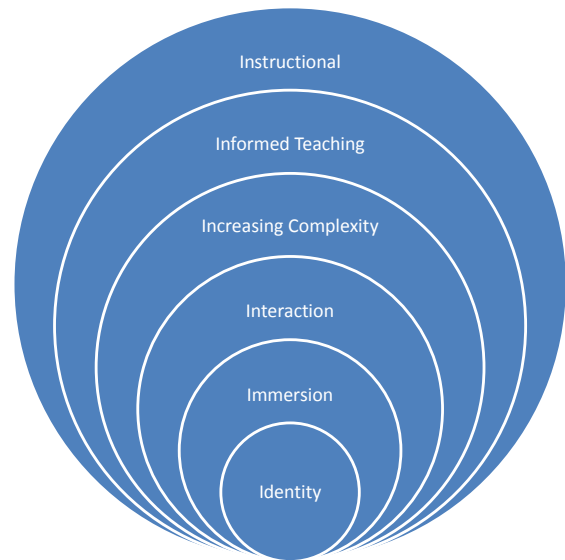


Fig. 3. A Nested Model of SEGs

1.3 The Education Perspective – A nested Model of SEGs

Whereas Bloom's taxonomy has the students' learning in mind and is based on cognitive theory, educational advices for how to design SEGs from an educator's perspective are often based on experience and research from commercial videos games. For instance, [1] proposes a nested model for SEGs that include "identity", "immersion", "interactivity", "increasing complexity", "informed teaching" and "instructional" (cf. Fig 3).

Giving the player an *identity* in form of an (ideally self-chosen) avatar is important for the players' individuality, subsequent engagement in the game and effort. Without an identity the experience is less authentic and the learning less intense. *Immersion* creates an intrinsic motivation (or even flow) to the player. Intuitive usage, clear goals and appropriate feedback create immersion whereas inappropriate challenges and a user-unfriendly interface hinder the engagement. *Interaction* with other player or the computer is essential for creating authenticity and fosters players to react in a similar as they would do in a real-world scenario. Interaction keeps the player engaged and active. *Increasing complexity* helps to ensure deep learning experiences. If the challenges are gradually increasing, the players reach at some point the pinnacle of flow. This state is also called *pleasurable frustration* and describes situation that is exciting but difficult. This state is the confluence of deep learning and good gaming [1]. If too complex challenges come too early, the player is just frustrated and does not reach deep learning levels. *Informed teaching* describes

the virtual observations of students (e.g. via log-ins, past decisions, process in the game). These virtual observations inform the educator about progress and learning and allows for tailored feedback and coaching. *Instructional* refers to students that are engaged in an SEG in such a way that learning is stealthy, i.e. that students do not realize that they are learning. If SEGs are designed well, they influence learning by connection a link between virtual game reality and real life and thereby influences long-term memory, and encourage critical thinking. This is the ultimate goal for educators and arguable challenging to develop.

Taken together, for developing our SEG, several levels have to be taken into account: the conceptual – technical level, the students learning, and educator's role in providing the learning. Fig 4 integrates the elements into one framework.

2 TEACHING ENTREPRENEURSHIP THROUGH A SERIOUS GAME

2.1 SEGs and Entrepreneurship Skills

Today's offer of SEGs primarily focuses on providing topic-related skills in either engineering or Entrepreneurship (e.g., Marketplace Venture Strategy, SimVenture, Virtual Trader, Intopia, Beer Game, Zapitalism, Virtual U, Industry Giant II, Virtual U, Innov8, EagleRacing, The Enterprise Game, The Finance Game, MetaVals). To date, none of the games combines engineering education with an innovation-related career as entrepreneur, scientist or innovation facilitator. Moreover, although there is a strong need for long-term behavioural training, simulations today focus on skills only. Research has shown, however, that a number of nascent entrepreneurs drop their venturing idea because they lack self-confidence, persistence, and the ability to shield their intention against drawbacks and obstacles along pursuing their goals. Likewise, in engineering education, grades are usually below those in social sciences and other subjects. This does not only prevent students with a low self-confidence from starting an engineering education, it also inheres uncertainty in the belief of successfully finishing the chosen study path. Particularly women lack confidence in their skills when the environment is uncertain and provides a risk for failure.

With an educational tool that trains and reinforces behavioural components, we aim at overcoming the lack of confidence, persistence, and tolerance for ambiguity related to engineering skills and STEM based career paths in innovation. As every entrepreneur shows specific traits such as persistency, self-efficacy, and a low fear of failure, we expect boys and girls alike to benefit from an integrated behaviour-related training within our simulation.

2.2 Status quo: Entrepreneurship SEGs and Learning Outcomes

SEGs in entrepreneurship have not been reviewed comprehensively with regard to technical and educational aspects. However, [4] have reviewed the most commonly played SEGs (i.e., Hot Shot Business, SimVenture, and Any Business) with regard to Blooms revised taxonomy [3]. They conclude that with regards to the learning goals remembering, applying, and analyzing, existing SEGs are helpful. Through images,

animations and compelling situations, and the repetitive nature of many games, remembering is supported. The learning-by-doing approach supports the application and the variety of analytics and documentation tool provide real-time feedback to the players, and hence, help assessing the students' performances. Hence, these positive elements should be kept.

With regard to understanding, the available games are not very efficient as they lack supervision and in-depth information. With regard to the highest levels of learning – evaluating and creating – [4] conclude that current games lack an understanding of the effects of the player choices and suggest supervision by a teacher to improve the player's assessment and improvement through appropriate indications and suggestions. Given the scripted nature of SEGs, creating is limited. Technical advancements such as machine-learning-based classifiers might overcome this problem. These elements allow for improvement.

2.3 Applying Educational Game Design Elements to Entrepreneurship

Taking together, we aim at keeping the benefits of existing games and overcoming their limitations with a game that 1) provides an immersing “real-world” experience by providing realistic, compelling and impactful cases students can choose from based on their engineering specialization. The game should 2) allow for reflective observation by a variety of graphics and data and reflection tasks, and 3) active experimentation. The experimentation might lead to 4) drawbacks in the game to create challenges on an increasing level and but allows for failure in a safe gaming environment that should prevent 5) frustration. The games will be structured in 12 sessions – with feedback after each session to provide 6) interaction and informed teaching. To provide 7) abstract conceptualizations (e.g. theoretical foundations), the game will be played in parallel to classroom teaching. To allow for different levels of experience in students, we will also provide 8) tutorials within the game that players can consult before making decision. To reach highest levels of learning, the players won't be assessed on their performance but on their 9) reflections on critical decision with regard to course content and personal experience while playing the game.

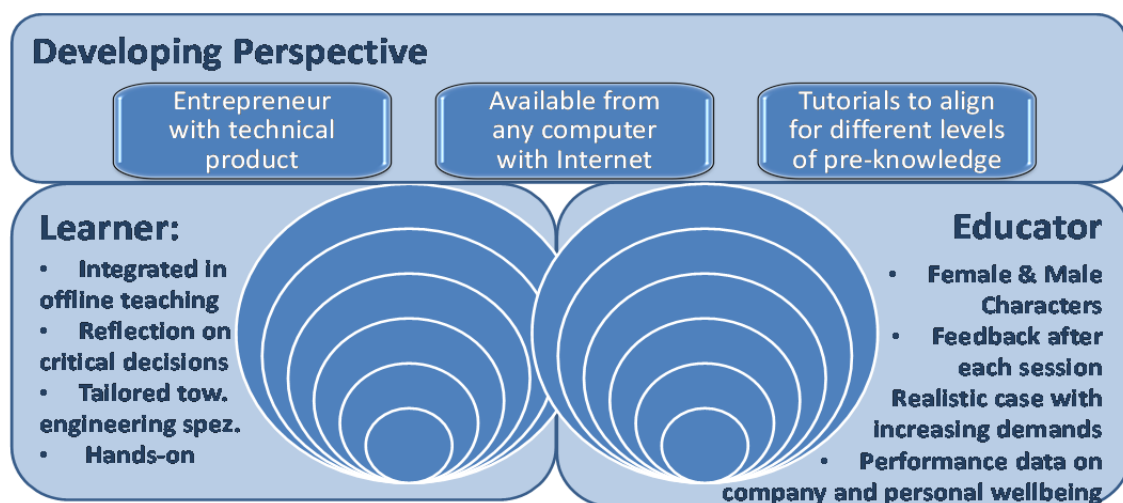


Fig. 4 An Integrated Framework for Designing SEGs

3 CONTRIBUTION

3.1 Player/Student

Our game will provide a hands-on start-up experience that embeds the learning in a playful environment. It will jointly increase specific engineering and entrepreneurship knowledge, but also impact the students' intrinsic motivation. The game will provide a close link of students' newly acquired skills to a possible career-path and thereby show the usefulness of their education for their future occupation. It will provide additional training of personality and behavioural components (such as persistence, reduced fear of failure) that will increase students' self-efficacy and thereby help to reduce dropout rates in general. After playing the game, students will be encouraged and better prepared to create successful start-ups within their engineering domain.

3.2 Educator

From an educator's perspective, teaching bigger groups of students prevents the close monitoring of each and every student. Traditional ways of teaching have to be generic enough to address a broader group of students. The amount of time and costs needed to provide very specific support and training prevents a teaching style that takes into account individual learning styles and preferences. Our SEG will provide a cost- and time-effective way of improving each student's skills and behaviour and provide additional specific training where needed. The flexibility of the tool makes it is useful for a variety of target groups starting from young pupils, high-school students, early-stage students and students that are close to their graduation.

3.3 Researcher

As for researchers, the analytical power—both predictive and prescriptive—may serve as a basis for better understanding how students learn based on their behavioural traits. Moreover, researchers will get some valuable insights of the process of nascent entrepreneurship. There is increasing recognition amongst researchers of the need to study the process of entrepreneurship rather than view it as a single entrepreneurial act. To date we have a limited understanding why some individuals who embark on an entrepreneurial journey persist and succeed to build a sustainable venture while others show a lack of progress or drop out altogether. The information we will get from the quasi-longitudinal simulation dataset will provide some new insights in the process.

4 CONCLUSION

Developing a game that supports detailed in-depths practical aspects of a "learning-by-doing"-approach with a broad and more generalizable theoretical underpinning is challenging as it implies finding a balance between abstraction and application, reflection and fun. We hope that the combination of having a game complementary to traditional classroom teaching allows for reaching such balance. The results of the pilot testing will show whether we have reached our goals of creating an innovative learning tool that simultaneously provides deep learning and the inspiration and encouragement of becoming an entrepreneur within a technical domain.

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Quality assurance at Faculty level: finding the balance between HEI-accreditation and transnational programme-accreditation

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Keywords: Quality assurance, Accreditation, Curriculum development, Instruments

INTRODUCTION

The Faculty of Engineering Science at XXX has a longstanding tradition in engineering education. A wide variety of different engineering programmes are offered both at the Bachelor's level (2), at the Master's level (23) and at the Advanced Master's level (6). Over 3,000 students are trained in line with an academic tradition in which education is strongly based on research. The quality of the education is a top priority of the Faculty.

The Faculty strongly wishes to aim for quality assurance at an international level through a transnational accreditation by an international agency. However, because the Faculty is embedded in a major university, which houses about 60 000 students across 16 faculties, the requirements of the national institutional review of XXX (HEI-level) also have to be met.

The Faculty developed a quality assurance system where the standards of transnational accreditation as well as the national Higher Education Institutional review were fulfilled. Several challenges were encountered during this development: the 4-year cycle of the national HEI-accreditation had to be integrated in the six-year cycle of the transnational agency; the need for customized quality assurance of the different programmes of the faculty had to be

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acknowledged. Two main cornerstones for faculty quality assurance were defined: a strong involvement of all stakeholders and well-considered curriculum development.

This paper will describe the resulting quality assurance system, the instruments integrated and choices made.

1. HEI-ACCREDITATION VS TRANSNATIONAL PROGRAMME ACCREDITATION?

HEI-accreditation

In June 2015, the Flemish Parliament approved a revision to the system of quality assurance and accreditation in higher education, with an evolution towards full institutional accreditation in 2020 and a suspension of the previous programme accreditation system. The institutional review is a periodic assessment of the quality of the educational policy pursued by an institution. The Accreditation Organisation of the Netherlands and Flanders (NVAO) commissions an external panel to conduct the review.

As described in the Framework for Institutional reviews [1], this review enables the institution to demonstrate the vision from which it operates, the policy it pursues, the achievements resulting from that policy, the measures for improvement it has taken, and new policy it has developed. Each institution chooses a structure and quality culture that suits its vision. As a component of an organisational culture, the quality culture is focused on continuous quality improvement. It is reflected in an institution-wide quality assurance system and thus constitutes the foundation of the quality of an institution's educational policy as well as the actual education provided.

Also XXX installed its own institution-wide quality assurance system, called COBRA. COBRA stands for Cooperation, Reflection and Action, with attention for Checks and Balances. COBRA starts from having confidence in the discipline-specific quality culture of every education programme and faculty. The programme committee is the pivot in this continuous process of quality development. A quality culture such as COBRA attributes ownership to the programme's primary actors: students, teachers and staff. Systematically, these actors engage in an open dialogue with external stakeholders: alumni, professionals in the field and (inter)national experts in the discipline. COBRA engages in a substantive dialogue about education and the necessary preconditions to support good education, and this at three levels of the university: education programme, faculty and institution. Throughout three cycles, COBRA ensures preconditions are adjusted at the appropriate level and feedback is given to adjacent levels. Transparency and public availability of information about the quality of education are necessary conditions for a sound quality culture. Quality assurance reports are published on the public website 'quality report'.[2]

At the end of 2016, a review panel visited XXX. During a first site visit, they formed an image on the vision for education and the way in which XXX shapes its educational policy and quality assurance. During a second site visit, the review panel focused on how theory is put into practice. They visited faculties, spoke to teaching staff and students, and attended several Programme Committee meetings. KU Leuven received a favourable report.

Transnational programme-accreditation

As described by Remaud et al. in 2017 [3], already in 2010 Flemish universities acknowledged the opportunities and benefits of a transnational accreditation and sought contact with CTI. CTI or "Commission des titres d'ingénieur" (CTI) is a French accreditation organization and is

equally composed of representatives of employers and professional engineers and academia [4]. CTI is also a member of ENQA (European Network for Quality Assurance) and EQAR (European Quality Assurance Register). Furthermore CTI is authorised by ENAEE (European Network for Accreditation of the Engineering Education) to award the EUR-ACE label.

Under the aegis of the Flemish Interuniversity Council (VLIR), CTI and the Flemish faculties set a procedure, based on an agreed Terms of Reference (TOR). As described above, even before the start of the visitation and accreditation procedure, a change occurred in the legal context. However, even though they were no longer legally required to, all Flemish engineering faculties decided to go on and to ask CTI to execute the visitation and accreditation of their programmes. SER's were finalized in December 2014, CTI visited the Faculty in February 2015. For the Faculty, this visitation process was a strong momentum. The preparation and the writing of the SER gave the Faculty and its programmes a good mirror.

1.1 Integration of both systems

In the aftermath of the first visitation and accreditation cycle and the simultaneous changes in legal context, the Faculty was forced to reflect on the Faculty quality assurance system as such. Should the Faculty limit its quality assurance system to the obligatory HEI-accreditation and its accompanying COBRA-system? Or is the transnational visitation and accreditation and –more specifically- the preparation process of the former, valuable and worthwhile enough so that both systems should be combined? And could these two systems be combined in an efficient way without creating excessive administrative workload?

Being part of XXX, a faculty needs to be in line with the institutional quality assurance system COBRA, implemented to develop a strong quality assurance culture university-wide and to meet the requirements of the institutional review system. As COBRA engages on a substantive dialogue on education at different levels, the vision and concerns of the faculty are also taken into account at all those levels.

The fact that the EUR-ACE label can be acquired through CTI is obviously a strong incentive for continuing with CTI. Nonetheless, the Faculty also acknowledges other aspects of added value resulting from the CTI-accreditation cycle. One main benefit of the whole process lies in the strong groundwork that was done, with a lot of attention for curriculum development. The process of CTI, including the table of contents of the SER, guided this reflection. The procedure involved all the Faculty staff for the self-assessment, resulting in an empowered quality assurance culture. Additionally, since this is an accreditation by engineers, receiving feedback by these international peers is believed to be very valuable, well-tailored and useful. So the Faculty decided to develop a quality assurance system where the standards of transnational accreditation as well as the national Higher Education Institutional review were fulfilled. The challenges that accompany this decision and the subsequent integration and implementation of both systems, will be discussed in the next paragraphs.

2. INTEGRATED FACULTY QUALITY ASSURANCE SYSTEM

The Faculty quality assurance system had to be designed in a way that prerequisites and standards of both review systems can be fulfilled in a meaningful, yet feasible way.

A first and rather practical challenge was the integration of the 4-year cycle of the national HEI-accreditation in the six-year cycle of the transnational agency. The different deadlines and deliverables had to be aligned. A second important challenge involved the sheer size of the Faculty and the significant differences in characteristics between the engineering

programmes. Workflow and exercises had to be developed in a way that they could be customized and adapted to each specific programme without creating massive workload for the Faculty staff. Therefore many already established actions and habits were revised, upgraded and structured in an integrated system. Finally it was the Faculty's explicit policy to make quality assurance more accessible to teaching staff and to all other stakeholders and to encourage them to participate in ongoing didactical debates. To realize the Faculty's vision on an integrated quality assurance system, quality assurance at the Faculty is embedded in the actions of the educational committees (ECs) and is based on two important pillars: large involvement of all the stakeholders on the one hand and well thought-out developments of the curriculum on the other.

2.1. Cornerstones

Achieving a strong involvement of all stakeholders

Over the last decade, HEI's are slowly moving from a collegial to corporatist mode, where the roles of various stakeholders are being fundamentally redefined [5]. In order to be successful when involving stakeholders in quality assurance, Assif and Raouf [6] remarked that because of the complex nature of the new customer-supplier relationship, HEIs need to include stakeholder perspectives when designing the programme instead of "making arrow attempts to identify and address customer requirements only". Therefore, as earlier described by Wyns et al. [7], it is strongly recommended to involve stakeholders at every level of the programmes' design and updates, rather than consulting them at the final stages of the quality assurance process. Both intense cooperation and keeping a careful eye on the HEI's own interests seems to be necessary.

In the preparation of a first visitation and accreditation cycle by CTI, the Faculty, stated that all quality measures need to be implemented systematically. Existing means of consulting stakeholders were inventoried and large differences between the Faculty's departments were noticed. Several scenarios were therefore devised, depending on protocols the departments already had in place, and supervised actions which were taken to improve stakeholder participation. At first, four main groups of important stakeholders were identified: students, teachers, representatives of industry and alumni. More recently, the Faculty also recognised the importance of involving different groups of employees such as teaching assistants, student counsellors, ombudspersons and administrative support staff as well.

Pursuing a well-considered curriculum development

Curriculum development forms a vital aspect of a quality assurance process, as it is important for each programme to be sharply profiled and to form a clear identity. It allows for overlap, to be spotted both in form and in content.

A systematic approach in developing, maintaining and defining all the programmes enables the entire Faculty to discuss and exchange experiences at the same level. This causes quality assurance to be more accessible to teachers, teaching assistants and other stakeholders. In this way participation in ongoing educational debates is encouraged. Additionally a systematic approach to profiling programmes, formulating programme outcomes, clarifying learning objectives and subsequently executing curriculum mappings, entails the involvement of as many teachers as possible, thus creating a common plane on programme profile and programme programme outcomes. [8] Also the sheer size of the engineering faculty and the different characteristics of the different programmes, made a thoroughly systematic approach to curriculum development necessary.

A systematic approach needs a flexible and transparent framework. Since the Faculty had a positive experience with the AQCA framework in the context of benchmarking, it was a logical next step to use this framework for curriculum development.

The ACQA framework distinguishes seven areas of competence that characterize an engineer. It was inspired by a competence-based approach and was developed specifically for technological programmes and is based on the Dublin descriptors². The use of this framework makes it feasible for all stakeholders to discuss programme outcomes, programmes and other educational matters in a recognisable and transparent way and using the same terminology. [9] Based on ACQA, a three-step approach to curriculum development was therefore designed:

1. Formulating programme outcomes
2. Performing a curriculum mapping and developing competence profiles
3. Composing or updating ECTS-course descriptions

This three-step approach serves several purposes and the implementation thereof will be discussed further in this paper.

2.2. Implementation and instruments

At the Faculty, quality assurance is embedded in so called 'Educational Committees' (ECs): each EC is responsible for the coordination of one (cluster of) programme(s) and typically meets four to six times a year. Besides the organization, development and implementation of a coherent curriculum, the key mission of an EC is the quality assurance of its programme(s). All ECs are chaired by a programme director, and all programme directors take part in the Faculty Educational Committee (FEC), which is chaired by the vice-dean of Education. At Faculty level, the FEC is responsible for quality assurance and all associated actions, and can therefore be considered as an important part of the Faculty management. To facilitate and support the FEC and EC working of the Faculty, a team of staff members and project assistants specialized in educational issues, is employed. This team is called the Faculty Educational Development Unit (FEDU).

As discussed earlier, the substantive dialogue on the quality of education and the programmes is a basic requirement for creating a culture of quality. That is why the Faculty and its programmes commits itself to engage in conversation with all stakeholders involved at regular intervals (*involvement of all stakeholders*).

- Students are involved every two years through student conversations. During these conversations, students independently engage in conversation about the strengths and points of improvement of their programme. The student union is in charge of the organization of the conversations and is supported in this task by the FEDU. The results and information gained from the conversations are supplemented with the results from two structural, at HEI-level organised online questionnaires.
- At least once every three years, though preferably yearly, every EC organizes a conclave or a "teachersday". During this day there is room to reflect on the curriculum, content, profiling, evaluation policy, etc. The inclusion of the professors during this process of reflection enhances their sense of ownership and involvement, which is crucial when creating a culture of quality. The organisation and approach of these activities is in the hands of the ECs. During the preparation as well as during the activities, the FEDU can provide substantial support if desired.
- Every EC maintains relations with industry through Industrial Advisory Boards (IAR). At those consultations, the EC asks feedback on its programme(s) and its alumni. These

² See <http://www.jointquality.nl/> for the Dublin descriptors

conversations typically concern necessary programme content and required knowledge and skills. Furthermore, a work field event is regularly organised by the Faculty. The approach and working of the IAR is also in the hands of the EC, but the organisation of the work field event is entirely in the hands of the Faculty.

- (Recently graduated) Alumni are evaluated every year by the central services of the University. The evaluation contains questions regarding their education as well as employment. The Faculty set up an alumni evaluation with a wider reach during the last CTI-cycle (spring 2015). The alumni were split up into three groups: recently graduated, graduated less than five years ago, graduated more than five years ago. The evaluation contained generic questions at Faculty level and more specific questions at the level of the EC. The evaluation had been initiated by the FEDU in close consultation with the ECs. The response rate was relatively low. The Faculty is reflecting on a new method that would make it possible to keep in touch with the alumni more efficiently. Additionally, the Faculty is analysing if there are alternatives for this large-scale evaluation.
- Different groups of employees, which are involved with the programmes, are invited annually by the Faculty:
 - Almost every teaching assistant (TAs), mainly PhD students, take on curricular assignments ranging from organizing exercise sessions, coaching teamwork, guiding master's theses, etc.
 - Student counsellors and ombudspersons also are invited every semester for a meeting.
 - Administrative support staff of all the different programmes also meet twice a year with the vice-dean, the FEDU and the Faculty Administrators, to inform them about Faculty policy but also to make sure they feel involved in the Faculty quality assurance system.

Another cornerstone of the Faculty's quality assurance system is the investment in a balanced and well-considered curriculum development. Since the ECs are responsible for the curriculum of its programme(s), it is obvious that activities concerning curriculum development are conducted in the context of the EC. However, to lessen the workload of programme directors, the coordination, logistics and documentation is done by the FEDU.

As discussed earlier, the Faculty chose a three step approach based on the ACQA-framework. Firstly, the programme outcomes for each programme are formulated according to the seven areas of competence, described in AQCA, which results in similar structured programme outcomes for all programmes without losing each programme's unique character. Based on the formulated programme outcomes, curriculum mappings are conducted. Such curriculum mappings visualize the link between the programme outcomes, the content and evaluation of individual courses. This entailed that each teacher responsible for a course, was provided with the programme outcomes that were formulated during the first phase. Through a custom made online tool teachers indicated whether the outlined competences were practiced in the course and whether they were assessed as well. [10]

In a next step, the teachers have determined the distribution of the study load over the seven areas of competences. Based on this data ACQA-competence profiles are drawn up for all programmes or parts of programmes (e.g. only a certain option of a programme). These profiles allow the ECs and FEC to describe its different curricula in a uniform way. Finally the ECTS-course descriptions of all courses are composed accordingly. Important to acknowledge is the fact that this final step, together with the curriculum mappings, includes all teachers, not only the ones involved in the EC.

By checking a course's ECTS-course description and course-specific programme outcomes against the programme outcomes as described for the entire curriculum, a programme can check whether the intended curriculum matches the realised curriculum. Potential overlaps can be spotted and possibly superfluous courses can be eliminated from the curriculum.

Evaluation, learning method and programme outcomes can be matched a lot more accurately when working with completed curriculum mappings and streamlined programme outcomes. All these exercises are initiated every six years, but in case of major programme changes (some of) these exercises might be organized sooner.

The results of all these exercises are concluded in the programmes' blueprint, a document in which the university's as well as the Faculty's vision on education is translated to the programmes vision and profile. This document is updated every three years and revised every six years, in a cooperation between EC and FEC, supported and guided by the FEDU.

Besides the structural exercises concerning curriculum development, the results of other, more ad hoc exercises as feasibility analyses, ad hoc (student)hearings, etc... are also taken into account every step of the process.

In conclusion, the faculty believes that through this three-step approach higher levels of transparency, uniformity and efficiency are reached in the quality assurance process.

As already stated, the quality assurance system of the Faculty is based on two important pillars: large involvement of all the primary actors on the one hand and well thought-out developments of the curriculum on the other. All reports and results of the questionnaires and exercises conducted in this perspective are discussed at the EC. In this way, all these results serve as direct input for the programme specific SER and programme action plan. Generic aspects, general points of attention or questions regarding policy are transferred to the FEC, where they deliver input for the faculty action plan and SER on their part.

The programme specific SER is drawn up every six years, or every three years in case of an unfavourable visitation, while the programme action plan functions as a permanent instrument. The state of affairs of the action points that are put forward in the plan are discussed at least once a year by the EC that is responsible. In addition, the programme action plan as a whole is brought up to date and adjusted yearly on the basis of results of questionnaires and exercises. The Faculty action plan is updated and completed analogously at the yearly FEC conclave.

3. DISCUSSION AND CONCLUSIONS

Both accreditation systems discussed, strive for the installation of a strong, broadly embedded quality culture. The programme accreditation performed by CTI comprises an important institutional component, since all the degrees of the Faculty were concerned in a single round. This approach fits well in the COBRA system, built around three levels, adding the university wide level to the faculty and programme level focused on in the CTI approach.

The HEI quality assurance system, COBRA, is based on regular reflection meetings with stakeholders, with a strong emphasis on student participation. CTI adds a transnational component to it, with visitation panels composed of international educational and domain experts. Next to stakeholder involvement, CTI focuses strongly on curriculum development. The latter is of importance since this Faculty of Engineering Science is embedded in an HEI built on the "von Humboldt"-model: research-driven with strong emphasis on scientific excellence and academic freedom of their academic staff in research and lectures [12]. In context of quality assurance this might become a thread for establishing a culture of quality assurance, which is built on dialogue and objectives at programme level and not at the level of the individual course. That is why the Faculty felt that a strong involvement of stakeholders was not sufficient to truly create a culture of quality assurance and acknowledged the importance of well-considered curriculum development as a means for quality development than mere administration and regulation.

The efforts made during the first CTI-cycle clearly initiated an increasing culture of quality assurance and created a stronger involvement of the stakeholders at programme level. This awareness was further sparked by the implementation of the HEI-system COBRA. The Faculty has high hopes that these developments will not be temporary but aspires to establish

them further and more structural by implementing the above described integrated quality assurance system were benefits of both accreditation systems are combined.

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The use of constructive alignment in the design of laboratory activities

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Conference Key Areas: Methods; Curriculum Development; Engineering Skills

Keywords: Laboratory; Experiment; Design; Constructive Alignment

INTRODUCTION

Laboratory experimentation has long been considered an important component of engineering education, allowing students to explore and understand physical phenomena in a controlled environment. Despite this claimed importance there has been relatively limited research into approaches for effective engineering laboratory design, or even the intended learning objectives of laboratory activities (a key exception being an ABET colloquium which resulted in a taxonomy of thirteen laboratory learning objectives [1]). While it is generally accepted that for any teaching and learning activity thoughtful design is required to elicit demonstrated achievement against the associated learning outcomes, such thoughtful approaches are not always evident in the design of laboratory experiments where it may be assumed that by simply viewing the physical phenomena students understanding of the associated theory is automatically improved. The application of thoughtful laboratory design processes is required if the significant potential educational outcomes are to be achieved through this important educational modality.

In this paper we explore the relevance and use of constructive alignment as a guiding framework for laboratory learning activity design. Constructive alignment promotes an approach that combines constructionism in learning and alignment in teaching and

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assessment. Constructive alignment “makes the students do the real work” with the instructor simply acting as a coach or facilitator to assist students to engage with the learning opportunity and environment that supports the learning activities [2, p27]. It commences from an articulation of the intended learning outcomes, and then uses these to drive the design of assessment methods and learning activities. Given that laboratory experiments are inherently experiential, there is a risk that their design focuses on the learning activities to the exclusion of consideration of the educational drivers. We analyse an exemplar undergraduate engineering laboratory activity guide and consider the extent to which it focuses on the equipment and activity versus the extent to which it makes explicit both the learning outcomes and the assessment criteria. We then extend this by proposing a framework, based on constructive alignment, for the design of laboratory experiments that more directly address designed learning outcomes.

1 LABORATORY EXPERIMENT DESIGN

1.1 Educational Laboratories

Laboratory-based experimentation has long been considered an important element of education in the physical sciences and engineering. Allowing students to explore physical phenomena in a controlled environment through various forms of carefully designed first-hand practical work, including experimentation, can potentially support effective learning and motivate students' engagement while fulfilling specific curriculum requirements [3], [4]. This recognition has become so embedded, that the inclusion of experimental laboratories into the curricula is essentially mandated in many accreditation frameworks (e.g. from Engineers Australia accreditation criteria: “3.2.4.5. *Practical and ‘Hands-On’ Experience: There must be substantial hands-on practical experience manifested through specifically designed laboratory activities, investigatory assignments and project work....*” [5]).

Despite this recognition of the value of laboratory experimentation, and the close to universal utilisation of laboratory experimentation in engineering degree programs, there is surprisingly little research that focuses specifically on the design of laboratory experiments and how this design might differ from more general educational design. As long ago as 1982, aspects that were being neglected in research into laboratory education had been identified [6], with most of the elements identified at that time still to be adequately considered. Of particular note is the paucity of research into the types of learning outcomes that might be suitable for laboratory experiments. One key exception is the work that emerged out of a 2002 ABET Colloquy on laboratory education. This resulted in the articulation of a taxonomy of thirteen learning objectives [1] that might be relevant to laboratory activities.

The ABET taxonomy has been subsequently used in exploring comparisons of the level of achievement of learning in laboratories (see, for example, [7], [8]) but not explicitly in the design of laboratories. Indeed, whilst there is a significant volume of work in the literature outlining the technical design of, or student responses to, specific laboratory experiments there is very limited work that has been reported on the pedagogic design of experiments. Where such work has occurred, the focus has generally been on specific characteristics rather than broader design approaches. For example Terkowsky and Heartel [9] explored the types of objectives and activities that might be suited to developing creativity.

By developing a clearer understanding of laboratory experiment design approaches we can potentially improve the quality of the student learning outcomes. One possible approach that is worth consideration is the use of constructive alignment.

1.2 Constructive Alignment

The concepts underlying constructive alignment were originally developed by Tyler in 1949 [10], but the main formulation was carried out much later by Biggs [11]. Essentially constructive alignment (CA) promotes an approach that commences from an articulation of the intended learning outcomes, and then uses these in driving the design of both assessment approaches and learning activities so that all three components – objectives, assessment and activities – are appropriately aligned. CA could potentially provide a mechanism for ensuring that laboratory experiment design does not focus on the nature of the activity to the exclusion of broader objectives and assessment.

CA promotes an approach that combines constructionism in learning and alignment in teaching and assessment. It “makes students do the real work” with the instructor acting as a coach or facilitator to assist students to engage with the learning opportunity and environment that supports the learning activities [2, p27]. Biggs comments that surface approaches to learning arise from a focus on getting a task out of the way as easily as possible while appearing to achieve the learning outcomes. He suggests that the nonalignment of teaching and assessment methods promote surface approaches. Hence when students behave and respond to our learning activities with a surface approach we need to improve the alignment of our learning outcomes, assessment methods and teaching and learning activities. Conversely, deep approaches to learning are associated with positive feelings, a belief that what is being learnt is important, valuable and meaningful [2]. Students who learn deeply often feel excited, enjoyment and exhilarated by the challenges associated with their learning.

Hence in the context of laboratories it is important to consider how students behave and respond to our laboratory learning outcomes, activity design and assessment. Are students able to simply join the dots and report what they have seen or are they required to critically evaluate and interpret the theory to explain their observations. Are they excited about what they discover, curious to understand or simply focused on completing the assessment task at the desired level of achievement by taking the path of least effort and resistance?

Assessment defines what is important for students to learn. Biggs stresses that activities are verbs and should be used to enable students to learn both how to, and what is required to, demonstrate achievement at different levels (grades) described by the learning outcomes. Hence grade descriptors are an important part of constructive alignment. Even with the best aligned educational design we cannot assume that students will automatically know how to engage with the learning outcomes activities and assessments. Hence scaffolding should be used to explain to students [12]:

- i. why the assessment activity was designed this way;
- ii. what learning opportunities the activity provides students;
- iii. how students can evaluate their learning from the activity; and
- iv. how it is going to impact on their reality (enable them to see the world differently).

CA has been explored relatively extensively in the context of engineering education (see [13] for a good example) but has seen very little use in supporting laboratory experiment design. The exceptions to this are a small number of specific cases where CA has been used to *evaluate* the design of laboratory experiments. For example Smith [14] used CA to explore issues of misalignment in the design of laboratory experiences, and Bhathal, Sharma, and Mendez [15] have also used CA to carry out an educational analysis of a specific laboratory. These previous studies do suggest that CA may be a useful analysis and design tool. In

particular, by exploring the concepts that underpin CA we can identify a range of critical elements that can either be the basis of an evaluation for an existing laboratory experience (Table 1) or can guide the design of a new laboratory experience (Table 5).

Table 1. Laboratory Design Evaluation

Focus	Evaluation questions
1. Learning Outcomes	
<i>1a. Outcomes Description</i>	Are the learning outcomes clearly described?
<i>1b. Outcomes Levels</i>	Have levels of achievement of the learning outcomes been identified?
2. Assessment Tasks	
<i>2a. Assessment Description</i>	Are the assessment tasks clearly described?
<i>2c. Assessment Levels</i>	Do the tasks allow for demonstration of the different levels of achievement?
<i>2b. Assessment-LO Alignment</i>	Are the assessment tasks appropriately aligned to the stated learning outcomes?
3. Learning Activities	
<i>3a. Activity Description</i>	Have the learning activities been clearly described?
<i>3b. Activity-LO alignment</i>	Are the learning activities explicitly connected to the learning objectives?
<i>3b. Activity-Assess alignment</i>	Are the learning activities explicitly connected to the assessment tasks?
<i>3c. Activity levels</i>	Do the learning activities provide opportunities for demonstrating levels of achievement against the assessment tasks?

2 CASE STUDY ANALYSIS: LOGIC ANALYZER LABORATORY

To illustrate the potential for Constructive Alignment to assist in the evaluation and design of laboratory experiences, we apply the approach to a case study based on a microprocessor laboratory activity described in <https://goo.gl/gjExV3>. The experiment aims to introduce students to the use of a logic analyser for debugging microprocessor systems. Students are first required to set up an experiment board with a Z80 microprocessor and connect it to a logic analyser. They then use the logic analyser to observe the operation of a known program and analyse the data. Students are finally given an unknown program which they are required to decode using the logic analyser in order to decipher what the program is doing. The experiment instructions consist of an introduction describing the purpose of the experiment, a detailed background section which covers required knowledge, and then step by step instructions guiding students through the set up and execution of the experiment. The final instructions are for the students to complete a report describing their results and answering the questions that are posed. An analysis of the information presented in the laboratory instructions according to the criteria in Table 1 is presented in Table 2.

Table 2. Logic Analyzer experiment - evaluation

Focus / Evaluation Questions	Evaluation observations
1. Learning Outcomes	
<i>1a. Outcomes Description</i> Are the learning outcomes clearly described?	Yes, partially. The experiment instructions include a description of what students should be able to do by the end of the lab:

	<p><i>"This lab will be your introduction to the use of a logic analyzer to study the operation of complex digital circuitry in real time at speeds up to 500 MHz. By the end of this lab, you will be able to:</i></p> <ul style="list-style-type: none"> <i>• Connect a logic analyzer to a microprocessor system</i> <i>• Set-up the acquisition system of the logic analyzer</i> <i>• Trigger the logic analyzer on a specific state event</i> <i>• Disassemble the bus cycle information to decode the instruction and data flow of several simple Z80 programs..</i> <i>• Use a logic analyzer to debug your project design"</i> <p>These are however presented in such a way that students would expect each point to have equal relevance which is not the intention of the teacher who is focussed on students learning to decode the instructions of the microprocessor.</p> <p>In addition, the description of the experiment clarifies that students are using the Z80 microprocessor as substitute for the 68008 microprocessor they will use in the rest of their labs. This is because the Z80 has no features such as prefetching - what is seen on the logic analyser is exactly what the processor is doing. Implicit in this is that students are expected to take what they learn in the experiment on the Z80, and understand how it may apply to the 68008 microprocessor. This learning outcome has not been clearly described.</p>
<p>1b. Outcomes Levels</p> <p>Have levels of achievement of the learning outcomes been identified?</p>	<p>No.</p> <p>The learning outcomes described do not allow for different levels of achievement, rather they are binary, students achieve them or not.</p>
2. Assessment Tasks	
<p>2a. Assessment Description</p> <p>Are the assessment tasks clearly described?</p>	<p>Yes, partially.</p> <p>The assessment is in the form of a report with a breakdown of what should be included in the document, however there is no weighting given to any of the components of the report.</p> <p><i>"The paper should have an introduction, a section on what your procedure and process, a section on what you observed, and any conclusions."</i></p> <p><i>"Your lab report should include:</i></p> <ol style="list-style-type: none"> <i>1. Answers to any questions posed in the report</i> <i>2. A screen capture of your timing diagram that you used to measure the bus cycle timing</i> <i>3. An analysis of the measured timing from your circuit versus the published specifications, being sure to cite your references</i> <i>4. A printout of your Excel spreadsheet after filtering</i> <i>5. You disassembled instruction listing</i> <i>6. A description of what the program does and your assembly language source file</i> <i>7. A bibliography of any resources you consulted, as well as citing any assistance you received from your classmates"</i>
<p>2c. Assessment Levels</p> <p>Do the tasks allow for demonstration of the different levels of achievement?</p>	<p>Yes, in terms of the quality of the written report students may demonstrate different levels of achievement.</p>
<p>2b. Assessment-LO Alignment</p> <p>Are the assessment tasks appropriately aligned to the stated learning outcomes?</p>	<p>Not clearly. In this case the assessment is described in the form of a report which does not clearly align with the outcomes of "connect a logic analyser" and "set up ... the logic analyser".</p>

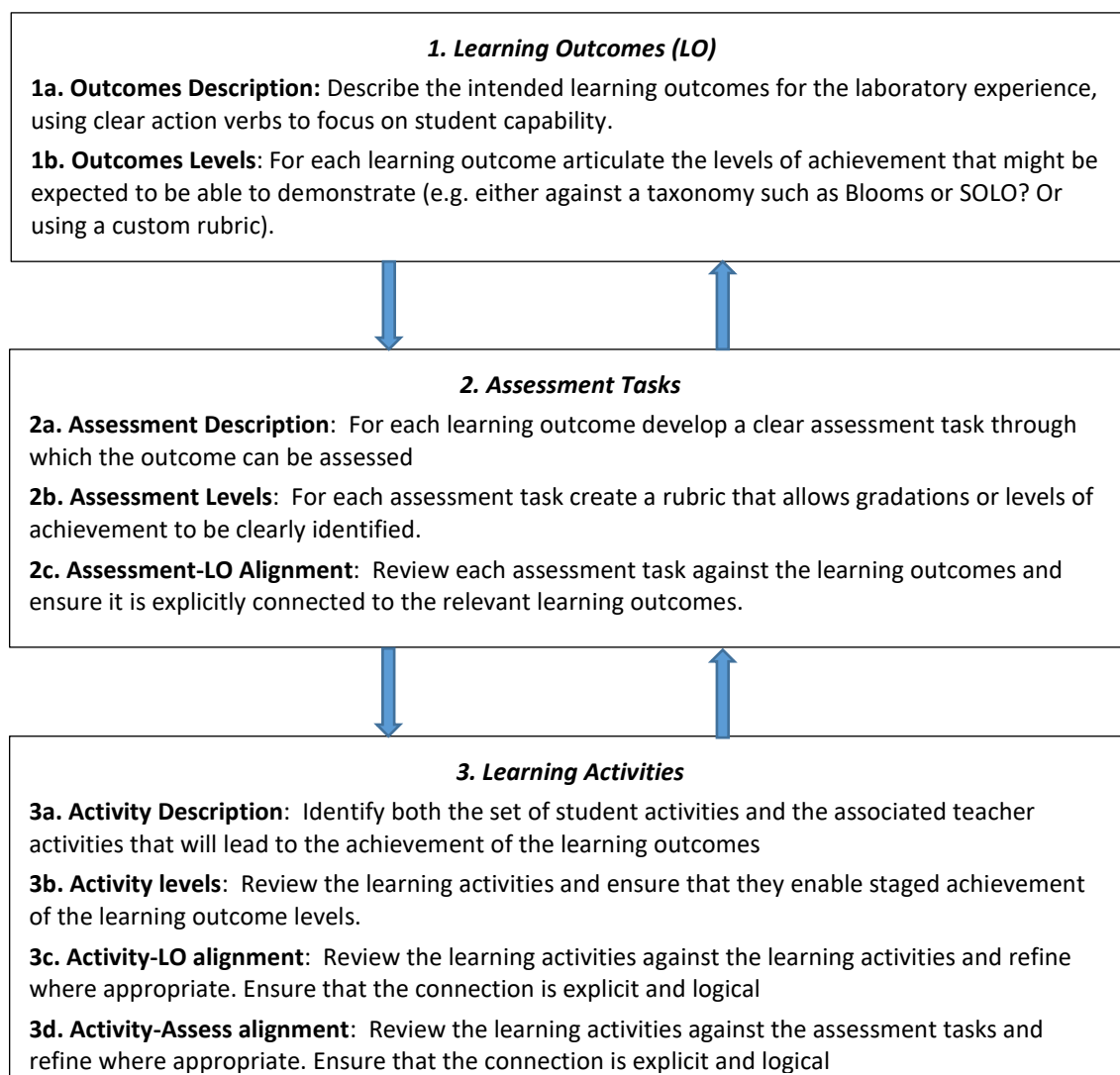
3. Learning Activities	
<p><i>3a. Activity Description</i></p> <p>Have the learning activities been clearly described?</p>	<p>Yes.</p> <p>This is described by a series of steps:</p> <ul style="list-style-type: none"> • <i>Steps 1-7: Procedure to set up the board and connect it to the logic analyser</i> • <i>Steps 8-11: Procedure to use the logic analyser to take and store a trace from the board</i> • <i>Step 12: A description of the program running on the microprocessor and how it relates to what is observed on the logic analyser</i> • <i>Steps 13 and 14: Procedure to use the logic analyser to collect trace and analyse it to decode an unknown program</i>
<p><i>3b. Activity-LO alignment</i></p> <p>Are the learning activities explicitly connected to the learning objectives?</p>	<p>Yes partially.</p> <p>For the articulated learning outcomes, many are explicitly connected to the learning activities and would be achieved through the successful completion of the steps, such as “Connect a logic analyzer to a microprocessor system”. The final learning outcome (using a logic analyser for debugging) is not covered in this experiment.</p> <p>The learning outcome not clearly described (that students are able to understand how this learning will apply to other microprocessors) has not been included in any of the learning activities.</p>
<p><i>3b. Activity-Assess alignment</i></p> <p>Are the learning activities explicitly connected to the assessment tasks?</p>	<p>Yes.</p> <p>The assessed report explicitly connects the learning activities to assessment as it is expected to contain information gathered through the learning activities.</p>
<p><i>3c. Activity levels</i></p> <p>Do the learning activities provide opportunities for demonstrating levels of achievement against the assessment tasks?</p>	<p>No.</p> <p>The learning activities do not allow for students to demonstrate different levels of achievement.</p>

The conclusion from this analysis is that whilst the experiment is an interesting activity which exposes students to debugging microprocessors, the quality of the outcomes are potentially compromised by a lack of clarity in the intended learning outcomes in terms of their importance and the fact that there is an important ‘implicit’ learning outcome not clearly expressed to students. Taken together with the corresponding lack of weighting information for the assessment and the fact that there is no assessment of whether students have understood to the level that they can transfer their knowledge to other microprocessors, it is possible that the learning outcomes from this laboratory are not in line with the teachers’ expectations.

3 DESIGN FRAMEWORK

The above example illustrate that CA can be used to gain insights into the design of existing laboratories, but we can also turn this around and reframe the evaluation questions into a set of design steps in order to guide the laboratory experience design process.

Space limitations in the paper prevent a detailed case study from being presented, but Figure 1 presents the key design stages and the sequencing of the design. This process adheres to that defined for Constructive Alignment: beginning by specifying the laboratory learning outcomes; then moving on to specifying how those learning outcomes will be assessed; and then finally determining the learning activities that will be carried out. At each stage the alignment is assessed and, where necessary, the process is iterated to ensure appropriate alignment is achieved.

Figure 1. Laboratory Design Stages

4 SUMMARY

Constructive Alignment has been widely shown to be a valuable approach to educational design, and yet there has been very limited exploration of the application of CA to the design of laboratory experiences. An analysis of existing student information on laboratory experiments shows that most student guides focus on describing the experimental activities to be carried out and often fail to provide clarity in the intended learning outcomes that are being targeted or connect these to assessment activities that allow students to assess their progress in achievement of those learning outcomes. We have argued that the application of CA to laboratory experiments will allow much more effective design. Future work in this area would focus on assessing the extent to which improved student learning outcomes can be achieved through the application of CA.

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A Whiteheadian Approach to Self Efficacy and Creative Confidence in Electrical Engineering

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Conference Key Areas: Innovative Teaching and Learning Methods, Curriculum
Development, Engineering Skills

Keywords: Self Efficacy

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1 INTRODUCTION

A technical university should educate engineers who are competent in their scientific discipline and confident in their own ability to fill important engineering roles [1]. One critical factor in gaining competency and confidence is that students have the opportunity to experience mastery during their education, as these mastery experiences will help them to develop self efficacy [2,3], as well as creative confidence [4].

Self-efficacy is defined by Bandura [1] as a personal judgement of "how well one can execute courses of action required to deal with prospective situations", and is affected by the following four factors:

1. Experiences of mastery
2. Vicarious experiences ("if they can do it, so can I")
3. Social persuasion
4. Psychological factors.

Of these four factors, *experience of mastery* is identified as the main one, and this is the one we have been focusing on in our study.

In a modern engineering education program, a multitude of subgoals and courses are involved. A successful education program depends on a sound structuring of objectives and learning activities. In the following we describe how A. N. Whitehead's ideas on learning can be applied to a five year integrated master program in Electronic System Design and how an application of these ideas can foster the mastery experiences needed for the development of self efficacy and design confidence. Methods and results are discussed based on three types of student survey.

2 WHITEHEAD'S LEARNING THEORY

A. N. Whitehead's *The Aims of Education* [5] contains 10 essays written in the period 1912–1928. In these essays he criticized the prevailing English education system for teaching *inert ideas*, i.e. "ideas that are merely received into the mind without being utilised, or tested, or thrown into fresh combinations" [5, p.1]. In order to replace the mere transmission of inert ideas with a meaningful education, he outlines a program in the essay *The Rhythm of Education* [5, Ch 2-3]. The idea is that all learning should take place in cycles of three stages:

1. **Romance:** characterized by interest, discovery, curiosity, enthusiasm and exploration.
2. **Precision:** The stage of systematic treatment, formalism, analysis, theory and tools.
3. **Generalization:** The stage of synthesis, application and carrying over of principles to new situations.

Whitehead stresses that, whereas *discipline* is the characteristic of the precision stage, *freedom* should dominate the two others. Thus, a sequence of learning cycles will give an alteration between freedom and discipline. Within each of the three stages, there will be sequences of cycles within cycles: "the development of mentality exhibits itself as a rhythm involving an interweaving of cycles, the whole process being dominated by a greater cycle of the same general character as its minor eddies" [5, p. 27]. It is this rhythm that provides a

balance between discipline and freedom in students' learning experiences.

The three stages each provide three essential stimuli: *the evocation of interest*, *the acquirement of technique*, and *the excitement of success* [5, p. 38]. Students often experience the stages when discipline is required as the "hard" part of education. In order for the students to be motivated for these parts, they should not lose the inspiration from the romance stage. An anticipation of success in the generalization stage is also a source of motivation for bringing them through the sometime "dull" precision stages.

An emergent question then is whether Whitehead's ideas remain relevant for modern engineering education and how they might be applied. According to Whitehead's scheme, an education program should start with student activities having elements of curiosity, exploration and discovery giving experiences motivating for the next step, which is precision. This is very much in line with contemporary ideas about integrating project- and problem-based learning into first year engineering curricula [6]. Following Whitehead, precision, with its emphasis on discipline, analysis and tools, should not be introduced before the students have some knowledge of and experience with the concepts and phenomena the theory focus on and tools handle. Finally, students can gain from the tools learned in the precision part in order to perform on a higher level during the generalization stage.

Traditionally, engineering programs finalize the education with a capstone project where the candidates show that they have attained the competence for independently fulfilling a task within their discipline. Before that project, a large body of courses secure that necessary technical and methodical knowledge is acquired. Such courses fall well into Whitehead's precision category, whereas the capstone project is an example of generalization. What is often missing is a sufficient amount of romance. For some subjects in the engineering curriculum, such as mathematics, the romance stage should already be passed during high school, and the students are ripe for further precision. In technological topics, this is not necessarily the case for most students. Therefore, we argue that an engineering program should set aside at least one year where romance is the keynote.

3 AN EXAMPLE OF APPLICATION

The program Electronic System Design and Innovation (Elsys) at The Norwegian University of Science and Technology (NTNU) was established in 2014 with curriculum built around Whitehead's threefold rhythm. The overall structure of the program is illustrated in Figure 1.

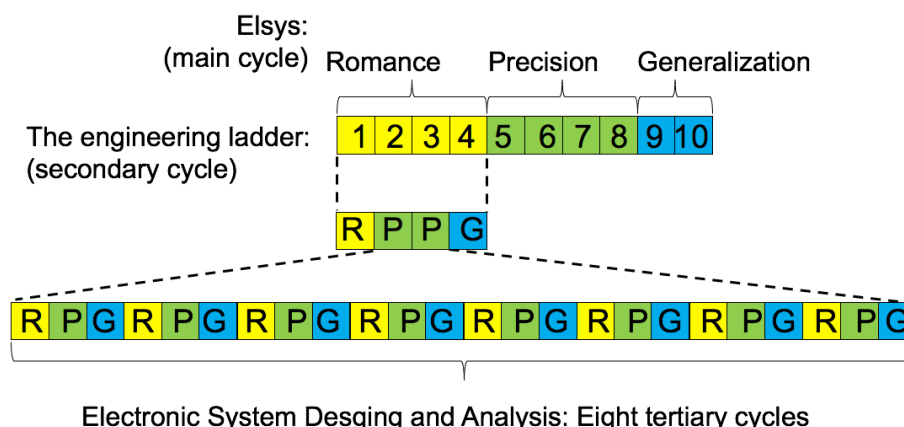


Figure 1. Example of ten semester program with Whiteheadian "cycles within cycles".

The program is a five year integrated master program (no bachelor degree after three years), where the first four semesters have a romance key note, followed by four semesters of precision before the final year which is devoted mainly to a master project constituting the main generalization stage. Within the romance stage, a sequence of four courses *The Electronic Engineering Ladder* [7–8] comprises in itself a Romance-Precision-Generalization (RPG) cycle. The first semester is dominated by a course (Introduction to Electronic System design) where the students do a project working in teams. Intermingled with the project work, there are guest lectures from industry presenting role models discussing future career possibilities and the need for electronic system design. This course mainly falls into the romance category. This stage of romance is thus intended to give motivating momentum for the two next semesters, which are devoted to precision. During semester two and three of the Engineering Ladder, the course *Electronic System Design and Analysis (ESDA)* is given, before the project from the first semester is taken up in the fourth semester providing generalization of the competence gained from the two preceding precision flavoured semesters.

Note that the terms *romance*, *precision* and *generalization* indicate key notes, i.e. the prevailing atmosphere that colours the student's experience. Taking a closer look at the ESDA course with a key note in precision, it is organized as eight smaller RPG-cycles. Thus a "fractal" structure is obtained with cycles within cycles, as prescribed by Whitehead.

During the two ESDA semesters the students should apprehend several abstract theoretical concepts such as impedance, frequency response and signal spectra. In addition, they should become familiar with components such as transistors and operational amplifiers. This requires applications of mathematics, advanced instruments and models of electronic components. Students should also train to develop their creative skills in designing simple electronic systems.

As illustrated in figure 1, the structure of this course, where the key note is precision, is made up as a sequence of several three-week cycles. Within each cycle, the first week is focused on a video lecture, giving motivation and also presenting some theoretical concepts, after which students and instructor meet in class for discussions at a conceptual level.

The discussion is based on principles from *peer instruction* [9] where multiple choice problems are given in the classroom and student responses are recorded by a student response tool using smartphones and laptops. The problems are of a conceptual type not requiring calculations but an actual understanding of the underlying principles. Since the formal methodology required for exact calculations is left out at this stage, the week can be said to play a romance role in the cycle.

After the conceptual discussions, exercises are handed out that require mathematical, analytical and experimental skills. This type of precision work takes up the next week. Finally, a week is set aside for generalization through an individual design project, thus completing an RPG sub cycle.

In contrast to traditional exercises and exams, the experience of having completed eight design projects, which are more similar to what an engineer would do, this kind of mastery experiences should give students the opportunity to better develop their self-efficacy through the experience of mastery.

One challenge here is to align the activities in the ESDA course with the assessment practices, as learning relevant for a future career, becomes manifest primarily during the generalization stage, which is not so easy to test on an exam.

In the ESDA course, the generalization stages are organized as eight individual design projects, D1-D8, and the intention is that as many students as possible shall enjoy success and an experience of mastery during these eight projects. A short report, typically 5-10 pages, is required from each student, and these reports count towards the final grade together with a written exam. Only one week is allotted to each design project, but the students are allowed to hand in improved versions of each report until the end of the semester. It is stressed that the grading of the report depends not on the quality of the design but on how it is documented. Thus, a faulty design can result in a top grade if the report presents an adequate discussion of the failure. By this emphasis, we attempt to reduce performance anxiety during the design process that could otherwise hamper creativity and initiative.

Students are encouraged to help each other during each design projects. Instructors and assistants are also present to provide guidance. To ensure individual learning, each student is given individual specifications. To encourage creativity, the students are free to choose their own approach to solving the problem, but we furnish information to how one *might* proceed.

4 EXPLORING STUDENT EXPERIENCES

Three types of survey have been used in order to assess the impact of the program structure. One is "Studiebarometeret"; a national survey conducted each year among students of all Norwegian University and College programs. In addition, we have used a questionnaire issued at the end of each course. Finally, a poll is performed after the completion of each of the eight design projects during the ESDA course.

4.1 Overall student satisfaction

A national survey is performed annually probing student satisfaction in all Norwegian programs of higher education. At NTNU a traditional program of electrical engineering was phased out as the new Elsys program was introduced. A comparison of the two programs with respect to student satisfaction is given in Figure 2.

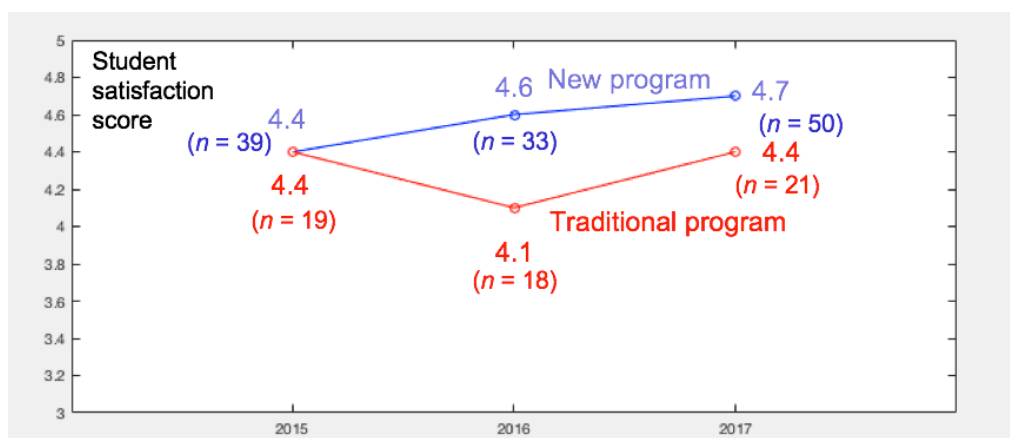


Figure 2. Overall student satisfaction for the traditional electronic engineering program (red) and the new approach (blue). Number *n* of survey participants is shown for each data point.

Average score for all Norwegian programs is 4.0, meaning that both programs have fairly good results. Very few programs, reach 4.6 or 4.7, indicating that the new approach gives a substantial improvement in student satisfaction. Since the new program emphasizes application of skills, it is reasonable to interpret the rise as a rise in mastery experience as well.

4.2 Experience of mastery

In an attempt to measure the degree of mastery experience, a survey was given to the students after the completion of each design project, where the students are asked to express their subjective experience of mastery with the alternatives *little degree*, *some degree* or *large degree*. They were also asked to assess the workload and difficulty of the assignment compared to earlier ones². The distribution of the answers, collected autumn 2017 and spring 2018 in percentage are summarized in Figure 3.

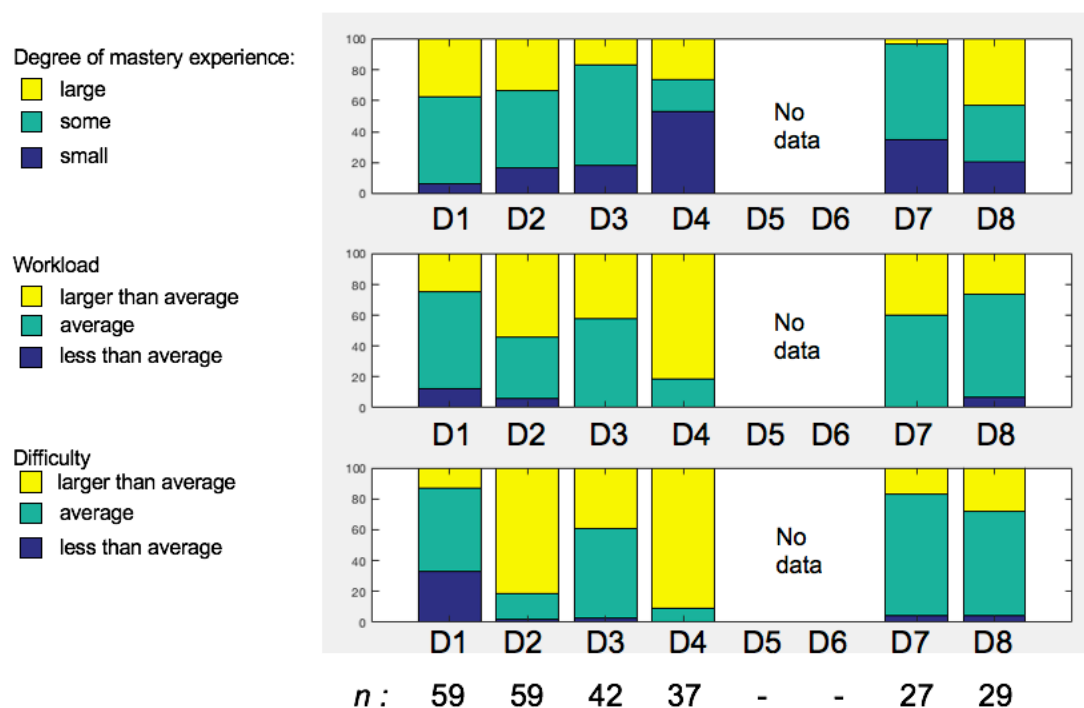


Figure 3. Distribution of answers on survey about student experience during design projects 1-8 in the ESDA course. Data for D5 and D6 are not available. Number of participants n in survey is indicated at the bottom.

From the figure, it is evident that the degree of mastery experience varies among the students. For the majority of the projects, "some degree of mastery" is the most common answer, except for D4 and D8, with "small degree" and "large degree" respectively.

There is also quite some variability with respect to workload and difficulty. Not surprisingly, these parameters are quite correlated.

4.3 In students' own words

At the end of semester two and three, the students were asked to reflect upon the course in general and respond a number of open-ended questions. One thing that emerges from these

² For project D1, where no earlier projects were available, the respondents were asked to compare workload and difficulty with a regular weekly assignment.

reflections is the importance of the design projects. The students describe the projects help them to connect theory to practice and to experience mastery:

“I enjoyed the design projects especially well, then you get to combine theory with practice. You were also “forced” to work individually with these projects and develop an understanding early in the semester. This gave me an experience of mastery”

The students, further, explain that achieving a solution after working on a difficult project makes them feel satisfied:

“It is a really good feeling to finally get a working solution on a design project.”

It is this feeling of satisfaction and mastery that motivates the students to work on the new problems and helps them to go through the precision stage of the next RPG cycle. If, however, the experience of difficulty is too high, the design projects can have unintended consequences and lead to frustration instead of experience of mastery:

“When the design projects work, they are really good tools for creating an understanding, but when you do not really get it working, frustration and low willingness to learn can quickly arise.”

One important factor that the students highlight for a well-designed design project is a suitable workload, with some students reporting a fair amount of work required to complete the projects, while others relate that the workload can be too high:

“Even though the design projects are very educational, the workload can be a bit high.”

Another challenge that the students describe in their reflections is their uncertainty about the scope of the design projects. The students explain that it can be difficult to directly understand what is expected within the design project and that this can limit opportunities to experience mastery:

“With many of the design projects, it was difficult to know what was expected to be able to achieve, this resulted in a lot of insecurity.”

It is through careful scaffolding, continuous formative assessment, and feedback that this uncertainty can be reduced and the students can feel that they have control of the situation. In summary, the students report that the design projects give a feeling of mastery, however, also emphasizing that the projects need to be well designed with respect to both difficulty and workload.

5 CONCLUDING REMARKS

Based on the initial empirical data of students' experiences of the ESDA and particularly their experience of mastery, the design projects have a large potential, but need to be framed and scaffolded carefully. It is a recurring challenge in PBL to formulate problems that both result in intended learning objectives and are adapted to the level of the students. The challenge is escalated when the body of students encompasses a large variety of skills and understanding. In addition, the current university admission system, where students are admitted based on their grades from upper secondary school, creates additional problems. For the Elsys program the requirements are rather high. This means that most students will have strategies that are adapted to solve standard textbook problems and perform very well on that type of

tasks. The independent design problems D1-D8, present, however, a new kind of challenge for most students, and the ability to meet this challenge varies to a high degree across the student population.

For an engineer, self-efficacy should encompass mastery of method and tools, as well as the less specific quality of *creative confidence*. Although both qualities should be developed during the education, their emphasis will vary. With only a week available for each design project, the attained degree of mastery/self efficacy will most likely be experienced with respect to methods and tools. This corresponds well with the projects taking place within a *precision* sub cycle. As mentioned, some hints as how to go about with the design are given initially, and most students follow these hints. There are, however, some students who eagerly try to find their own way also in these short projects. For the majority, creative confidence is mostly developed during the generalization stage in the fourth semester of the Electronic Engineering Ladder [8].

We have, based on a framework inspired by Whitehead, implemented a three stage rhythm including *romance*, *precision* and *generalization* in an electrical engineering program, with special focus on the first two years. By using his rather simple principles as guiding posts, we have given an example of how to organize a study program resulting in increased student satisfaction, and engineers with well-founded self-efficacy. Generally, by letting imagination and freedom be in focus during the romance and generalization stages, we avoid that the precise knowledge gained in the precision phases becomes inert and passive, with the result of increased understanding.

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PROJECT-BASED LEARNING IN AUTOMATION ENGINEERING CURRICULUM

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Conference Key Areas: Engineering Skills, Teaching Creativity & Innovation

Keywords: project-based learning, team teaching, human-computer interface, skills

INTRODUCTION

The Ukrainian system of higher engineering education has been undergoing progressing reformation in the recent years. Experts have identified the following most significant driving forces for the transformation processes in the system of higher engineering education [1, 2]:

- Global processes related to the change of the role and place of engineers and engineering at the beginning of the 21st century.
- System changes of approaches to learning and teaching in Ukraine and across the world.
- Economical factors, which in the case of Ukrainian engineering education are closely related to the solution of ongoing issues of laboratory equipment modernisation.

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According to the surveys, which were carried out in 2012-2013 [3, 4], Ukrainian stakeholders identified the following skills and abilities whose lack is most significant for Engineering graduates: practically oriented professional skills; problem-solving skills; skills for working with experts and customers from different fields. In addition, stakeholders emphasised the importance of the ability to communicate effectively in foreign languages, analytical skills and abilities related to project management. Moreover, the great problem is to find employees who have acquired knowledge and skills from more than one narrow field.

According to the factors listed above, the development of educational initiatives in the context of the reformation of Ukrainian system of higher education, and approximation to the standards and recommendations of the Bologna Process have been considered as an urgent objective for academic staff and administration of Ukrainian higher educational institutions.

The paper outlines the on-going experience and the first findings concerning the following steps aimed to improve the Automation and Computer-Integrated Technologies (ACIT) degree programme at Bohdan Khmelnytsky National University of Cherkasy (BKNUC):

- Implementation of problem-based and project-based learning as efficient methodologies for the development of a wide range of subject-specific and general skills and abilities.
- Selection of practically oriented projects, which simultaneously helps to solve such pedagogical tasks as contextualisation of the learning process and encouragement of students to participate in applied design and scientific research, as well as urgent university organisational tasks, namely, updating and upgrading of laboratory equipment.
- Using of advanced software allowing to smooth over the lag of technical equipment of Ukrainian engineering departments and, in future, will lead to the full-grown using of emerging technologies.

It should be noted that most Ukrainian authors have maintained a prevalent focus on very particular aspects of discipline projects implementation, staying within the frames of traditional discipline-led approaches. Respectively, the lack of procedures for explicit application of PBL approaches within the context of the Ukrainian system of higher education is noticeable.

1 CURRICULUM DESIGN

1.1 Context and preconditions

BKNUC offers Bachelor of Engineering degree in Automation and Computer-Integrated Technologies (ACIT) with a 4-year normative period of training. Each year, 25 to 30 students holding that degree graduate from the university. Bachelor's thesis is a compulsory part of the curriculum of the ACIT degree programme. According to the traditional for Ukrainian system of higher education approaches and regulatory documents, the bachelor's thesis was treated as an individual learning activity of engineering students. At the same time, the need to prepare students for their future work, which corresponds to the stakeholders' demands, led to the necessity of the inclusion of group student projects as a significant element of the curriculum.

The first experience related to introducing PBL approaches was based mostly on the individual initiatives of teachers [5, 6]. The point was that each member of the Department of ACIT is a scientific advisor to three or four student theses each academic year. Respectively, teams of ACIT students working on mutual engineering projects were organised [7].

Monitoring of the projects is performed through examination of feedback from students and faculty using qualitative methods of collecting, analysing, and presenting data on project activities. The survey is conducted via semi-structured questionnaires covering pedagogical and organisational aspects, with student participation in conferences, startup competitions and the like being viewed as indirect indicators. The main aim of the monitoring is a) to find the

possibilities to improvement of ACIT curriculum in the future; b) to analyse faculty and students PBL experiences including the organization of multidisciplinary projects by collaboration in academic sphere.

1.2. Design of PBL curriculum elements

Problem-based learning and project-based learning are widely used in educational approaches which have both differences and similarities [8, 9]. In our work, we focused on the compliance with the following theoretical and applied principles of PBL [8]: a problem is the starting point of learning process; learning is student-centred; the learning process takes place in small groups of students working with a tutor who acts as a facilitator; self-directed learning in order to acquire new information; multidisciplinary nature of projects.

Introduction of PBL is related to all parts of the curriculum including learning objectives and knowledge, type of projects and problems, progression and size, space and organisation, students' learning, academic staff and facilitation, assessment and evaluation [10]. We used the following model of PBL curriculum, taking into account the necessity to build an integrated approach which engages not only the academic staff but also the administration and local industry representatives. In addition, the monitoring of projects implementation was added as an important element of the learning process organisation (Fig. 1).

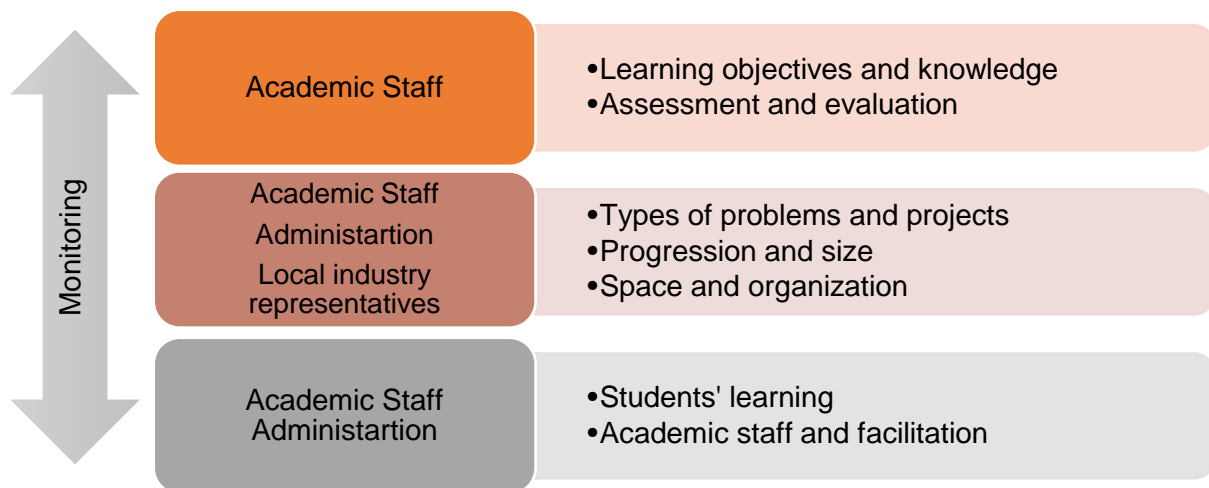


Fig. 1. PBL curriculum elements (based on [10])

Below we consider the main elements of curriculum in details.

Learning outcomes

While developing the list of learning outcomes and related subject-specific and general competencies we took into account the specificity of the educational programme and general specifications prescribed by the Ministry of Education and Science of Ukraine. The Tuning list of competencies and Tuning-AHELO engineering competence framework were used [11, 12].

The list of main learning outcomes is as follows:

- To be able to demonstrate comprehensive knowledge and understanding of the scientific and mathematical principles and key aspects of physics, higher mathematics, automation, microprocessor-based systems etc.);
- To be able to apply knowledge and understanding to formulate engineering problems and choose appropriate methods of solution as well as to analyse engineering products, processes and methods;
- To be able to choose and use appropriate methods and techniques of data acquisition systems design to meet defined and specified requirements;

- To be able to select and use appropriate equipment, tools and methods and to demonstrate an understanding of applicable techniques and methods and their limitations;
- To be able to use different sources of information, to analyse and verify information;
- To be able to carry out the planning, management and completion of a project;
- To be able to function effectively as an individual and a team member;
- To be able to communicate effectively with the engineering community and with experts from different fields;
- To be able to independently organise and manage personal learning process in the context of life-long learning.

In addition, we defined the pedagogical objectives and learning outcomes for students working on projects, which made it possible to determine the most urgent pedagogical issues and, after the finishing of the project, to assess the efficiency of chosen learning approaches. Some of the pedagogical objectives and related learning outcomes are presented in Table 1.

Table 1. Example of pedagogical objectives and relative learning outcomes

Pedagogical objectives	Learning outcomes
Contextualisation of the learning process through the creation of the conditions close to professional ones including interaction with customers and teamwork	To be able to formulate an engineering problem and choose an appropriate method of solution; ability to communicate effectively with experts from different fields
To provide the involvement of students in the creation of own learning trajectory	To be able to independently organise and manage learning process in the context of life-long learning
To provide student involvement in information search and processing when working with ill-defined problems	To be able to conduct searches of literature, and to use different sources of information, analyse and verify information
Enable students to use modern project management approaches (e.g. Agile-methods) in own projects	To be able to carry out planning, management and completion of a project
Encourage students to propose own engineering solution and ideas (e.g. in the form of a start-up) and to take part in competitions and grant programmes	To be able to estimate implementation potential of own products as real-life application
Encourage students to participate in scientific research	To be able to recognise the importance and perspectives of scientific research

Organization of students' projects: topics choosing

The choice of topics for student projects is influenced by several factors:

- current relations between the university and local businesses;
- limited financial resources of the university;
- students' own interests.

For a certain period, the ACIT educational programme has been aimed at the training of engineers in the field of automation of production processes. However, the economic

developments in the last 10-15 years have significantly influenced the industry pattern of our region, with the IT sphere undergoing a notable boost. Local business is dominated by small and medium-sized enterprises focusing on mid-term projects and the development of a wide range of automation systems. Accordingly, there is a demand for the training of specialists who can develop cyber-physical systems. With short-term industrial placement programmes being the main form of cooperation that small and medium-sized local businesses have with our university, the choice and organisation of projects often mean searching for potential partners elsewhere.

The authors propose a feasible way of topic selection for student projects by organising collaboration in the academic sphere. The academic staff of the Department of ACIT collaborates with the colleagues from the departments of Physics, Biology, Applied Mathematics, Mathematics, and Econometrics etc. Such contacts provide opportunities for generating ideas for projects of senior engineering students. In order to introduce multidisciplinary projects and engage the students and faculty from other departments, a local pilot survey was carried out by the authors in 2015 at BKNUC. The survey involved 37 members of academic staff of the Institute of Information and Educational Technologies. The results of this survey show that 73% of teachers are ready to be facilitators of student teams, and 27% prefer individual forms of student activity. In addition, the respondents were asked to choose the team type – with representatives from other specialities, without them or a team which includes students from closely related specialities. 62.3% of respondents preferred to work with a team of students from related specialities; 32.4% were ready to work with multidisciplinary teams and 5.3% preferred teams without representatives from other specialities. 56.8% of surveyed teachers were ready to collaborate with colleagues from other departments as co-facilitators of student projects regardless of project themes and 43.2% preferred topics which support their research interests. In general, the results of this survey demonstrate that academic staff are open to new educational initiatives fostering the implementation of student projects.

According to the level of involvement, teachers from different departments could act as co-facilitators of teams of students or as "customers". The latter role is very important because it opens an opportunity for students to act in a professional way, analysing the needs of the customer and defining what exactly is needed to solve a particular problem. Such collaboration also partially solves the issues with the limited financing available for student projects.

Another decisive factor in the choice of student project topics is that most of the senior undergraduate students are or become employed during their final year at university. This inevitably reduces the time they can spend doing the projects, especially if it is outside of their current area of interest, the level of motivation may also decline.

2 PROJECTS BASED ON COLLABORATION IN ACADEMIC SPHERE

Teachers of Ukrainian engineering departments are well aware of the intensive development of emerging technologies, such as the Internet of Things – a net of interconnected smart physical objects which includes embedded sensors and software providing data communication and exchange between real-world and computer tools. It seems reasonable that engineering projects of ACIT students involve the design of DAQ systems and various application-based software. One of the constraints was that the designed products should be usable for experts from different fields. Respectively, LabVIEW was chosen as the element of the human-computer interface which allows to carry out the acquisition of data in a continuous cycle, its processing and presentation in a suitable form. In order to minimise the cost of student projects, we use available equipment or low-cost elements like Arduino programmable

microcontroller boards. Project tasks include the design of DAQ system, coordination of processes of data acquisition and processing, and demonstration at runtime.

One of the first examples of a student project was the design of DAQ systems in which the thermocouple L (chromel-copel) was used in order to provide precise measurement of temperature. The challenges for the students were as follows: to analyse the physical and technical aspects of temperature measurements; to choose the type of thermocouple with regard to the previously defined constraints and to provide the correct voltage-temperature conversion; to provide the conversion of measured data to digital format; to write a program for microcontroller initiating the measurements after obtaining the signal from PC and reading of data from the converter and sending to PC; to write a LabVIEW program with the possibility of measurement initiation and processing of measured data. In addition, it was necessary to design a user interface to present the measured data in a suitable form.

In the case of this project, students used built-in VISA modules. Engineering and physics students used the designed system during laboratory works in the course of thermodynamics, e.g. in the investigation of specific heat of liquids when the liquid is heated by use of an electric current. The special LabVIEW VIs was written and during the laboratory works second-year students had a possibility to initiate the process of measurement as well as save and analyse the obtained data. Moreover, a special laboratory work guide was written.

In 2014, we started to use Arduino in student projects. The availability of LabVIEW Interface for Arduino (LIFA), which is the API based on the conception of virtual instruments, was among the advantages of Arduino. In the presented example (Fig. 2) the digital sensor DHT11 which contains a calibrated digital signal output of the temperature and humidity was used.

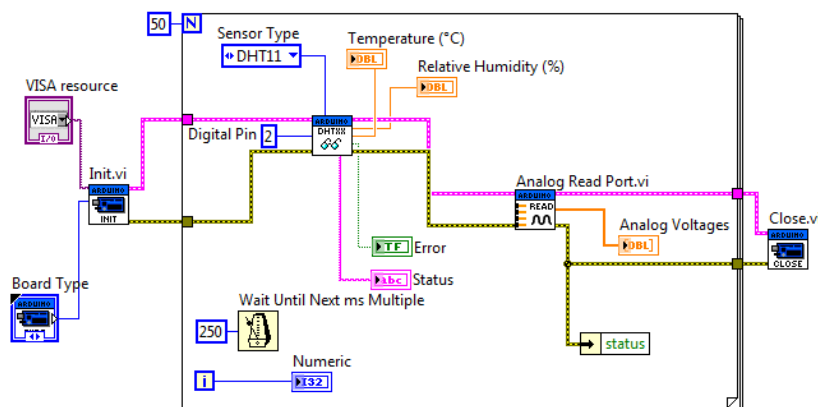


Fig. 2. An example of designed block-diagram of Arduino-based system

One more interesting practically oriented project was carried out as answer for inquiry from Another interesting practically oriented project was carried out in response to an inquiry from the researchers of the Institute of Natural Sciences. The task was to design a system capturing the digital images of some biological samples placed on a glass plate and process these images according to the requirements of the researchers. Such processing included the calculation of statistical parameters, the area of investigated objects etc. The biological microscope and digital camera were used. Firstly, students used the Ni Vision Assistant, in which special sketches were developed. The next challenge of the project was to design LabVIEW VI in which a wide range of tools and functions were used in order to process the series of images (Fig. 3).

Since the products were designed for use in research and learning practice, the development of clear instructions for the designed system (which conditions are necessary to carry out the measurements, typical errors, demands related to hardware etc.) was a compulsory task.

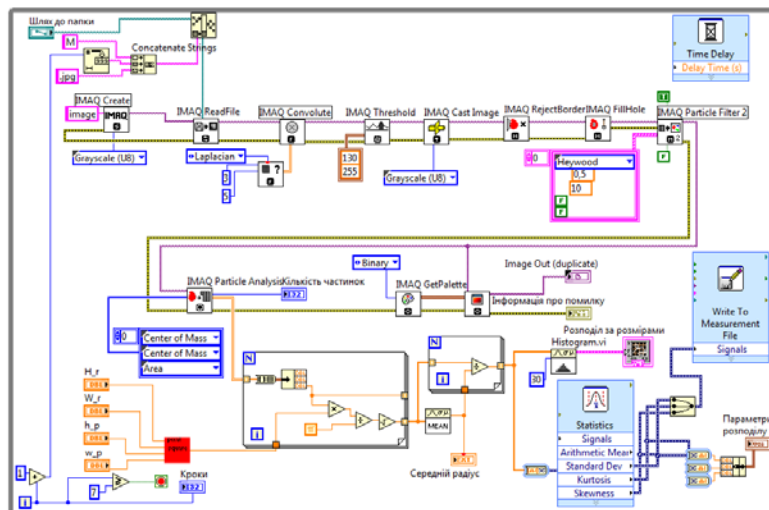


Fig. 3. An example of designed block-diagram of digital image processing

3 RESULTS AND DISCUSSION

The presented learning activity has become a certain reference point for academic staff and students. The formal integration of the introduced changes to the educational programme is in progress. Overall, the employment of practically oriented team-based projects has received positive perception among the academic staff of the Department of ACIT as well as among our colleagues from other departments.

All difficulties which emerged during the implementation of student projects could be divided into two categories. The first one is related to learning aspects such as a transparent and appropriate system of assessment of student activity both individually and in a team. In order to overcome such difficulties, we proposed a form of assessment which includes evaluation of the process of project design (log-book, mid-term report), peer-review of text (content, style and structure), presentation, and answers to questions. The second category of difficulties was related to administrative and organisational issues, like the formal definition of the workload of teachers from different departments, budget-planning for the student projects etc. We also observed special moments related to the interaction between students and teachers who acted as the "customers" of the designed systems. In the case of facilitators, it was very important to find the balance and help the students to organise direct communication with these teachers. One of the problem points with the search for student project supervisors was that faculty members from different departments were ready to act as such only if the projects lay within the area of their scientific interest.

At present, a lack of project management skills is very notable. Students also indicated that they experienced difficulties with time management and when working with information. Additionally useful was the opportunity to observe and to analyse student behaviour in terms of the economic aspects of the projects. Although the students demonstrated responsibility in financial planning, they were less confident in making the final decisions. At this stage, they needed additional consultations with the facilitators.

4 SUMMARY

The development of computer-aided data acquisition multipurpose systems which could also be used in scientific research and education, enables contextualisation of the learning process when students develop competencies concurrently with the solution of real-world problems. Students involved in the projects have noted positive perception of own activity. They were enthusiastic about the possibility to design real things and to observe how these things could

be used in research and learning. Students who were involved in the projects took part in the annual student conference hosted by our university.

5 ACKNOWLEDGMENTS

The one of the authors (G.V. Lutsenko) would like to acknowledge the support by the Ministry of Education and Science of Ukraine (#0117U003909).

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Transforming the learning and educational culture at a university

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Conference Key Areas: Open and Online Engineering Education, Innovative Teaching and Learning Methods, Educational and Organizational Development

Keywords: blended learning, online learning, innovative teaching, educational technology

INTRODUCTION

New students enrolling in universities in the 2020-tale have lived their whole life in the middle of rich interactive digital resources and services. Using Internet and available online resources are self-evident parts of learning for almost all of them regardless of

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their background. Traditional classroom-based educational models from primary school to universities are heavily challenged in this new digital environment. On the other hand, digitalization is also a strong asset that provides universities wide opportunities to enrich students' learning experience, both on campus and in distance learning. It can provide students access to novel rich interactive learning resources, better facilities for student-student and student-teacher communication, and more versatile feedback on their exercises and projects. Digitalization can also support changing teacher's role from a lecturer towards a coach. However, these benefits can be achieved only, if university teachers truly adopt the available new tools and methods to use them. Creating new digital content, such as online videos, interactive e-books, automatic assessment tools or virtual reality resources may have a high learning curve for many teachers, who already struggle in the pressure of time management and increasing workloads. Moreover, adopting such resources also challenges teachers to change their pedagogical practices, because classroom pedagogies can rarely be transformed into online practices as such. For example, research on how students view online lecture videos in MOOCs (Massive Open Online Courses) showed that the length of videos that most students are willing to view, is around only 5-6 minutes [4]. This is very far from the duration of lectures, which are widely given in lecture halls.

Aalto University, with 11000 full time Bachelor's and Master's level students and 4000 faculty and staff members and researchers, is the leading university in Finland in the areas of technology, business and arts & design. The mission of the university is to *"build competitive edge by combining knowledge from different disciplines to identify and solve complex challenges, and to educate future visionaries and experts"* [2]. When the university defined its strategy for years 2016-2020, it identified one of the key goals as: *"Develop and deploy forerunner digital learning solutions to improve learning outcomes."* The university decided to invest an order of 10M€ to support this goal over these years, and a new 5-year project Aalto Online Learning (A!OLE)² was launched in the beginning of 2016. The goal of the project is to develop novel digital learning resources in all fields of the university, support building new pedagogical models for applying them, as well as develop new services for teachers to support their work in creating and adopting new digital learning tools and resources [1]. From the beginning it was stated that the goal is *not* to proceed towards fully online education; instead, the goal is to develop solutions that allow combining the best practices in both online and classroom learning.

In this paper, we present the experiences of the first two years of the A!OLE project and discuss our approaches to create a cultural change in the university. The main volume of the A!OLE comprises pilot projects that develop novel resources and pedagogies in different fields. This is supported by active workshops, which build teachers' competences in various areas of online education and at the same time strongly support networking with colleagues to build a new teacher community. We analyse a set of 24 pilot projects, covering their initial goals and expectations and contrast them with their experiences later on. Thus, we seek to build a holistic picture about the results of the whole project.

²<https://onlinelearning.aalto.fi/>

Our research questions are:

- 1) What were teachers' initial challenges and/or motivations for initiating a development project (A!OLE project),
- 2) What were the concrete development actions that the teachers took?

RELATED WORK

Universities are increasingly active in organising activities and support for enabling e-learning and online learning settings for their courses. These activities range from projects and hubs to service points and centres, some of which are briefly discussed below.

The EPFL Center for Digital Education (CEDE)³ serves teachers via the production team of MOOCS Factory and conducts research related to online learning. The Rolex Learning Center provides inspiring spaces for CEDE to operate at. Initiating a development of a MOOC at EPFL starts from a submitted application, after which the production team will handle and help with the actual production and operation of the MOOC. Our open call for idea proposals in A!OLE project is certainly related to their model but it is more widely looking for any kind of online/blended learning ideas, and the support they might need, accordingly.

In USA, the HarvardX⁴ is a strategic initiative of the Harvard University *“to enable faculty to build and create open online learning experiences for residential and online use, and to enable groundbreaking research in online pedagogies”*. This is very much a shared goal of our A!OLE project, as well. MITx, the initiative of MIT, says⁵ their *“goals include expanding access to quality educational opportunities worldwide, enhancing on-campus education, and advancing understanding of teaching and learning through research”*. HarvardX and MITx have published statistics about their online offerings: already in their “4 Year Report” they report about significant activities, including for instance 4.5 million participants having 28-million participant hours at their courses [3]. The Explore Digital Learning -initiative of the Northwestern University offers *“to connect with other instructors and find ideas to enhance teaching and learning”*, also a very shared idea with our project. Stanford | Online⁶ is also a large scale and well-known activity of Stanford university online courses, and has clearly inspired many of their central stakeholders and teachers to get involved. Further on, The University of Minnesota offers⁷ openly online a number of useful resources for developing online learning facilities.

Another related initiative, the TU Delft Online Learning Experience (OLE) [5] is a pedagogical model that serves as a basis for activities with TU Delft to ensure the quality when developing online learning for their courses. To further support teachers TU Delft operates an Online Learning Hub⁸, which is essentially a portal guiding its

³ <https://moocs.epfl.ch/>

⁴ <https://courses.harvardxplus.harvard.edu>

⁵ <https://openlearning.mit.edu/beyond-campus/mitx-edx-moocs>

⁶ <https://online.stanford.edu>

⁷ <https://cei.umn.edu/online-learning/resources-support-online-and-blended-learning>

⁸ <https://onlinelearninghub.tudelft.nl>

users to prepare online courses. Further on, also a center type of activity, but more focused on research is the Learnt⁹, Center for Digital Learning Technology at DTU in Denmark.

A!OLE PROJECT

Aalto Online Learning is a strategic project at Aalto university for years 2016-2020. Its leadership includes a professor level academic chair and a full-time project manager, who plan and coordinate activities and budgets, accordingly. The funding decisions are made by the vice president of education. The overall funding has been around 2-2,5 M€ annually of which roughly 70% is used for pilot projects and the rest for various support services.

The main project supports and funds pilot projects, which are solicited through *calls for idea proposals* for the faculty and staff members and students twice a year. The call is – on purpose – a light-weight process. Instead of requesting a complete project plan from the applicants, we request that the proposals are submitted through a web form that includes a number of questions directing the applicants to consider their initial problem in teaching or learning, how online learning could help resolving it, how the pilot could be evaluated and what kind of support is needed. The answers form a basis for an interview where we elaborate the challenges and plans further, identify possible synergies with other pilots, and discuss funding needs. It is notable that not all proposals request funding, but only wish to join the A!OLE teacher community and get support from the core project. Moreover, while projects are called A!OLE pilots, most of them target to build new resources and/or methods that will be used in real courses immediately when the pilot project is completed. That is, pilots are not just for testing ideas, but applying them to support or revise education in courses in full scale.

We support the accepted pilot projects in several ways. Weekly voluntary workshops are available to learn and discuss novel tools and methods for online learning. Pilot leaders are encouraged to attend the workshops that best fit to their needs. Pilot projects developing similar resources are combined into thematic groups, which have their own meetings. These groups include topics like blended learning, video production, online textbooks, automatic assessment, gamification, online social interaction, augmented reality and virtual reality. Twice a year we organize a large gala type celebration, which is open to all people in the university and where results achieved in completed pilots as well as work-in-progress are demonstrated. Overall these activities have a goal of building the A!OLE *coaching network*, where teachers can exchange ideas and get support and encouragement from each other when developing practical skills.

DATA COLLECTION

We collected the data for this paper with an online-survey from A!OLE pilot proposals, which received funding in the academic year 2016-2017. The survey was designed and sent to pilot leaders in January 2018, and 25 responses were received by the end of February 2018. One respondent did not give permission to use the answers for research purpose and thus our data pool consists of 24 answers to the survey. The

⁹ <http://www.learnt.dtu.dk>

online survey consisted of 20 different mostly open-ended questions, in which most significant areas covered eventual changes in education, experiences gained, successes, challenges and results. Furthermore, we inquired in particular how the projects had supported students' learning. One important question for the pilots was the level and quality of support received from the A!OLE-project. A minor part of the questions were Likert-type polls.

The pilots in the data pool focused on bachelor and master level degree programme education in Aalto schools. Language teaching as service education for the entire university was also well represented. Most pilots concerned developing a single existing or new course. However, several ones developed two or many courses, typically in bachelor education. Student numbers in pilot courses and education varied from under 10 till some thousands (in case where many large courses were combined under one pilot). The typical size of a single pilot course ranged from 30 to 100 students. Most academic leaders in the pilots were lecturers and professors. One pilot had a team of experts with also some students as a resource.

The data was rather rich, and the respondents in general had described well their own pilot's experiences. However, a few pilot leaders mentioned that their project was still on-going, and they could not yet properly respond to all questions.

METHODOLOGY

We used qualitative, inductive content analysis [6], a systematic analysis method to extract and summarize the essence of the open-ended responses that were related to the motivation and goal of each A!OLE project. Two authors of this paper split the data into two so that each researcher analysed 12 survey responses. However, in the cases where one researcher was unsure how the utterance should be interpreted, the two researchers discussed together until they reached consensus. The two researchers did together the final stage of the analysis, where we sought for the common denominators.

At the beginning of the analysis process, the two authors read through all survey answers marking sentences that conveyed ideas and themes relating to our two research questions. The essence of each utterance was then summarised into few words and utterances that conveyed similar content were placed into the same pile. Next, we read through all the phrases in one pile and sought for a common denominator (raising the abstraction level of how we talk about our data), which then became the name of the category. In the final phase of the analysis, we took a closer look at the categories to identify what each category seemed to focus on (student, teacher, teaching approach, ...) to emphasize the root reason or motivation for doing the A!OLE pilot project.

RESULTS

In our first research question we were interested in teachers' initial motivation for initiating a development project (A!OLE pilot project). Our results suggest that the teachers' motivation can be divided into five large categories.

Student: The aim of the project is to find ways to support and enhance students' understanding and skills. For instance, in one pilot the teachers developed

"... virtual reality molecular modelling application to aid students' understanding of the three-dimensional atomic-level structure of molecules and matter."

In another pilot the aim was

"... to expand the students' ability to communicate scientific data through other than written media."

Some pilots focused on improving students' learning experience, for example:

"To try out different technologies that would support learning and teaching, the course integrated elements from game design to create a gameful learning experience."

Teacher: The aim of the project is to enhance teachers' skills and knowledge on how to best teach/organize the course or to make teachers' work more efficient. One project leader expressed the essence of this category as follows

"... we have had a chance to make interesting technical and pedagogical experiments to understand how to best teach our students ..."

Several different teachers reported that they had experimented with, for instance, internet streaming, online exams, and students' self-made videos as a means to report the results of a project work.

Community: The aim is to change the way teaching and learning related actions/processes are carried out, e.g., the way feedback is given. This includes also support and help from peer teachers and network, which has been gradually developed during the project's existence. One response formulated this, as follows:

"To change the feedback culture from static to dynamic."

Teaching approach: The aim is to make a transfer from one teaching approach to another, e.g., from traditional to flipped classroom. The common theme among the pilots in this category is that the teachers want to rethink their use of the classroom time. One teacher perceived his/her A!OLE project as

"... a resource for flipped learning to help increase time available for teacher student interaction."

Another teacher told that he had turned

"... all lectures into gamified online modules and focussing classroom time on applications."

Tools: The aim is to develop/test technologies and tools that aid the teaching and learning process. The focus of a number of A!OLE projects was mostly on developing and experimenting with technology that might help students with their studies. For instance, one teacher listed the following concrete actions s/he had made:

"... implementing and producing scalable automatic grading back ends, developing the automatic feedback provided by the back ends."

Because developing rich interactive content is not technically trivial, one pilot

"... developed processes to design, create, and maintain interactive learning materials for programming courses."

Our second research question concerned "What were the concrete development actions that the teachers took? [in their AIOLE pilot]". The actions were manifold varying from developing concrete tools and systems to trying out new teaching methods or new ways to organize the course.

Many pilots created novel types of online content. Creating online videos, online episodes and podcasts was popular. Virtual reality content was generated in some pilots, and one form of this was utilizing 360-degree videos to support students' familiarization to laboratories and their facilities. Streaming lectures to the Internet was also one method.

One specific area in creating new content was developing rich interactive content, such as modelling applications, tools connecting the lab equipment and simulation models, or automatic feedback and grading tools. One aspect here was improving the usability of the tools from students', instructors' or maintenance point of view. Building online exams was also one concrete action.

Some projects ended up developing new teaching methods, e.g. using course design cards¹⁰, or building student collaboration between two Aalto schools. More radical approaches ended up redesigning the course completely. For instance, in one pilot the role of students changed radically towards active creators of the course content, and in another one they turned all lectures into gamified online modules and focussed classroom time on applications.

CONCLUSION

Based on the data from the survey, the authors conclude that the AIOLE-project has already now well enlarged and supported developing blended learning and teaching at Aalto University. While this sample data was collected only from one third of the ongoing or finished pilot projects after the first two years, the results demonstrate many very good examples of novel online and blended learning resources and how they have been or will be integrated with classroom teaching.

¹⁰ These cards support innovative design as follows. The cards identify various dimensions of course design by setting questions and possible answers to a teacher: What learning theory will your course be based on? Perhaps Constructivism or Connectivism? What learning approach will you take, perhaps case-based learning or challenge-based learning? Which instructional methods will you use? Perhaps peer teaching or demonstration? What is the course frame? Will your course be a self-paced or instructor-paced? Which platform will you select? A commercial MOOC or will you create your own platform? When it comes to content production, which online tools and techniques will you use? Webinars, wiki, blogs, quizzes, podcasts? How about monetization, are you aiming to generate profit and if so what is the business model? Selling additional content, selling certificates, subscription? How will you market your course? Through teaser content, high-profile people, social media? See also: <https://www.slideshare.net/mileht/idbm-challenge-manual>

The results also suggest that the majority of the teaching personnel in the pilots have gained more encouragement and new visions to develop their teaching. In many pilots, cooperation between teaching staff and students has been strengthened as well, when students have been a part of the pilot. Yet, many respondents were still slightly cautious to assess longer-term impacts when their own pilots were on-going.

We are currently defining clear processes to support teachers in building various types of online learning content, and we have recognized several issues to be addressed in the future. How to support the maintenance and further development of the created online resources when the pilot project funding period ends? How to implement more systematic blended learning development in degree programme level and how to support the role of degree programme leaders in this? How to support expanding the new teaching and learning culture in departments and get new teachers involved in redesigning their education?

We would like to gain more insight into how the pilots and various new methods, tools, platforms etc. may have had impact on teachers' pedagogical growth and development. We acknowledge that a survey could provide us only an initial overview of the impact of the A!OLE project on teachers' work. Therefore, in the next phase we deepen our data collection in terms of interviewing teachers who gave their permission for the interviews further qualitative analysis of this richer data. Moreover, we could expect that in the subsequent phase the pilots would have received more experiences on students' learning results, and also on the eventual impact on curriculum development in programmes or departments.

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A Case for Case Instruction of Engineering Ethics

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Conference Key Areas: Ethics in EE; Philosophy and Purpose of EE;

Keywords: case studies; engineering ethics; engineering ethics education

INTRODUCTION

Recently, the use of case studies for teaching engineering ethics attracted criticism pointing to its inadequacy in capturing the complexity of the profession [19], [5]. Our paper examines case instruction of engineering ethics, arguing that the microethical use of this teaching method does not fully capture the metaphysical and epistemological dimension of engineering. We proceed by looking in the first section at the beginnings of case instruction, highlighting its main characteristics and benefits according to empirical research. We then zoom in on the use of case studies for engineering ethics instruction, presenting four deficiencies that fail to fully materialize the strengths of the method. We claim that these deficiencies are rooted in a microethical approach to engineering ethics education, which leads to a dilution of the major features of case pedagogy.

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1 CASE STUDY PEDAGOGY: CHARACTERISTICS AND BENEFITS

Case studies were first used as a teaching method in law and business, their history tracing back to the law professor and dean of Harvard Law School Christopher Langdell, who first taught a case study in 1870. The cases designed by Langdell were inspired by real sources and were meant to encourage students' independent thinking, thus moving away from the lecture and recitation format focused on presenting information and then asking students to memorize it. Harvard Business School adopted the method almost 100 years ago, in 1920, under the leadership of Wallace Brett Donham, himself a law graduate. With Donham as dean, the school developed approximately 18000 cases during a 27 year span.

How case studies are conceptualized and taught varies between disciplines. The dialogical format of case studies became the mark of legal education [25], while in the medical field case studies developed as problem based learning, with students receiving patient records based on which they had to formulate diagnostic hypotheses or propose treatment protocols [13]. Although the case study method is not the same as problem based learning, both approaches are inductive in nature, drawing inferences from particular instances and empirical observations. The inductive format proved suitable in addressing ill-structured problems like the ones typically arising in law, business and medicine, such that case centered pedagogy grew to become a widespread teaching method in these fields [13].

[18] defines ill-structured problems as allowing conceptualization of multiple - sometimes opposing - solutions, which means there is "no explicit means for determining appropriate action" [16, p. 69]. In the absence of generalizable principles and a directive theory, contextual factors play a significant role that can both shape and constrain action. Such problems thus contain "uncertainty about which concepts, rules, and principles are necessary for the solution or how they are organized" [23, p.8], and so evade deductive approaches that rely on inferences from general theories towards an anticipated solution which is logically sound. Besides their inductive format, other important characteristics of case studies are:

- verisimilitude

Case studies are meant to closely reflect features of a profession [13]. They are expected to contain authentic problems an engineer might encounter [27]. As such, case studies "illustrate the art of engineering and help students cultivate judgment and an appreciation of what is involved in that attribute" [31, p.56]. Thus, they manage to capture the "background and complexities actually encountered by an engineer" [17].

- extensive scope

[1, p. 234] notes that a case study is "more general in its framework and purpose than a normal engineering problem, including the interaction of engineering and non-engineering topics." As opposed to typical well-structured problems employed in engineering pedagogy that have a strong or exclusive mathematical component, case studies include additional aspects that are part of engineering practice. Besides technical information, they also rely on contextual information [24]. [11, p.413] remarks that case studies consider "not only quantitative relations amenable to computations, but other factors such as the interactions of people, the malevolence of inanimate objects, and the pressures of time and resources under which engineers work".

-context driven

Given their extended scope and realistic character, case studies have a significant contextual component [7]. This can include information about the various stakeholders involved in the design and decision process of an engineering project, socio political and economic attributes of the environment in which the project is set, organizational details, a.o. Context gains a crucial importance that cannot be neglected, as it can shape or restrain individual agency. Different contextual information can lead to different strategies for tackling the scenario, allowing even the possibility that none of these strategies is entirely satisfactory.

- tolerate and even cultivate ambiguity and complexity

This means there is no predetermined strategy or theory that can be applied to reach a desired solution, as well as no predetermined ideal outcome. Case studies contain a wide range of contextual information, often ambiguous, leading to a lack of clarity whether one or another specification or constraint should weigh in when deciding on a strategy, or how each factor can affect the outcome. Case studies allow to be formulated as to incorporate “the complexities and ambiguities of real-world ethical problems in an effective and memorable way” [28, p.11].

-multidimensional perspective

As such, case studies are envisioned to tradeoff certainty for nuances. The lack of a definite absolute solution or a predetermined solution path means that a problem can be represented in various ways, and the perspectives of multiple subjects influence the design and decision making process. [16, p.81] remarks that “ill-structured problems possess multiple solutions because there are multiple representations of the problem. The problem solver's perceptions of problem constraints are the primary factors that determine which alternative is selected.” Thus, case studies can make students aware of others' viewpoints and how to take them into account. Unlike textbook problems that assume a single objective viewpoint, in the formulation of case studies various stances are voiced. Such that “in the presentation of a case study, every attempt is made to provide an unbiased multidimensional perspective”[24, p.54].

-allow interactions

The inclusion of different perspectives in the problem description means that unlike textbook problems, case studies are dynamic. The solution emerges out of a wide array of factors and subjectivities that interact in the design and decision making process of an engineering project. The scenarios presented by case studies can thus be enacted by participants to simulate such interactions [21].

The success of case studies in addressing complex and ill-structured problems in law and business prompted their adoption in 1950s also in engineering. As [26] point out, the traditional methods employed in engineering instruction are deductive, focused on providing principles for deriving mathematical models and showing their application. Research focused on case instruction highlighted several benefits for engineering education. [34] conducted a survey among 101 science faculty members in US and Canada, which revealed that the use of case studies improved students' critical-thinking skills, the ability to make connections across multiple content areas and the understanding of concepts. Instructors also considered that case studies helped students to better view an issue from multiple perspectives.

2 CASE STUDIES IN THE TEACHING OF ENGINEERING ETHICS

In regards to the use of case studies in teaching engineering ethics, there is little or no empirical evidence proving its effectiveness compared to other teaching methods [35]. In other fields such as medical education, case studies were shown to significantly increase students' awareness of ethical issues compared to students who were not exposed to this teaching method [20]. Despite no proven benefits, case study pedagogy is nevertheless the prevalent method employed in teaching ethics in engineering colleges in U.S. [4].

There are two major frames for teaching engineering ethics according to [15, p. 373]: a microethical approach focused on ethical dilemmas faced by individual engineers, and a macroethical approach concerned with "the collective responsibilities of the profession and societal decision making about technology." The goal of the first is refining moral reasoning or developing moral character. While the later, by treating engineers as members of social, political or organizational structures, is envisioned to enable correcting those structures "that may need to be changed if engineering and technology are to contribute to human welfare" [5, p. 226].

We argue that microethical case instruction is weak on both metaphysical and epistemological grounds. From a metaphysical perspective, the microethical use of case study in the teaching of engineering ethics fails to fully capture features of the engineering profession related to the nature of (i) the artefacts produced [3], [33], (ii) engineering practice [2], [29]) and (iii) the professional environment [6], [8]. While the epistemological deficits of the microethical use of case studies, focused on clear cut dilemmas and situations of crisis, rest on the assumption that (iv) engineering knowledge is fully explicit and readily available by consulting codes and theory, neglecting its strong tacit and practice based character [30], [32].

2.1 Metaphysical deficits of microethical case instruction

There are three ways in which the microethical use of case studies in engineering ethics fails to capture the metaphysical characteristics of the engineering profession:

(i) A first objection from a metaphysical perspective is that microethical approaches to case studies seem to elude the nature of engineering artefacts. These are not mere products whose creation is restricted to the application of scientific principles, but they also comprise a certain social dynamic or can have political effects [33]. As [33] has argued, a bridge can display one's view about race or social class, inasmuch as it displays technological expertise, as the example of the bridges in Long Island designed by Moses shows. [3, p. 10] further elaborates on how technical artifacts are important in the constitution of power. What seems now an unproblematic everyday engineering artefact, the fluorescent lamp, is in fact the outcome of "a complex economic power play in which General Electric, the electric utilities, the U.S. government, and consumers all played roles. Conversely, the power map of the electric manufacturing scene in the United States was substantially modified by the introduction of the new lamp." By being formulated according to a binary scenario focused on disaster and prevention, case studies tend to neglect the political or social beliefs that govern the creation of engineering artefacts and the manner in which technology mediates human activity.

(ii) Second, as [2, p. 15] points out, the practice of engineering is not solely an application of technical skills, but "a social process involving interaction between the

design team, the client and others". Microethical case studies present an individualistic perspective that asks an agent to take a decision – postpone the Challenger launch, design weapons of mass destruction - neglecting what [9] call "the social arrangements for making decisions". There are different subjectivities involved in engineering practice, each with their own values, backgrounds and goals, which come to shape the solution chosen, the artefact created or even the meaning of the values in use. [29] shows how incremental change over time in what was considered acceptable risk by the organizational culture of NASA led to a "normalization of deviance," which later contributed to the explosion of the Challenger shuttle. What happened was that the meaning and range of what was deemed "safe" was altered through the continual interaction of multiple subjects.

(iii) Third, microethical case instruction rests on the assumption that moral values are independent and objective, rather than embedded within a social or political context, institutional practice or corporate culture. If we consider that making a moral choice in engineering means pursuing values such as social responsibility, safety and sustainability, and these values exist independently, we are assuming full agency to pursue them on the part of the individual. In this case, the engineer is regarded as having agency regardless of the characteristics of the structure she is part of. Cases describing moral dilemmas are seen to allow for a win-win outcome, which given the objective nature of moral values, can be solved through appeal to professional codes or ethical theories [6]. In practice however, even if the engineer successfully identifies a course of action, she might still be unable to act upon her moral beliefs given the contextual constraints encountered [8].

2.2 Epistemological deficits of microethical case instruction

The dominant underlying assumption of microethical case instruction about what type of knowledge engineers use in their day to day practice is divergent with the way in which engineers conduct their practice. Case studies presenting clear cut dilemmas and situations of crisis that can be solved through appeal to professional codes or moral theories assume that engineering knowledge is fully explicit and readily available by consulting theoretical provisions. [32] identifies six types of knowledge an engineer uses in her work, one of them being "practical considerations" represented by "information learnt mostly on the job and often possessed unconsciously, rather than in codified form." [14] also points out that according to interviews conducted with engineers, much of their expertise was based on tacit knowledge. While a study conducted by [12, p. 209] revealed that two-thirds of the knowledge structural engineers employ is practice generated, meaning it is "context specific" and "constructed in the course of everyday activities", with only a third representing historically established knowledge, retrieved from "design manuals, building codes [...]" and the bulk of what they learned in university courses."

This sort of tacit knowledge, argue [30, p. 64], "is often essential when it comes to deciding what risks to take or uncertainties to accept instead of carrying out further tests or developing more accurate models." According to [14], the tacit character of engineering expertise had a significant contribution to the Challenger disaster, as Boisjoly was unable to articulate his tacit knowledge during a final meeting where it was "particularly hard to discuss tacit knowledge and experience-based intuitions." Practical as well as ethical judgements are made by appeal to tacit knowledge. This is due both to the rapid pace and pressure under which engineering work is carried,

and to the frequent lack of theories in tune with the continuous technological advancements in contemporary society that could recommend a line of action over the other, note [30]. The reality of engineering practice is often ahead of prescriptions immortalized in codes or regulations that one can appeal to or consult, and in their absence, an engineer relies on her expertise gained through years of practice.

By presenting black and white scenarios which take place in situations of crisis, based on concrete and certain data, case studies end up resembling well-structured textbook problems. Case studies were developed as an alternative to deductive mathematical exercise, with a clear cut answer and a predetermined reasoning procedure leading up to it. In microethical instruction, the ill-structured function of case study pedagogy dillutes into a well-structured approach to situations an engineering student might face as a professional.

These four metaphysical and epistemic deficiencies of the use of microethical case studies overlap with a dilution of important features of case pedagogy, purporting to their verisimilitude, multidimensional perspective, rich context, interactivity, ambiguity, implicitness and inductive character. A microethical approach leads to case studies neglecting their ill-structured function and the characteristics of the method. Thus, in order to render the metaphysical and epistemological dimension of the engineering profession, case studies used in the teaching of engineering ethics need to make students aware that: (i) the artefacts created incorporate **also** social and political values, (ii) the decision and design process of creating an artefact is **also** a social process, (iii) even if identifying the moral thing to do is a necessary first step for being a socially responsible engineer, acting upon it depends on wider structural factors, (iv) engineering practice often includes ambiguous problems that do not lead to an ideal solution. Macroethical approaches to case studies based on scenarios that integrate roleplay [22], rich contexts portraying institutional dynamics, governmental measures and policies ([10], [14]) as well as ambiguous data could better incorporate the major characteristics of case based instruction.

CONCLUSION

There is a rich potential for case studies to help enhance students' professional and ethical responsibility or the ability to understand engineering solutions in a global and societal context [26], but there is no consensus about the most effective means of developing and employing this method of instruction in engineering ethics courses. Our contribution aims to argue that a microethical approach to case studies is nevertheless unsuitable for teaching engineering ethics, as it does not capture the characteristics that made this method successful in other disciplines such as law, business or medicine. A microethical approach to case studies leads to four significant metaphysical and epistemological deficiencies in rendering the complexity of the engineering profession, which are linked to an application of case instruction that neglects the major characteristics of the method.

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From workshop to classroom: examining the perceptions of Phase 4 apprentices in Dublin Institute of Technology, Dublin

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1. INTRODUCTION

There were 12,000 apprentices registered in Ireland in 2017, an increase of 19% in the number of apprentice registrations that occurred between 2015 and 2016[1]. It is envisaged that this will grow to a cumulative target of 31,000 apprentice and traineeship registrations by 2020. The Irish government has reiterated its commitment to apprenticeships and how they form a central plank of the Further Education and Training Strategy. There are currently 36 apprenticeship programmes, with a further 47 at approval seeking stage [2].

This increased investment in apprenticeships is happening at a time of significant change in the apprenticeship programme itself. The curriculum for certain craft apprentices (Metal Fabrication and Heavy Vehicle Mechanics) has changed recently to include the introduction in September 2017 of Communications and Leadership modules in the Phase 4 programme [3].

A research group of Faculty who teach apprentices has examined the perceived experience of Phase 4 apprentices in two trade areas – Metal Fabrication and Heavy Vehicle Mechanics.

This paper aims to identify both positive and negative perceptions of apprentices' experiences as they engage in modules (workshop and classroom based) in the Dublin Institute of Technology (DIT). Following on from the analysis of interviews with a group of current Phase 4 apprentices, a survey was created and administered to a larger group from the same apprentice trade areas. The interview and survey analysis, combined with a literature review exploring what has been written on this topic to date, will propose an answer to the question of whether these apprentices have a positive or negative perception of their learning experience in Phase 4 in DIT.

1.1 THE IDEA OF APPRENTICESHIPS

Apprenticeship is defined as 'a contract of employment and training....it involves a substantive training programme both on the job, in the company and off the job, by a training provider' [4]. Solas is the body that holds statutory responsibility for the management of the National Apprenticeship System in Ireland [5]. The Irish Standards Based Apprenticeship (SBA) consists of seven Phases, with overall duration of 4 years training as shown in *Table 1* below [2].

Table 1 Apprenticeship Phases

Phase	Location
1	Workplace
2	Solas Training Centre
3	Workplace
4	IoT/DIT
5	Workplace
6	IoT/DIT
7	Workplace

Phases alternate between a workplace and an education centre. Phase 2 is in a purpose built training centre, while Phases 4 and 6 are in a third level Institute (Institute of Technology - IoT)

The current qualification of the National Craft Certificate is placed at Level 6 (the equivalent of a two year full time course at third level) on the Irish National Framework of Qualifications scale [6] and is therefore recognised nationally and internationally. Apprenticeships can now also be awarded up to Level 8 in Ireland [2].

2. METHODOLOGY

This section of the paper outlines the methodology applied to answer our research question, i.e. *Do Phase 4 apprentices perceive their learning experience at DIT to be either positive or negative?* Included are the details and justification of the research method used; the profile of the participants; the research protocol, ethical considerations and how the results were obtained and analysed.

2.1 Research Methods

This study utilised a number of methods, namely a qualitative approach in the form of one-to-one interviews conducted by Faculty members, some of whom lecture on apprenticeship programs, and follow-up quantitative/qualitative research by means of an anonymous online survey. Given the complex nature of apprentice perceptions the qualitative approach was applied first to gather insights on the “how” and “why” of apprentice experiences in order to enable common themes to be identified. No Faculty members interviewed their own students. The quantitative approach was to investigate whether these identified themes or issues could be generalized to the larger apprentice population. As it was anticipated the information may be sensitive, the online survey was anonymous and only general profiling data was gathered from participating apprentices as outlined in the next sub-section. The information provided by interview and surveys was supplemented with a literature review to identify recent research in Ireland and globally on apprenticeships, and apprentice perceptions. This approach is similar to that taken by Greenbank [7] and Winter and Dismore [8].

Interviews lasted on average 15-20 minutes. Prior to the commencement of the interview students were asked to read an information sheet outlining the parameters of the study and they also signed consent forms. It was clearly stated that they could conclude the interview at any stage.

Howieson's research on the student's experience of transition [9], provided a useful source for the online survey format. There were 10 questions in total, with initial questions designed to gather information on student profile. Most questions were structured with a comment section provided for respondents to explain or justify their selection. A final open-ended question required students to suggest what the DIT could do to improve the participant's experience in Phase 4. All apprentices currently studying on Phase 4 received an email requesting them to participate in the anonymous online survey. The quantitative data received from the survey was exported and a graphical analysis was completed. The comments provided to support the selection made by the apprentices was examined in order to help understand their responses more thoroughly.

3. WORLD CLASS APPRENTICESHIP PROGRAMMES

Before examining the perceptions of current apprentices, it is worth assessing what it is that distinguishes a world class apprenticeship programme from others.

In a review of apprenticeships in Ireland, carried out by the Department of Education and Skills, it was established that new apprenticeship programmes should not be unduly narrow or specialised, but be designed to prepare participants for broadly based sustainable and durable careers. In a recent report by Mieschbuehler and Hooley [4] in World-class apprenticeship standards, it is suggested that world-class apprenticeship standards require (inter alia), apprentices to acquire all the skills and knowledge necessary to work effectively in an occupation.

The report notes that in well-functioning apprenticeship systems, there are a number of desirable conditions which support the delivery of world-class apprenticeships, including, good off-the-job training provision that supplements scientific and industrial skills and knowledge with a broader education that enhances, for example, an apprentice's knowledge in inter alia, communication.

World class standards demand training that exceeds the immediate job role. Consequently world class apprenticeship standards ensures that apprentices have broad skills which support their long term employability.

All of the above research may help to explain the rationale for the broadening of the curriculum. As do the findings of a study published by the UK Skills Funding Agency (SFA) 2015 [10]. In the SFA report, employers were asked, "what employability skills and attributes does your company typically expect higher apprentices to have when they start a higher apprenticeship at your company?", 37% of respondents answered writing skills, while 65% answered communication skills. Surprisingly, only 25% of respondents said that they expected technical skills relevant to their company's sector – possibly because this is expected as a minimum.

4. RESULTS

4.1 Participants' Profiles

Apprentices enrolled in the 2017/2018 academic year Phase 4 stage of the Metal Fabrication (MFA) and Heavy Vehicle Mechanics (HVM) apprenticeship programs were considered. Previous research by Bates [11][12] had concentrated on Phase 6 Painting and Decorating Apprentices.

The total cohort available was 32 apprentices across the two craft areas. Apprentices were asked to volunteer to participate in the face-to-face interviews. Numbers participating are shown in Table 2 below. Overall, 14 apprentice volunteers were separately interviewed (44%) and 9 apprentices took part in an online survey, giving a response rate of 28%.

The number of apprentices who participated is shown in *Table 2* below.

Table 2 Number of apprentices participating

MFA		HVM	
Interview	Survey	Interview	Survey
6	9	8	0

The numbers participating in the online survey were lower than anticipated. Unfortunately, no HVMs took the online survey. This is interesting in itself and may be an issue of timing – the survey is best taken when apprentices are close to the end of their Phase, but not so close that they are engrossed in exams and assessments.

All participants were male, white ethnicity with a minimum qualification of Leaving Certificate Applied – most had their Leaving Certificate, the final exam in an Irish secondary school.

Interestingly, while 29% of participating apprentices said they had a learning disability, only one had registered with the DIT Disability Service.

The areas in which participating apprentices worked were varied and included light/structural engineering, boat yards, Irish Rail, Dublin Bus and other transportation companies.

4.2 Participants' Satisfaction Levels

Apprentices' levels of satisfaction and dissatisfaction were captured in both the online survey and in interviews.

In the online survey, 44% of the metal fabrication apprentices expressed that they were quite positive about the course, whilst 56% said that they were not positive about the course.

The areas in which apprentices expressed satisfaction and dissatisfaction during interviews are shown in Figure 1 and Figure 2 below.

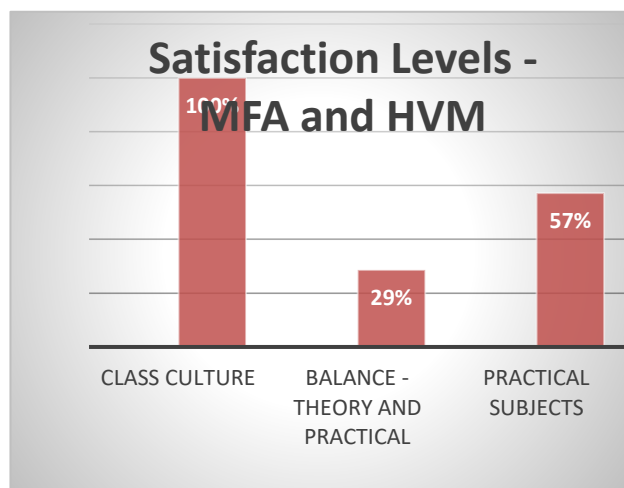


Figure 1 Levels of satisfaction among Phase 4 apprentices

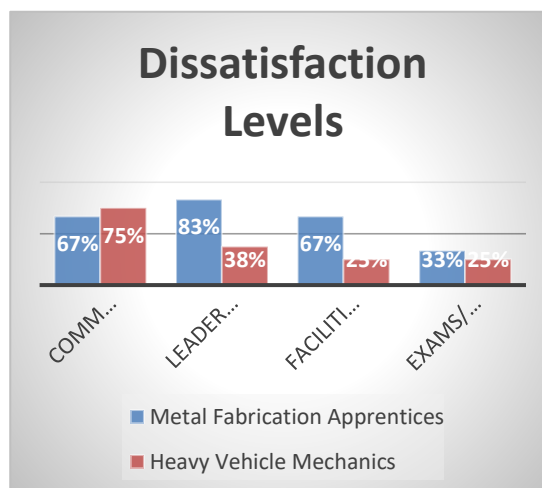


Figure 2 Levels of dissatisfaction among Phase 4 apprentices

These findings are categorised into three theme areas: content, facilities and culture. These themes are analysed and discussed below.

5. ANALYSIS AND DISCUSSION

The question this paper set out to answer was: do Phase 4 apprentices perceive their experience at DIT to be positive or negative? This question was analysed using qualitative and quantitative data, and was examined under several themes. These themes derive from apprentices' comments collated during interviews with faculty, and from an online survey, and they now provide a useful framework for discussion of the results.

5.1 Theme 1 - Content

As anticipated, 57% of the participants said they were satisfied with, and enjoyed the practical subjects. Welding and technical drawing were mentioned in particular.

The highest level of dissatisfaction was expressed with regard to the Communications module and the Leadership module, and this was common to both craft areas – 67% MFA and 75% HGM expressed dissatisfaction with these modules.

Comments made in relation to these modules included 'too much time is being spent on this', 'it takes time away from other modules like CAD and welding', 'there is no application for this' and 'it's not what we are here for'. One student noted that he could 'see the relevance' but would probably do a relevant course later on.

It was observed that these two modules, Communications and Leadership, were referred to as one module by almost all apprentices, i.e. they did not distinguish one from the other even though they are separate modules, each with different content. This might suggest a general bias against these modules, causing the participants to close their minds to the modules *before* they take them, to the extent that they do not see the difference between them, or indeed the relevance of these modules from an employer's perspective.

The negative comments regarding these modules contrast with the fact that almost 30% of participants were happy with the balance of time on Phase 4 split between practical and theory subjects. They also contrast with other positive comments made. One apprentice commented that he enjoyed getting a 'broader perspective' on his craft area, and another, that he enjoyed learning the 'theory behind the practical tasks'. Their comments reinforce the research on what constitutes a World Class Apprenticeship Program [4]. However, the negative comments suggest that participants do not see Communications and Leadership modules as 'theory' that is relevant even in the broader sense to their role in their craft area. This may again be caused by bias, by the content of the modules or their current career level, where the relevance of 'softer skills' is not yet obvious.

5.2. Theme 2 - Facilities

Some dissatisfaction was noted with regard to facilities and workshops by both craft areas. It is notable however, that the highest level of dissatisfaction was noted amongst the Metal Fabrication Apprentices (MFA) with 67% of participants expressing dissatisfaction, versus 25% Heavy Vehicle Mechanics (HVM) participants. Comments from the MFA group included 'not enough welding equipment for 16 students' and concerns were expressed regarding the quality of equipment. These comments again contrast with positive comments made by MFA that they enjoy and are mostly satisfied with the practical subjects in their program. They also contrast with comments from the HVM participants regarding facilities which were mostly positive and included 'well equipped workshops'.

The contrast between both groups suggests that the MFA group have suffered the effects of wider budgetary issues. Indeed, it has been confirmed that this group are in the process of ramping up investment again after several years of under-investment.

However, dissatisfied HVM interviewees noted that 'chairs are hard' and there are 'not enough computers' in one of the classrooms. Also, the issue of long days was raised by almost 38% of the participants.

5.3. Theme 3 - Culture

A high level of satisfaction was noted with regard to classroom culture, with 100% of participants (MFA and HVM) answering this question positively in interviews. Satisfaction was expressed by both groups with regard to culture in the class. Comments in this regard included 'we all get on', 'we mix well' and 'good atmosphere'. One reason given for this was that the classes are small. Comments regarding lecturers were also, in general, positive and included 'lecturers are knowledgeable, and 'lecturers are easy to talk to'.

6. CONCLUSIONS

Various reports have shown the necessity for a broader curriculum in World Class Apprenticeships so that apprentices can acquire all the skills and knowledge necessary to work effectively in an occupation [4]. Indeed, a study of employers' experience of higher apprenticeships [10], shows a strong requirement on the part of employers for not just technical skills, but a broader range including writing and communications skills.

The purpose of this paper is to investigate, in the context of recently introduced changes to the Phase 4 curriculum [3] and significant commitment to apprenticeships on the part of the Irish government [1], Phase 4 Metal Fabrication (MFA) and Heavy Vehicle Mechanics (HVM) apprentices' perception of their learning experience on Phase 4 in DIT.

Apprentice perceptions were examined under three common themes - content, facilities and culture.

Examining the content theme, satisfaction was expressed with regard to practical subjects (welding and technical drawing), and dissatisfaction with the Communications module and the Leadership module, and this was common to both craft areas – clearly at odds with employer requirements

It is suggested that a bias may exist that blinds the apprentices to the benefits of these modules, and the difference between them, even before they take the modules. This bias may be as a result of age – 67% of participants were 20 -23 years of age, and/or experience levels. A further study could clarify whether or not a bias exists, and from where the bias stems. Additionally, a further study could examine the relevance of the content of these modules.

Examining the facilities theme, varying levels of satisfaction were identified between the two craft areas, with 67% MFA participants expressing dissatisfaction versus 25% HVM participants with facilities and equipment. It is suggested that the issue with the MFA group is one of investment in facilities. Indeed, significant funding has recently been approved

by the Higher Education Authority to upgrade equipment in this area and new equipment is currently being commissioned [13].

Finally examining the culture theme, high levels of satisfaction (100% of participants) were identified with classroom culture and collegiality. It is suggested that reasons for this may include small classes (16 students) and the approachability of lecturers – both of these points were highlighted by participants.

In summary, and to answer the question posed, participants have both positive and negative perceptions of their learning experience on Phase 4 in DIT. Positive perceptions were identified with regard to some facilities, culture and some content, negative perceptions with regard to the recently introduced modules Communications and Leadership.

Further research areas include:

- Can the findings in this small study be generalised across other craft areas, in other locations? Expand this research out to other craft areas and to other phases.
- Is there bias with regard to Communications and Leadership modules in the craft areas?
- What are employers' perceptions of the newly introduced Communications and Leadership modules?
- Why are apprentices who state they have a disability not registering with the Disability Services at DIT?

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Teachers' and Students' Perspectives about Curriculum Development in Engineering Education: Implications for academic work

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Conference Key Areas: Teaching Creativity & Innovation, The teacher as a supervisor, Educational and Organizational Development, Curriculum Development

Keywords: Engineering Education, Curriculum Development, Project-Based Learning, Academic Work

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INTRODUCTION

The educational changes under the Bologna Process have challenged, amongst other issues, the teaching practice in Higher Education (HE). Particularly regarding to curriculum development [1], the referred challenges relates to implementing active learning strategies [2, 3], planning different ways to assess students [4] and also defining learning outcomes considering the competences that students must be able to develop [5, 6]. Furthermore, Higher Education institutions are often criticized for the lack of preparation of graduates to solve real problems [7], and several studies highlight the gap of competences identified in graduates regarding to their professional context [8, 9]. The teaching approaches influence the way that students become engaged in their own learning process. In other words, the teacher is a key element to create meaningful learning experiences to benefit of students, allowing them to develop a wide range of competences related to their professional practice [10].

All over the world, engineering programs have been innovating the teaching and learning approaches [11, 12]. A recent report developed by the New Engineering Education Transformation (NEET) initiative from the Massachusetts Institute of Technology (MIT) provides a worldwide picture of successful innovation in engineering education [13]. Three important engineering education trends were identified in this report, namely: “a tilting of the global axis of leadership in the field; a move towards socially-relevant and outward-facing curricula; and the emergence of university leaders that deliver an integrated and world-class curriculum at scale” (p.47). Thus, the MIT report and current research emphasise the importance of curriculum development in the future of engineering education, as well as the role played by teachers, students, leaders and other stakeholders in this context.

With this in mind, this work focuses on the teachers’ and students’ perspectives about curriculum development in Engineering Education (EE). This implies to look at different dimensions such as: planning the learning process (including the learning outcomes), defining the strategies to present contents to students, as well as defining and planning the delivery of innovative teaching methodologies, creating learning environments to promote interaction between students, developing tools and materials for student support, and finally manage the assessment and evaluation processes. These dimensions are some of the criteria for the quality of teaching in HE identified by Zabalza [14]. Understand them in a specific context helps to understand how it is possible to contribute for the quality of an engineering program, in terms of practices, processes and stakeholders.

Based on the need to improve engineering programs, this paper aims to analyse the perspectives of the teachers and students on curriculum development in Engineering Education, using a case study approach, focusing on three dimensions: 1) planning the learning process; 2) implementation of an interdisciplinary approach; 3) engagement of teachers in collaboration.

1 METHODOLOGY

The Industrial Engineering and Management Integrated Master program (IEM-IM) at the University of Minho was analysed as a case study, considering the innovative curriculum context, in which several semesters are organized in interdisciplinary project-based learning (PBL) approaches. In these approaches, group of students develop a project during a semester, to solve an open-end problem related to the professional practice and to the courses of that semester [15, 16]. The perspectives, experiences and beliefs of teachers and students of IEM-IM program were taken into account. Implications for academic work will be discussed, as a contribution for the definition and improvement of the quality of teachers' professional development in engineering programs.

Based on a case study approach, this work seeks to address the following research questions: What are the perspectives, experiences and beliefs of teachers and students regarding curriculum development in the IEM-IM program? What are the implications of curriculum development for academic work in Engineering Education? In regard to data collection and analysis, a qualitative approach was considered, in order to get an in-depth understanding about the several issues related to curriculum development. Four focus groups were conducted with a total of 14 teachers with engineering, science and technology background. Teachers were selected in terms of diversity of management experience (e.g. program director), teaching experience (e.g. years of teaching in the IEM program) and experience with curriculum innovation (e.g. implementation of project-based learning). Regarding to students, eight focus groups were carried out, totalising 30 students from the 1st to 4th year of the IEM-IM program (two focus groups per year). The participants were encouraged to share their opinions, beliefs and perspectives, highlighting the challenges, the difficulties and the suggestions for improvement. All focus groups were recorded with the participants' permission and transcribed *verbatim*. Data analysis was based on the dimensions of quality of teaching in HE identified by Zabalza [14], and referred on the section of introduction. These dimensions allowed using a structured approach to get an in-depth understanding about curriculum development in Engineering Education.

2 FINDINGS

In the context of this work, the data were organized in three dimensions, namely: 1) planning the learning process; 2) using an interdisciplinary approach; 3) engaging teachers in collaboration. The dimensions can be considered challenges for teaching practice.

2.1 Planning the Learning Process

Biggs [10] argues that the learning objectives are the central dimension of the curriculum, providing inputs for the others dimensions related to the teaching and learning process. This purpose is supported by other authors, whom claims for the relevance of the definition of the learning objectives in engineering programs [17-19].

The complexity of planning the learning process goes beyond the definition of the learning objectives. Implies making decisions regarding to the content, strategies, and resources, as mentioned by this teacher.

« (...) sometimes, the teacher' difficult is the selection of the content, particularly in an "Introduction" course in which we can talk about everything and anything related to IEM! » (Focus Group Teachers – Participant 11)

Furthermore, the teachers recognized how difficult it is to keep the alignment between all the dimensions of the curriculum, particularly between teaching strategies and assessment:

«I use examples to help them [students] to understand the content, but then, in the exam, they will reproduce that content in an abstract way, without any meaning, without thinking. So, I use examples and so on, but then when I am going to assess is completely against my original purpose... it is very hard» (Focus Group Teachers – Participant 9)

From the students' point of view, the objectives are important in order to understand what is expected. The following quote illustrates this purpose:

« (...) I need support, I need some orientation, I need clear objectives and, in this case, were not clear at all (...) I think the minimum of planning from the teacher is essential. » (Focus Group 4th year Students - Participant 27)

Furthermore, students' point out that linking theory and practice is a key-issue and, for that reason, must be considered in curriculum planning.

« (...) having the lecture and see where that content can be applied, see where that makes sense and where it will help us, that's important. We never know where some content is going to be applied, if we are going to need them in the future or not... If we know all this, I think our motivation increases. » (Focus Group 1st year Students – Participant 3)

In this sense, using an active learning approach is crucial to enhance students' motivation and engagement in the learning process. The teachers also highlight this idea, considering the impact of the project-based learning approach in the curriculum:

2.2 Using an Interdisciplinary Approach

Considering the value of linking theory and practice, students highlight the project-based learning approaches as their most meaningful experience.

«I think it is the best way to apply theory into practice; and it is not the theory that we had before, but the theory that we are having at that moment. This turns everything that we are learning much more powerful» (Focus Group 3rd year Students – Participant 21)

PBL model in IEM-IM program at the University of Minho started in 2004/2005 in the 1st and 4th semesters. Teams of students need to develop a project considering the content of the different courses of each semester [15, 16].

Interdisciplinary projects challenge teaching practice. Teachers involved in this study identified some of them, such as the difficulties of communication and cooperation between teachers, the complexity of planning and management of the project (e.g. organizing milestones, defining the problem, etc.), heavy workload when comparing with traditional approaches, amongst others. This can be noted in the following quote:

«The project also brings additional difficulties in order to foster the link between the courses and the integration that is needed. In fact, with the project we are in a different level, it is more complex and demanding for teachers, because everything needs to be coordinated and everybody needs to be engaged and committed. »
(Focus Group Teachers - Participant 8)

Despite the difficulties, teachers involved in this study also recognized the advantages of the interdisciplinary projects, in which students are able to solve engineering problems.

«The courses are organized in “lockers” and we know that this is not what the students find out when they go outside. But we can link some courses with each other and the IEM-IM shows that this can happen with the projects. » (Focus Group Teachers - Participant 10)

2.3 Engaging Teachers in Collaboration

Planning the learning process is one of the pedagogical competences for a teacher in Higher Education. However, considering the importance of the interdisciplinary approaches within the curriculum, other competences are also relevant, such as collaboration and teamwork. In fact, teachers' collaboration is a key-dimension to innovative curriculum development in engineering education [20].

According to the teachers' participating in this study, collaboration might be the most challenging dimension in curriculum development and also the most important to innovative teaching and learning environments:

«I think that more communication is needed. Between Mathematicians, Physicist, Engineers... we need to know what each one is going to need, what is possible to do, and so on. Nobody talks, so everything stills the same. Even if you look at an engineering program, basic sciences for one side, engineering sciences for another side... seems that are different things, but in fact they are closely related. And then, we expect that the student be able to link everything...» (Focus Group Teachers - Participant 2)

3 CONCLUDING REMARKS

The results reinforce the role of teachers in curriculum innovation. It is clear some of the difficulties identified by the teachers concerning their teaching practice: in the alignment between the curriculum dimensions, in the implementation of interdisciplinary contexts to foster a meaningful learning process, in practices of collaboration. The most surprised finding is the need to paid more attention to these

and other criteria in terms of teachers' professional development contexts in HE. In other words, teachers might be better prepared for needs demanded by students learning processes, by developing competences that might transform teaching and learning into a more effective and sustainable process. The teacher is a key-person to transform engineering education by creating meaningful experiences for students, innovating the curriculum and preparing them for the challenges of the world, defined by the 2030 Agenda for Sustainable Development [21]. Nevertheless, other dimensions in regard to academic work might be also considered in teachers' professional development, such as the impact of research, management and cooperation with the society in teaching practice. The findings of this study suggests that the complexity of academic work can have impact on the decisions to introduce innovative approaches in the curriculum. Particularly, the teachers' collaboration is a dimension that need to be considered: What is possible to do to foster collaboration amongst teachers? There are spaces and opportunities to develop teachers' collaboration? As an example, the focus on research activities and results often affects the time available to introduce innovative practices. Recent studies point out the relevance of developing research related to teachers' professional development in HE [22-24]. Different approaches can be used for teachers' professional development, such as training, coaching and mentoring, amongst other [25]. The lack of studies regarding to this topic provides opportunities for further research in Engineering Education.

ACKNOWLEDGMENTS

The authors thank all teachers and students that kindly participated in this research.

This study had the financial support of Research Centres ALGORITMI and CIEC, by the Strategic Project UID-CEC-00319-2013 and UID-CED-00317-2013, through the FCT (Foundation for Science and Technology) Portuguese National Funds, and projects POCI-01-0145-FEDER-007043 and POCI-01-0145-FEDER-007562, by European Regional Development Funds (FEDER) through the Competitiveness and Internationalization Operational Program (POCI).

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Hackathon as a Kickstart for Integrated ICT Engineering

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Conference Key Areas: Teaching Creativity & Innovation, Engineering Skills

Keywords: Hackathon, Project Based Learning, Integrated Curriculum

INTRODUCTION

The new Curriculum (started 2017) of ICT engineering studies is competence based and integrated (Project Based Learning). The student feedback from the first semester was collected using a questionnaire called INNOKOMP. As a result, a corrective action it was decided to make a Hackathon experiment. The first Hackathon was arranged to start the semester project. In this case, the project included courses:

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Entrepreneurship, Product Development, Embedded Programming, English Language, and Project Management. The selected learning project was based on a customer need to automate manual operations. Hackathon events' duration is usually 2-3 days. In this pilot, the Hackathon last one working day. After giving the assignment, ten project teams started to generate new ideas by the ideation method they selected to use. Students practiced different ideation methods beforehand. During the Hackathon day, student teams produced new ideas, prototypes and finally made a short sales pitch. Afterward, the Semester project was continued to finish the learning outcomes of the integrated courses. This article describes how to the student feedback was responded and what the results of the Hackathon experiment were.

1 ORGANIZING THE LEARNING TASK

1.1 Integrated courses

ICT Engineering Department renewed the Curriculum year 2017. The new Curriculum was constructed in collaboration with working life. It is competence based and uses the Project Based Learning methodology [1]. For each semester, there is a learning and/or problem-solving project, which is supported by the other courses of the semester. The selected courses are integrated into the project and build upon the knowledge intended for the semester along with the project [2], [3]. For this research, the project included courses: Entrepreneurship, Product Development, Embedded Programming, English Language, and Project Management.

1.2 Hackathon as a kickstart

From the previous ICT Engineering student feedback, some changes for the semester project timing and start had made [2]. The new idea was to use a Hackathon as a kickstart for the project. A Hackathon is an example of project-based learning methodology. Even though it is originated in technology communities, it is widely used in any kind of organizations. It is a competitive event where teams work to ideate, collaborate, design, prototype, iterate, and present a solution to a proposed challenge [4].

The word Hackathon is a term that combines the word "hack", meaning exploratory programming, designing, prototyping, and the word "marathon", meaning a long and difficult task completed in a limited period of time [5].

For this project, the creative work of the teams was organized in 5 phases that moved from the identification of a problem as an opportunity and the creation of a "prototype" as a solution. The five phases were: Inspiration, ideation, prototyping, testing, and presentation.

The end goal was to come up with a "functional" prototype to demo during the presentation, convincing the judging panel that the team's solution is the best. While the Hackathon is an event where teams are competing against each other, there is a strong focus on collaboration within the team, as well as outside for example with customers.

1.3 The Learning task

The teacher team designed a learning task for the semester project. ICT students were in their 4th semester and they had already done a project to design and develop a house with some IoT (Internet of Things)-solutions. During their first learning project, they were learned for example generic project management and basic ICT Engineering skills.

During the project, their project management skills were added with one of the agile methods, e.g. SCRUM with the other integrated courses. The designed learning project was continued with the theme to design and develop a solution for a “customer” to automate their office.

Student teams started their learning projects by establishing own companies. The customer then asked these companies a bid for an office automation. To fulfill the bid students ideated, designed, prototyped, tested, presented and had a final exhibition for the audience from local companies, other cooperatives and all university students and teachers.

2 STUDENT FEEDBACK

2.1 Self-assessment results

Commissions form the basis for solutions. The intent of the commission is to answer the requirements and goals we want the students to learn according to the curriculum. The preconditions related to teaching are determined by courses and their objectives as well as their content description that existed before the Hackathon. We must make sure that the students know and understand these preconditions, so the thought process of the students will not produce solutions that do not fit the objectives of the courses. The commission of the Hackathon event of the spring was related to intelligent systems and IoT. Figure 1 shows the study units integrated into the seasonal project.

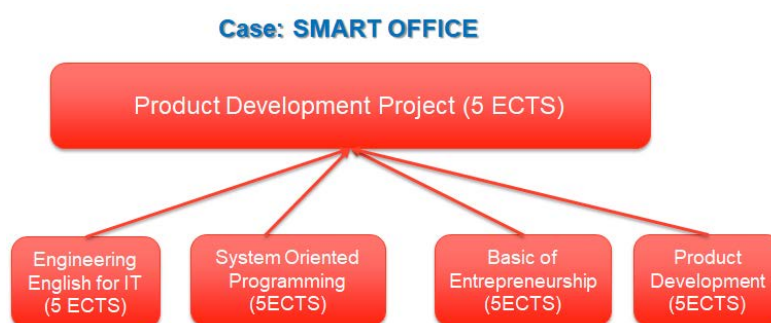


Fig. 1. Study units integrated into the project

The technology and technical solutions were provided by Lapland University of Applied Sciences. The goal of the organizers was to enable the fruition of good ideas with adequate technical and hardware resources. Before the event, the students were introduced to the hardware platforms, sensors, actuators, and to the necessary software tools. Although trying out new approaches encouraged, the students mainly

chose resources that they were already familiar. If needed, the students utilized other resources, not provided by the university. Using other technological solutions was due to students' skills or interest. Solutions based on familiar technologies were nonetheless creative and different from each other.

It should be noted that when working with a large group of students, the teachers do not necessarily always have a direct answer to the questions raised by the students. Several issues require professional-level expertise in which case problem-solving skills and creativity are emphasized to produce unexpected technical solutions. Ideation skills used in Hackathon will be useful in later projects and in working life.

The students were requested to evaluate their development in teamwork. The questionnaire was organized three times: during the spring of the 1st year, after the Hackathon, and after the prototype of the innovated product was finished at the end of the project.

The survey was based on the set of questions developed in the national ESR project. It measures student's innovation competencies through the self-assessment. There are total 22 questions to find out the student's own opinions in the following areas: [6]

- Ability to creative problem-solving
- Comprehensive
- Goal orientation
- Cooperation skills
- Networking skills

Teamwork skills were measured by a reflection questionnaire. The questionnaire was based on questions produced during the INNOKOMP project. The following five questions related to teamwork and innovation were chosen:

- Q1: I present ideas on how the task could be carried out for the approval of others
- Q2: I present new, practical solutions for meeting the goal
- Q3: I show interest in the subject
- Q4: I act persistently for meeting the goal(s)
- Q5: I take my group members ideas into account

Questionnaires have been made in three phases during one year so that the first one at the end of the last spring project, the second one immediately after the Hackathon event and the last when the project ended. The results of the questionnaire can be seen in theTable 1 below. The sample size was very small so reliable conclusions cannot be made. In general, the answers to the questionnaire were positive and all the students showed activity during the hackathon. In all questions, the number of students who selected an excellent choice increased.

Table 1. Results of the questionnaire. The Data are presented as frequencies and percentages of the total.

	Not at all	Poor	Moderate	Good	Excellent
Q1					
<i>Baseline</i>	0	0	5 (21%)	15 (63%)	4 (17%)
<i>After the Hackathon</i>	0	1 (3%)	7 (23%)	21 (68%)	2 (6%)
<i>After the project completion</i>	0	0	4 (17%)	14 (58%)	6 (25%)
Q2					
<i>Baseline</i>	0	0	4 (17%)	18 (75%)	2 (8%)
<i>After the Hackathon</i>	0	2 (6%)	12 (39%)	13 (42%)	4 (13%)
<i>After the project completion</i>	0	1 (4%)	2 (8%)	12 (50%)	9 (38%)
Q3					
<i>Baseline</i>	0	0	10 (42%)	12 (50%)	2 (8%)
<i>After the Hackathon</i>	0	1 (3%)	8 (26%)	19 (61%)	3 (10%)
<i>After the project completion</i>	0	0	6 (25%)	13 (54%)	5 (21%)
Q4					
<i>Baseline</i>	0	0	7 (29%)	13 (54%)	4 (17%)
<i>After the Hackathon</i>	0	1 (3%)	8 (26%)	20 (65%)	2 (6%)
<i>After the project completion</i>	0	0	4 (17%)	10 (42%)	10 (42%)
Q5					
<i>Baseline</i>	0	0	2 (8%)	14 (58%)	8 (33%)
<i>After the Hackathon</i>	0	0	2 (6%)	18 (58%)	11 (35%)
<i>After the project completion</i>	0	0	4 (17%)	9 (38%)	11 (46%)

After the hackathon, uncertainty increased. Later after the end of the project, however, students felt they were better than at the baseline. The biggest development took place in question number 2 in the initiative and question number 4 about perseverance. This can be easier to see in the figures 2 and 3 below:

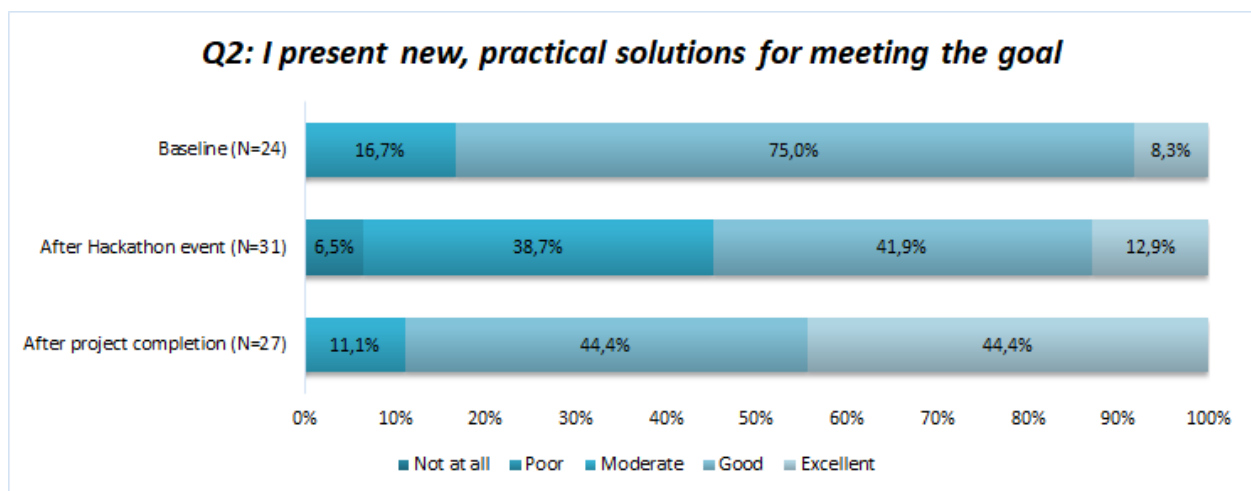


Fig. 2. The development of how a student presents new, practical solutions.

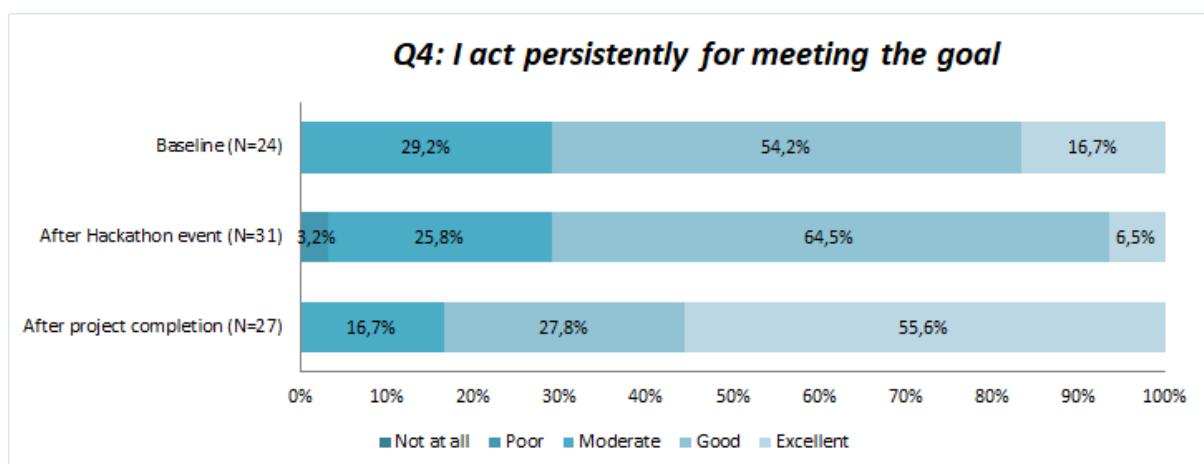


Fig. 3. The development of how a student shows interest in the subject.

The questionnaire included an open field for expressing the thoughts invoked by the Hackathon event in addition to the five INNCOMP questions. In this field, the students typically hoped that in the future, the commission/task would be provided earlier so that it would be better acquainted with. This set of questions will be used in the future; it is interesting to see then, how the perception of self and improvement of cooperation skills continue to evolve.

The members of the teacher team told in an interview after the Hackathon that they were positively surprised by the results. Each group came up with a different solution to the commission and the event clearly supported unifying the members of the group together. The groups seemed happy during the commission and enjoyed the innovation process. The teachers also noted that the leeway left in the goal specifications resulted in a flexible development of the product and offered an

opportunity to affect the solution of one's own team. This most likely affected positively by the motivation and overall mood of the students. In the future, it would also be useful to take advantage of cross- and multidisciplinary project teams, as has been done at the research of the Danish Technical University [7]. Teachers saw that especially business students could participate in teams and bring their own expertise through marketing and productization.

3 SUMMARY AND ACKNOWLEDGMENTS

In the first time participation in Hackathon, the ideation of the students is probably not in its full potential. During the events to come, the students will probably be more confident to innovate in a more versatile manner. If the team has unified before, the confidence to present new ideas and thoughts improves. On the other hand, the critical attitude towards their own activities increases, even though it would appear that skills have been developing steadily. Finnish culture also includes self-criticism and modesty, which is also stated on the site about Finland published by the Ministry of Foreign Trade [8].

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Changing direction: understanding and promoting mature female entry to undergraduate engineering programmes.

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Conference Key Areas: Continuing Engineering Education and Lifelong Learning, Open and Online Engineering Education, Gender and Diversity

Keywords: women, engineering, motivation, mature

INTRODUCTION

There have been many initiatives in the UK over the past 30 years aimed at increasing the number of girls studying STEM subjects, which have resulted in roughly equal numbers of girls and boys studying these subjects up to age 16. However, beyond this age only 20% of 'A' level entrants for physics are girls [1], and they report concern that studying physics limits their career options [2]. As a result, only 15% of engineering undergraduates in the UK are female. Other initiatives have focussed on encouraging women already qualified in engineering to return to the profession after a career break [3]. Despite these initiatives the proportion of women working in engineering professions in the UK remains low at approximately 11% [4]. The Open University (OU) is an open access, distance-learning institution which offers full and part-time degree level study in engineering, potentially providing an alternative route into the profession for mature women who are new to the discipline.

The aim of our research is to understand the motivations of mature women studying engineering qualifications at the OU. By developing an understanding of the motivations and career aspirations of these students we hope to increase the number of mature women studying and entering the engineering profession. An initial literature review of existing strategies and interventions from UK universities encouraging mature women into engineering revealed that no substantive work exists in this area.

This paper reports the initial results from a detailed online survey for all actively studying female engineering students at the OU, together with an equivalent number of male students, to gather information on the similarities and differences between female and male students' motivation for study, academic interests and career aspirations. The results indicate that mature female students are more likely to be motivated by a desire to change their careers, whereas a higher proportion of male students are already in engineering employment and are motivated by career enhancement. Interesting differences have also been identified in the aspirations, attitudes and interests of the female students compared to the men.

The implications of these results and plans for further studies are discussed.

1 ENGINEERING AT THE OPEN UNIVERSITY

The OU offers a range of undergraduate engineering qualifications at different levels, designed to support different professional recognition intentions: Foundation degree/Diploma of Higher Education (240 CATS credits with a vocational focus), BEng (Hons) (360 CATS credits, partial CEng accredited), Top-up BEng(Hons) (120 CATS credit top-up to a vocational qualification, IEng accredited) and MEng (480 CATS credits, CEng accredited). These qualifications are all in general engineering and cover a broad curriculum, with some limited scope for specialisation. For example, for the BEng(Hons), specialist options are available in engineering design, electronics, energy and sustainability, environmental technologies and mathematical methods.

With the exception of the Top-up BEng, there are no formal entry requirements to the qualifications. Approximately one-third of students begin OU study with no formal qualifications, while others already have degrees in other subjects. At the start of 2018 there were 5742 students actively studying for an OU engineering qualification, of whom 563 (9.8 %) were female. This is less than the sector average of 15% female students entering engineering degrees in the UK [5]. The most recent cohort of students, starting their study in 2017/18, were mostly in the 30-39 age group, with 73% working either full or part time, often in the engineering sector.

2 STUDENT SURVEYS

In order to find out more about the motivations and career aspirations of our female engineering students and, for comparison, their male peers, two surveys were sent out. Ethical approval was obtained and the project was approved and supported by the University Student Research Project Panel. We also sought guidance from the OU's marketing experts about the suitability and ordering of the questions. The first survey took place in November 2017 and was a small pilot survey sent to 65 women registered for an engineering qualification and studying their first module (T192 Engineering: origins, methods, context, 30 CATS credits). The same survey was sent to 125 male students to allow comparisons to be made. Responses were received from 18 women and 10 men. The surveys included questions exploring the reasons why students had chosen to study engineering with the OU, their personal interests and motivations, previous educational and career experiences, their feelings about their study experience and the attitudes of others.

Based on the results from the pilot survey some small changes were made and a second survey (described here as the main survey) was sent to all other actively studying female engineering students and a slightly larger number of randomly selected male engineering

students. Responses were received from 58 (out of 311) women and 51 (out of 489) men. OU policy limits the number of surveys an individual student can be asked to complete in an academic year, therefore the number of women surveyed is less than the number actively studying. For analysis the results from the two surveys have been combined, except in the few cases where a change to the survey prevented this.

3 RESULTS AND DISCUSSION

3.1 Overview

Institutional data including student age, geographical location, socio-economic status, ethnicity, previous educational qualification and disability enabled us to compare the overall profile of our sample with that of all OU engineering students. No significant differences were found, confirming that, with the exception of gender, our sample is broadly representative of the overall OU engineering student population.

Data analysis from the questionnaire revealed some similarities between the responses from men and women, but also several significant differences. A two-tailed chi-squared test was used to determine whether significant differences existed between male and female responses, with the null hypothesis being that there was no difference between women and men. The main differences are reported below and have been categorised into four areas: work, aspirations, attitudes and interests. Results have been rounded to the nearest whole percentage and options with very low response rates have generally been omitted, so totals may not add up to 100%.

3.2 Work

Table 1 shows that the majority of the students are working, although more men work full time than women. However, there are marked differences in their working situation: more than half the men are already working in engineering, while women are more likely to aspire to work in engineering in the future.

Table 1. Current work situation

	Women % n = 77	Men % n = 59	2-tailed chi-squared test p-value	significance
Working full time	71	84	0.0993	
Working part time	10	4	0.1886	
Total in work	81	88	0.4742	
Working in engineering	19	58	<0.0001	extremely
Working in STEM	23	12		
Never worked in engineering but want to	44	17	0.0008	extremely

The responses to the question 'What was your main reason for choosing to study engineering' confirm this finding, as shown in *Fig. 1*. The vast majority of students of both genders were studying for career related reasons, but for men the main motivation was to progress in their current career and this was a very significant difference when compared to the women ($p = 0.005$). For women there was a balance between studying to progress their current career, to change career, or to enter the engineering profession. Many of the women are already well qualified: it is notable that 46% of the female students surveyed already have a degree in another subject, compared to 16% of men, resulting in another very significant difference ($p = 0.0071$)

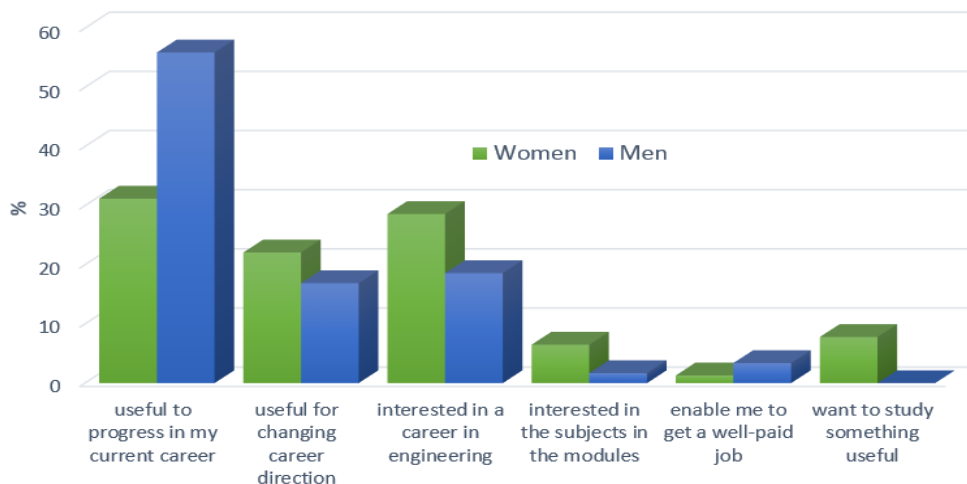


Fig. 1. Main reason for choosing to study engineering

Although the Open University collects employment details under eight broad categories, such as 'technical and craft occupations' and 'modern professional occupations' the main survey revealed an extremely varied spectrum of current occupations for both genders. There were 49 different occupations cited by female respondents, ranging from low-waged, low-skilled employment such as 'cleaner' to highly-paid, high-skilled employment, such as 'lecturer' and 'solicitor'. Similarly, the men in the main survey cited 45 different occupations, ranging from 'shop assistant' to 'quantity surveyor'. One student stated that he was a 'professional yachtsman'. The difference in work situation was reflected elsewhere: for example, 26% of men were being sponsored by their employer, with 68% paying the fees themselves or taking out a student loan. In contrast, only 7% of women were sponsored, with 82% paying the fees themselves or taking out a student loan.

3.3 Aspirations

Fig. 2 shows a comparison of the qualification intentions of male and female students. A greater proportion of women are aiming for the higher level qualifications, however this difference was not found to be statistically significant. Women are much less likely to be following a vocational pathway, which correlates with the fact that far fewer of them are already working in engineering and the difference was found to be statistically significant ($p = 0.0243$)

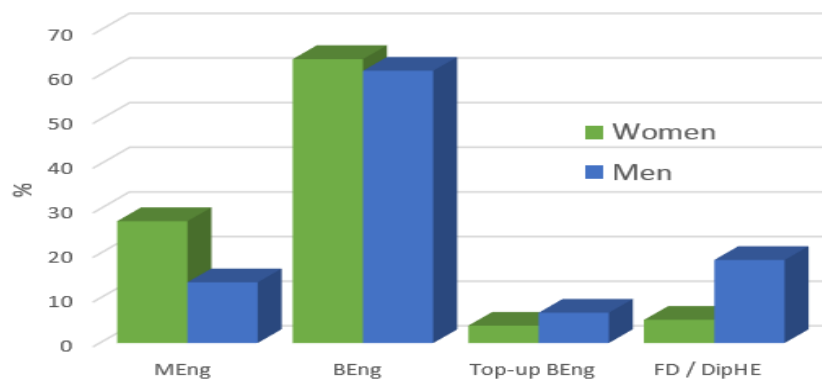


Fig. 2. Qualification intention

The higher aspirations of the female students are also reflected in their professional registration intentions, as shown in Fig. 3.

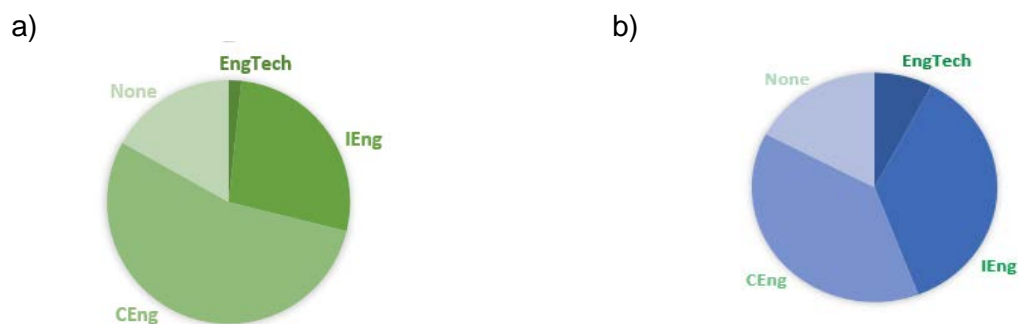


Fig. 3. Professional registration intention a) women b) men

3.4 Attitudes

The questionnaire asked students whether they had been encouraged to study engineering by different groups of people: the results are shown in Fig. 4. Men received greater encouragement in all categories, although the differences were not large and were not statistically significant. It is interesting to note that the percentage of women encouraged to study engineering by their employer (24%) is higher than the percentage of women currently working in the engineering sector (19%), so this could be regarded as a very positive result.

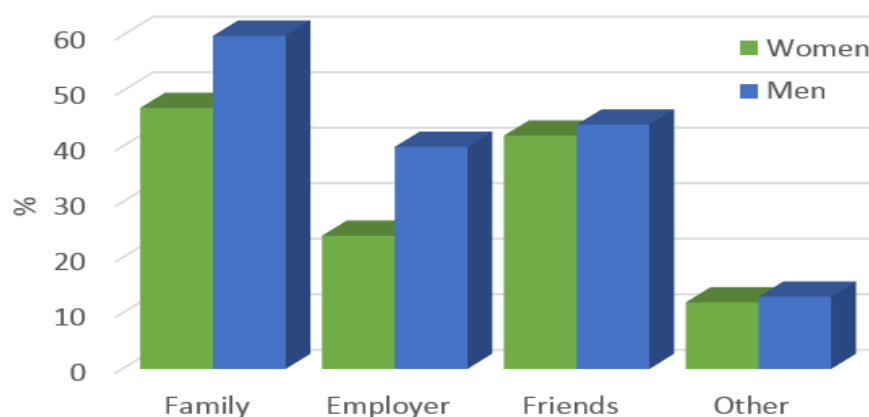


Fig. 4. Source of encouragement to study engineering

In the main survey only, students were asked a range of questions concerning how they felt about their studies and were asked to respond on a 5-point scale with options ranging from 'strongly disagree' to 'strongly agree'. A selection of the results are shown in *Fig. 5*. The main areas where there was a noticeable difference were around confidence to succeed, awareness of being in a minority and level of previous knowledge. Other questions were about ability to keep up with other people and working with others where the responses were very similar for both genders. Unsurprisingly, the statistical significance of the number of women who were aware of being in a minority was extremely high ($p < 0.0001$).

Fig. 5 shows some interesting differences in confidence levels: although a higher proportion of the women strongly agreed that they were confident to succeed on their qualification compared to the men (48% women, 35% men) the overall confidence levels (strongly agree + agree) are higher for men (84% women, 94% men). A similar but less pronounced effect was seen for confidence in mathematics. None of these observations were statistically significant.

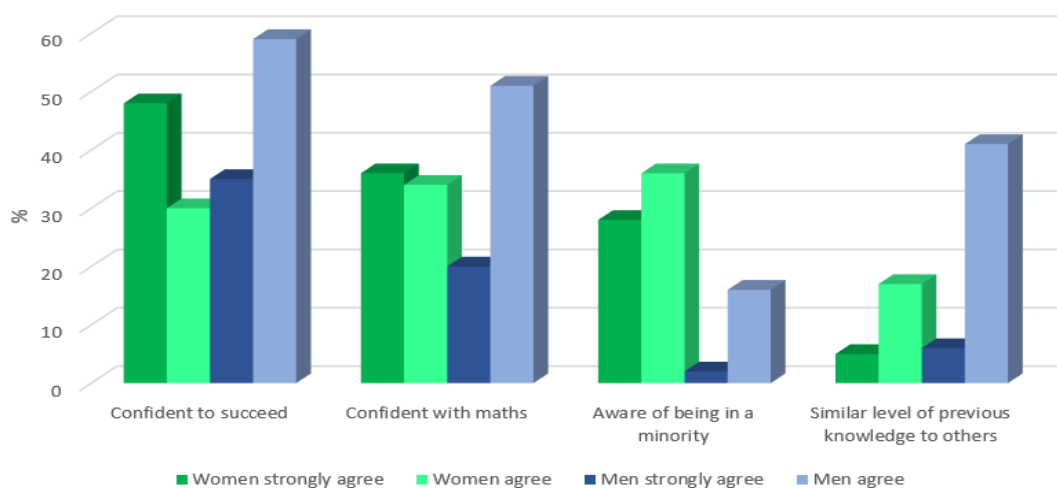


Fig. 5. Feelings about study

Women were far more likely to be aware of being in a minority (64% strongly agree, or agree), despite the fact that they are studying largely independently and rarely have opportunities to meet fellow students face to face. A smaller number of men (18% overall) were also aware of being in a minority, so this is an area that warrants more detailed investigation to identify whether ethnicity, disability, sexuality or some other reason are cited by men as placing them in a minority. There is also a marked difference in the response to 'I believe I have a similar level of previous knowledge to others on the qualification' (22% of women strongly agree or agree, compared to 47% men), which is perhaps linked to the fact that more men are currently working in engineering. This finding was statistically significant with $p = 0.0089$.

3.5 Interests

Students were presented with a list of current engineering challenges, influenced by those identified in the National Academy of Engineering Grand Challenges for Engineering report [6] and asked which were of particular interest to them. They were also given the opportunity to state other areas of engineering that particularly interested them. The results are presented

in *Fig. 6* in the form of 'wordles' [7] where the size of each word represents the number of times it occurred.

a)



b)



Fig. 6. Engineering topics of particular interest to a) women and b) men.

Fig. 6 reveals some common interests but also highlights some different priorities between the two groups. Sustainability and environmental engineering feature highly for both sets of students and, along with energy, are reasonably well catered for in the OU engineering curriculum. However, civil engineering, which emerged top of the list for women but was a much lower priority for men, is not offered as a specialism.

4 SUMMARY AND ACKNOWLEDGMENTS

The information obtained from both the pilot and main surveys has revealed some significant differences between the motivations and aspirations of both genders and their current employment situation. Although our female students tend to enter the University with higher previous educational qualifications than the men, they may be disadvantaged in their study by not being in engineering-related employment. This has implications for academic staff when constructing the curriculum as they have previously assumed that the majority of our students have an engineering-related background, will understand commonly used engineering terms and possess many of the technical and craft skills required for successful study.

The next phase of the study will be to conduct one-to-one in-depth interviews with students to enable us to gain a deeper understanding of their motivations and aspirations. 47 survey respondents (29 women and 18 men) have indicated a willingness to take part in these interviews which we hope to complete during August - September 2018. We also wish to understand the barriers to study that many students in a distance-learning environment have to overcome and whether these barriers are related to gender.

The authors gratefully acknowledge the support of eSTEEeM, the OU centre for STEM pedagogy, the University's survey team for administering the pilot and main surveys, and the students who completed the surveys.

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A Taxonomy for Virtual and Augmented Reality in Education

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Conference Key Areas: Innovative teaching and learning methods; Engineering Skills
Keywords: Virtual Reality; Augmented Reality; Taxonomy

1 INTRODUCTION

Both virtual reality (VR) and augmented reality (AR) have undergone considerable development in recent years. Even though it seems that we are still in a primitive technological stage, it is already recognised that VR/AR can provide exciting opportunities to support teaching and learning [1]. There have been numerous attempts to use this technology in education contexts [2], in most cases showing success [3]. Examples include military training applications [4], engineering applications through VR laboratories [5], and history [6] and astronomy [7] education. The possibilities to use VR/AR transcend to other contexts, such as interactive performances, theatre, galleries, discovery centres and so on [8]. The advantage of VR as an experimental and educational tool is the ability to place the participant inside any scene with high degree of immersion [9]. However, there are also examples where educational application has only been partially successful, such as the use of 3D anatomy models in medical education [10] or skill transfer in VR based microsurgery training [11]. Greater understanding is needed as to the features of such applications that are especially conducive to student learning. More fundamentally though, clarity is needed on the classification of the tools to accurately describe e.g. function and design.

In this paper, a taxonomy for VR/AR in education is presented that can help differentiate and categorise education experiences and provide indication as to why some applications fail whereas others succeed. Examples will be presented to

illustrate the taxonomy, including its use in developing and planning two current VR projects in our laboratory. The first project is a VR application for the training of Chemical Engineering students (and potentially industrial operators) on the use of a physical pilot plant facility. The second project involves the use of VR cinematography for enacting ethics scenarios (and thus ethical awareness and development) pertinent to engineering work situations.

2 CLASSIFICATION OF AR/VR IN EDUCATION

Key factors of the VR/AR taxonomy can be summarised as: (i) Purpose of the application, (ii) User experience, (iii) Technology of the delivery, (iv) Production technology, (v) Gamification type, (vi) User interaction and (vii) System interaction. A description of each of these factors is given below.

2.1 Classification by Purpose

The most important category in the taxonomy depends on the nature of the information being accessed and the intended purpose of this information. Specifically, purpose may involve:

A. Training

For training purposes the goal of the application is to convey information about how to use a specific real device (especially in case of AR) or its digitised equivalent (as in the case of model-based VR and cinematic VR). It is usually very specific in purpose, with the focus on training for equipment, machine or process operation rather than the understanding of the underlying principles of design. There are numerous examples of VR/AR training applications in education at the moment, extensively employed in medical training such as dentistry [12], laparoscopy [13] and ophthalmoscopy [14].

B. Teaching

For teaching purposes the goal is to prepare the student to retain and understand knowledge in a general situation. The student is being exposed to theory and underlying principles, and such knowledge is expected to be transferable to other situations and environments. Currently, the number of examples of successful teaching applications is relatively low, as often their development is challenging [15] with success relying on effective scaffolding [16] as well as effective integration of assessment and feedback. However, some examples of effective applications exist in areas of language teaching [17], general lab work [5] and agriculture [18].

C. Observing

For observing purposes, the primary goal is to show or convey information without the need for retaining or understanding it. In other words an *exhibition* purpose. Examples of such applications can be seen in the form of historical recreations of sights [6] or artefacts [19], the latter allowing for example shared analysis and research of objects between universities. The development of 3D scanners and video has played a key role for such observing purposes.

2.2 Classification by user experience and delivery technology

The two factors of *user experience* and *delivery technology* are closely related and are discussed together in this section. Currently, the taxonomy identifies three distinct user experiences:

A. Virtual Reality (VR) Experience

VR experience completely isolates the user from the outside environment inside an immersive world [20]. The experience can therefore transport the user into both reality-simulated and hypothetical environments.

B. Augmented Reality (AR) Experience

AR systems combine (overlay) virtual content (e.g. generated through a model, animation or video recording) with real-world imagery [21]. This occurs in real time as the user engages with the system, with aspects of the surroundings or other real-world objects registered in 3D [22]. In this way, AR can be used to enhance the real-world interaction and learning experience, helping to e.g. better elucidate principles and concepts.

C. Display Experience

A virtual world can be presented on a standard 2D screen / display, as well as through 3D visualisation. Although this paper (and current technology development) focuses on the latter due to the immersive experience potential, a standard display experience does offer some advantages over 3D immersion, such as the relative clarity of text and general reading experience, and much less prone to causing user dizziness, headache or eyestrain [23].

The user experience may be delivered through two distinct hardware devices: the screen and a stereoscopic head mounted display (HMD). Specific features of these delivery devices are summarised below:

A. HMD

HMD allows stereoscopic vision in VR [24] as well as in AR [20]. Stereoscopic vision arises when two views of the same scene with binocular disparity are presented to each eye. The effect depends on binocular fusion in order to yield perception of depth [25]. In both cases, the user is also hands-free, i.e. the user does not have to hold the device in their hands.

B. Screen

The user uses a stationery (e.g. desktop computer) or hand-held (e.g. tablet) device [26], or may in fact be surrounded by the screen as in the case of the CAVE system [27].

Consideration of both the visual experience and the delivery technology creates the VR/AR technology matrix shown in Table 1; demonstrative examples of how current commercial VR/AR equipment are categorised within this matrix are also shown. The delivery and experience are of course closely related: the type of experience defined by the technology of delivery and to some extent its production methods (see below).

Table 1: User's experience vs. delivery technology

	Screen	HMD
Display	computer monitor	Google Glass
VR	simulators; panoramic videos	Vive; Oculus
AR	iPad	Meta; HoloLens

Interestingly, the definition of AR as a 3D registered system [22] has a consequence for certain types of devices, such as Google Glass which, according to this taxonomy is actually a display experience, even though it resembles an AR experience. Since Google Glass does not show information related to what is in front of the user, nor is registered in 3D (Google Glass technology does not have the necessary sensors for that), it is basically a screen showing information similar to what the smart phone does but is strapped onto the user's head. Therefore, it should not be considered an AR device.

2.3 Classification by Production Technology

The production technology defines to an extent the type of delivery technology. In this taxonomy, it has been identified that it is possible to produce VR/AR experiences with 3D modelling, cinematography or combination of both.

C. 3D Modelling

3D modelling and generated computer graphics is the most common approach to develop computer games and by extension *serious games* for education (see section 2.4 below). 3D models can be designed using tools, such as Blender or using photogrammetry using 3D scanners [19].

D. Cinematography

In terms of cinematography, the footage is filmed with a specific field of view, most commonly 180 or 360 degrees, which then affects how much the user is surrounded by the image. The footage may also be filmed stereoscopically, i.e. to provide the illusion of 3D.

E. Mixed

The two approaches can also be mixed. Indeed, embedding 3D objects within filmed footage is a common technique in the film industry. A blended approach with a delivery method that is screen based is not novel. However, the use of HMD for stereoscopic footage, that has also been enhanced with 3D models, is a new approach, and provides much design potential for educational tools. It should be noted that theoretically it is also possible to embed cinematography in a 3D model, but the authors know no such current applications. Such video embedment could involve for example the teacher or real process or equipment footage.

2.4 Gamification

Gamification describes game-inspired techniques to engage students within the learning / interaction process. The purpose of gamification is to increase student motivation for learning or skills development. In order to categorise the different types of gamification, intrinsic and extrinsic motivation concepts have been considered in this work, as well as the method of integration of gamification elements into the learning content.

Extrinsic motivation can be supported by rewards, and most gamification systems focus on this by using e.g. points, levels, leader boards, achievements or badges in order to motivate students to engage with learning content. The biggest disadvantage of this approach is that when the reward stops, the behaviour may also stop unless the student has found some other reason to continue. Reward based gamification is suitable for immediate and short term-change and has been observed to create a short term spike in user engagement [28].

Intrinsic motivation is the motivation which is driven by internal rewards and that do not depend on external controls, because they are perceived as inherently interesting and enjoyable by the student [29]. Research has shown that extrinsic rewards can undermine intrinsic motivation [30]. Nevertheless, some elements of extrinsic cue may help students monitor their level of progress through the learning activity, whilst not over-riding (or overwhelming) intrinsic drivers for learning.

It is possible to either embed game elements into the learning environment [31] or to integrate educational content into a game [32]. The latter are also referred to as *serious games*.

From this conceptual framework, two types of gamification can be derived:

A. Reward based gamification

Adding elements such as leader boards, badges and achievements to the learning content in order to motivate students to progress through it. This on the whole may be seen as extrinsic motivators for the learning application.

B. Serious games

Using game elements to increase students' internal motivation by adding educational content to the game.

According to [28] there are six elements inspired by game design, that can be used to increase intrinsic motivation within serious games: (i) mimicking play to facilitate the freedom to explore and fail within the boundaries of the game; (ii) the creation of stories for participants that are integrated with the real world; (iii) giving student's choices / options that then dictate the game plot; (iv) giving user information that connects concepts with real-world context; (v) encouraging participants to discover and learn from other interests in the real-world setting; and (vi) allowing participants to find connections to other interests and past knowledge within the game so as to deepen engagement and consolidate learning.

2.5 User Interaction

The design of the VR/AR application must also consider the methods of *user interaction* (e.g. information selection or exchange) with the user. This typically involve tracked controllers (e.g. gloves or sticks), or if these are not available or desirable, a simpler application control can be employed in form of gaze control [33], and are further defined below:

A. Tracked controllers

Uses general-purpose controllers with buttons to interpret the user input. User points the controller in a direction and presses the button which causes the desired reaction from the system. Alternatively, the same effect can be achieved by tracking user's bare hands and interpreting gestures.

B. Gaze control

User can see a cross hair in the middle of the viewport, and by moving his/her head can position the cross hair on the desired user interface element. Action is evoked either by pressing a button on the HMD or by waiting for certain amount of time (i.e. fixed gaze for a 1s or so).

C. Special controllers

In terms of this taxonomy a special controller is a controller for input which cannot be replicated using a general-purpose controller and often employ precise simulated haptic feedback which helps students learn the required skill [13]. These controllers are common in medical training and can include for example virtual endoscopes [34], simulators of dental procedures [12] or ophthalmoscopes [14]. Such controllers can also be simpler, such as turning wheels for drivers [35].

2.6 System Interaction

The way the system communicates with the user is called *system interaction* in this taxonomy. It includes sophisticated subsystems embedded within the content, often based on research in artificial intelligence. It does not include basic menu and information that the application might include for the user to be able to operate its functionality. Two types of system interaction have been identified for inclusion in the taxonomy:

A. Dialog systems

According to explanation-based constructivist theories of learning, learning is more effective and deeper when the learner must actively generate explanations than when merely presented with information [36]. This theory is being used by dialog systems, which ask the student to provide explanations of the educational context by means of menus or direct textual input. Effectiveness of learning is reported to be higher when the student is asked to answer questions via direct textual input [37]. Dialog systems are successfully used in non-VR/AR educational related applications [38] but they are not as easily employed in such form in VR/AR because it is harder to implement an effective method of input, especially when the experience is delivered via HMD [39].

B. Intelligent agents

Intelligent agents are more sophisticated than dialog systems and interact with the user in a more complex way than just textual or audio information. The user can see their representation as an avatar which can move in the virtual space and operate objects in the virtual world [40], which adds life to the virtual world and improves immersivity of the VR application [41]. Intelligent agents can have the same effectiveness as human tutoring [42].

Interestingly, a lack of intelligent agents was identified as one of the problems of sustaining user immersion and interest in educational VR applications [43] and a number of authors planned to include such intelligent agents in future work (e.g. [44] and [6]). The intelligent agent can have at least three distinct functions that fall within the taxonomy:

a. Intelligent Agents for Training

Shows how to perform tasks [40]. An example of this in tutoring is STEVE, which is an interactive autonomous system designed to teach students tasks and machinery operation related to naval engineering [40]. The agent recognises student's performance and can correct them in case they failed the task. The system also has ability to work in a team with more than one student [45].

b. Intelligent Agents for Teaching

Explains abstract concepts [46]. Designing an explanation style of education is not trivial [15] and without preexisting scaffolding students may not be able progress in learning complex knowledge [16]. Software agents can have a significant influence on student motivation and it is important to ensure that agents facilitate, rather than dominate, the learning process [15]. Another factor to consider is importance of intentionality, orienting the learning activity around a problem-based teaching exercise which might promote a more intentional experience [15].

c. Intelligent Agents for Guiding

This involves guiding students in a complicated environment that they are learning about so that they do not get lost (navigational guidance). The agent can also be an *attention guide* directing the student's gaze using pointing gestures [47]. In order to make the models and environments immersive the agents fulfil relevant tasks as if in the real world [6]. Such agents might not interact with the student and just be part of the simulation in order to increase immersivity.

2.7 Taxonomy overview

Based on the above review and discussions, an overview of the entire taxonomy is given in Table 2.

Table 2: Taxonomy Overview

1 Purpose	2 Experience	3 Production Technology	4 Delivery Technology	5 Gamification	6 User Interaction	7 System Interaction
1.1 Training	2.1 VR	3.1 3D Modelling	4.1 Screen	5.1 Embedded game elements	6.1 General purpose controller	7.1 Dialog system
1.2 Teaching	2.2 AR	3.2 Cinema- tography	4.2 HMD	5.2 Embedded educational content (serious games)	6.2 Gaze control	7.2 Intelligent Agents
1.3 Observing	2.3 Screen	3.3 Mixed (rare)		5.3 None	6.3 Special controller	7.3 None
					6.4 None	

3 TAXONOMY APPLICATIONS

3.1 Chemical Process Pilot Plant Education Platform

A VR application of a Chemical process pilot plant has been developed in the VR lab of University of Surrey. Its purpose is for operation training of the actual plant within the same departments and providing a research platform for VR use in various educational settings. In terms of the taxonomy the platform can be used to develop applications for all three purposes, and so far, has been used for *training*. Specifically, the current application allows orienteering around the plant, helping students to understand the plant layout as well as recognize key items of equipment and instrumentation. The tool therefore enables safe and remote interaction with the plant. In terms of the developed taxonomy, the application can be classified as:

Purpose: Training, Experience: VR, Production Technology: 3D Modelling, Delivery Technology: HMD, Gamification: None, User Interaction: Tracked Controller, System Interaction: None

3.2 Stereoscopic Cinematography Storytelling

A second application has involved the set-up of a custom stereoscopic camera based on BlackMagic 4K cinema studio cameras for recording footage that can be viewed with HMD or on screen. The camera rig supports a viewing angle of 220° which eliminates all problems related to recording stereoscopic 360° videos. Since cinematography has higher potential for mobile device use due to lower hardware requirements, a gaze user interface was developed in order to provide interactivity to the video recordings.

The project has focussed on presenting students with a story related to chemical engineering, allowing them to make choices throughout the viewing, and eventually reaching an ethical dilemma near the conclusion of the story. The purpose of the learning interaction is therefore for ethical awareness within a professional / work context. In terms of the developed taxonomy, the application can be classified as:

Purpose: Observing, Experience: VR, Production Technology: Cinematography, Delivery Technology: HMD (both desktop and mobile grade), Gamification: None, User Interaction: Gaze, System Interaction: None.

4 DISCUSSION

For the applications described in section 3 above, future work will allow evaluation of their effectiveness with respect to the specific taxonomical features. Specific areas of development (and research evaluation) also arise through consideration of the taxonomy, including: (i) the use of mixed cinematography technology; (ii) the combined use of HMD and display delivery especially in group work situations (e.g. a student using the HMD and other group members viewing the student experience to facilitate additional discussion and reflection); and (iii) aspects of the application that would benefit from gamification and system interaction. Moreover, the taxonomy provides indication as to how the base applications can be evolved for other teaching / training / observing scenarios. For example, a greater teaching rather than training purpose may be created through the inclusion of relevant system interaction components.

In a related manner, it is also important to understand the critical definition of *purpose* in VR/AR application design. Imagine the following example: students are presented with a chemical engineering rig in VR, containing various instruments (filters, heaters, reactor, pumps, etc...), and are asked to locate these instruments. It might be that the student is learning what each instrument looks like, which would suggest the application purpose is *teaching*. It can be argued that the student is actually learning the positions of those instruments, which is specific for the given rig, and its purpose could therefore be *training* for subsequent plant operation. Whilst in real-world situations, both teaching and training elements may occur simultaneously (complemented by tutor / demonstrator input, reading material or lectures / tutorials), care is needed in VR/AR design to ensure the effective attainment of purpose through, e.g., appropriate production and delivery technologies, gamification and user and system interaction. This could arguably lead to an 8th category in the taxonomy, stand-alone application vs. complementary resource. However, in Higher Education contexts, it is envisaged that most learning tools (especially in engineering) are not disparate to other teaching and learning experiences.

5 CONCLUSION

A seven-factor taxonomy for VR/AR in education has been presented. This has been constructed through consideration of current applications and literature, as well as consideration of aspects of application purpose, design, interaction and engagement. The taxonomy provides a framework for categorising and verbalising educational applications in VR/AR, as well as for identifying areas for specific (and novel) development and research evaluation.

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**Leveling Up by Design:
Games Design + Technical/Engineering Communication =
Innovative Games and High-Functioning Teams**

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Keywords: technical communication, engineering education, games course,
outcomes, assessment, engineering communication

INTRODUCTION

At Cornell University in the US, two Games Design courses ask student teams to create, design, code, and publish original video games. Our courses combine game theory and design with engineering communication seminars, and they are the only classes that satisfy the Technical Communication Requirement for the Computer Science major in Cornell University's College of Engineering. The instructors' particular mix of scholarly expectations and innovative course design leads to public release of some very playable and successful games while teaching intricacies of team communication. (One 2017 team game developed in the course now has over half a million downloads from Steam.) Addressing how such high-functioning teams evolve, we provide this concept paper which demonstrates how qualitative and quantitative assessments gathered systematically from team assignments, milestone documents, and online assessments from the validated CATME system (Comprehensive Assessment of Team Member Effectiveness) [1].

The limited focus of this paper looks primarily at the Introductory Games course (CS/Info 3152), sophomore level, which uses a managed code environment. By simplifying the programming environment, there is a focus on design and software engineering topics. No more than three or four students on each team are programmers, with at least two designers (including artists, UI, or level designers). Similar good results have also been seen in the Advanced Projects course (CS/Info 4152, a capstone course); students use C++ and are provided coding resources beyond an SDL cross-platform layer. Students can integrate other elements such as graphics, AI, and networking. Both classes are similar in structure and consist solely

of a team-based semester-long game design project, graded at many points in the semester, and then exhibited at a public Showcase at the end of the semester.

After a departmental review in 2007, these courses were revised to teach both game design and writing equally to meet the university's Technical Communication Requirement. At first glance, many people assume that a Games class integrates writing for storytelling aspects of game design. However, the documents we assign – and other communication exercises in the courses – are technical/engineering communication pieces and are framed as pre-professional writing for the students.

For the communication aspect, we believe strongly in two mutually beneficial stances. *The first and most important is that the documents and in-class critiques are critical in propelling the game design process forward, not just recording what has already happened.* In this way, our approach differs widely from how many perceive documentation's role in technical work. *The second is that document revision beyond the first draft reflects and supports the iterative and agile design process so valued in game development.*

Thus, these courses incorporate a writing seminar style with at least one discussion section per week to discuss and workshop documents. Two revisions of each major document contribute to a rigor cycle that is at the heart of the course. Teams must communicate to different audiences including players, potential funding partners/bodies, internal teams, managers, app stores reviewers. Importantly, the documentation is tightly integrated with the agile development cycle of the course and is not an add-on activity; this allows the instructors to address external pressures (accreditation bodies and future employer demands), internal pressures (preparing our students for work demands), and self-imposed standards (ensuring that interdisciplinary teams run smoothly while making a viable game).

We begin by outlining the course structure for the Intro course specifically, but both courses use a similar development schedule. We then provide a review of recent writing outcomes for Intro and general team effectiveness (since 2016, using the CATME online team assessment system). We align course outcomes with guidelines from professional/accrediting bodies: 1) IGDA: International Games Development Agency, 2) ACM with IEEE: Joint Task Force on Computing Curricula Association for Computing Machinery and the IEEE Computer Society, and 3) the US's ABET: Accreditation Board for Engineering and Technology.

1 COURSE STRUCTURE

The basic structure for Intro and Advanced is shown in Table 1. While the primary grade in these courses is determined by the project completed at the semester's end, there are several intermediate deliverables throughout throughout the entire semester. Full course cycles, assignments, examples, and grading scales can be seen here, as they are too lengthy to cover herein: <https://gdiac.cis.cornell.edu/courses/gdiac-courses.php>.

While the Engineering Communication Program (ECP) has helped the CS courses with document design and assessment for 11 years, ECP has provided a dedicated instructor since 2014. This instructor helps maintain a writing seminar approach with high enrollments (the Intro course has 72 students spread across 12 teams; the

Advanced course hosts 54 students and 9 teams) with an average of 12 documents; two revisions are allowed for each major document (in bold in Table 1).

Table 1: Basic 16-week Intro and Advanced Course Structure with Deliverables

Week	Task	Deliverables (D), Planning Documents (P), or Reflective Activity (R)	Intended Audience for Documents
1-3	Learning game development technologies	Lab exercises	Instructors
4	Create game idea in team	Concept Document (P)	Investors (fictional); instructors
5-6	Demonstrate play for proposed game in non-digital form; present in class	Non-digital Prototype Game (D)	Class, instructors
7	Outline early game specifications	Gameplay Specification (P)	Internal team, instructors
8	Playtest in class an early online version of the game	Early Skeleton Playable Game (D)	Class, instructors
9	Game refinements; writing Architecture and Design Specs	Architecture and Design Specification (P)	Internal team, instructors
10	Present technical prototype	In-class presentation (D); revisions due (R).	Class, instructors
11	Create and outline level design specification; perform level design critique	Level Design Document (P)	Internal team, instructors
12	Present alpha game (early full game); player testing	Playable game (D) + in-class presentation; short 2-week spring report (R)	Internal team, instructors
13	Code walkthrough with instructors and classmates	Code via GitHub; in-class scrum (D)	Internal team, instructors
14	Present beta game (revised full game); player testing	Game Manual or App Store Proposal (P) ; short 2-week spring report (R)	Internal team, instructors, public
15	Final game release and in-class presentation	In-class presentation (D); revisions in process (R)	Internal team, instructors
16	Final game refinements for Showcase	Full game (D); portfolio of all revised documents due (R)	Internal team, instructors, public
17	Showcase: Public play and vote event	Post-mortem report (R)	Internal team, instructors, public

2 DOCUMENTATION WITHIN AN AGILE GAMES DEVELOPMENT CYCLE

Our game design courses are different in that the communication components are a major portion of the course. We do not frame the communication/professional elements as just another set of skills that employers want or as an add-on skill.

Instead, we believe that the communication components are critical for propelling

the development process forward. Professional skills support the management of a large team's complex task set, compel the maturation of game design, ground the way that tests are performed, and help the teams move to game launch. These communication elements are not outside of the games course outcomes. Indeed, they *are* the course outcomes, along with a playable game, and are so assessed.

The nuanced difference in how the communication elements are at the heart of our courses may challenge how CS instruction or engineering schools frame the concepts of “communication skills” or “professional skills” within their programs (we dislike the term “soft skills” as it implies that those skills are easier than the “hard skills” of engineering work). We maintain that heavy communication assets are integral to successful CS and/or engineering work, and within our courses it is always presented thus so that students are not able to silo their developing technical skills sets. There is much to be said about this philosophy within engineering education; one only needs to search for terms like “situated learning” and “active learning” to find a plethora of good work being done by others where cross-functional skills hone the abilities of pre-professionals. *Our core philosophy is this:* documents should always aid and inform the student teams throughout the development process, both in planning for high performance and reflecting for improvement.

3 TRACKING DOCUMENTATION IMPROVEMENTS

When looking at the document grades in the Intro course, we do see some interesting quantitative results over the years. Table 2 documents the average improvement for each revision (each document is allowed two revisions, and all students must contribute to the effort). Note that student improvement has been generally increasing over the years, with significant improvement for the Game Manual and the Architecture Specification, which have changed significantly with our recent approach. But the significant improvement since 2014 can be linked to the addition of the full-time communication instructor in that year working in concert with the CS instructor.

As an example, Table 2 highlights some of the categories we track across academic years and their spans of improvement for the Intro course. Such tracking of outcomes regarding student work can provide to the instructors some insight into effectiveness (or lack thereof) of course alterations, assignments, and rigor cycles.

Table 2. Percent Average Grade Improvement Per Document Revision Versus Original First Draft in the Intro Course (3152)

Document	2011	2012	2013	2014*	2015	2016
Concept revision	16.48%	25.51%	33.46%	31.01%	22.30%	29.85%
Concept final	16.48%	7.99%	14.41%	14.25%	18.91%	15.66%
Gameplay revision	10.87%	9.82%	23.07%	20.30%	29.71%	33.08%
Gameplay final	18.44%	9.60%	14.37%	18.03%	15.89%	7.55%
Architecture revision	21.10%	48.76%	32.26%	57.06%	73.80%	55.64%
Architecture final	27.02%	11.92%	13.91%	29.83%	26.77%	26.77%
Manual revision	13.10%	3.30%	18.82%	5.93%	12.94%	13.20%
Manual final	11.29%	10.83%	17.40%	12.15%	28.07%	29.87%

Note: Most first revisions show an initial large jump in improvement, with final document versions achieving more modest improvements as the work for the final is simple fine tuning.

*Technical/engineering communication instructor added to course in 2014.

Since 2014 when both Games courses added a dedicated communication instructor, student teams have experienced increased acceptance rates and recognition at external game festivals such as Boston Festival of Indie Games (FIG), Casual Connect, and the Independent Game Festival (IGF). Another aim of the structure of these classes is to simulate (with constraints) a more industry-like experience for the students. In 2018, an undergraduate, working now as TA for the Intro games course, reflecting on his experience in the Intro course, said this:

CS 3152 is the only class in the entire CS department at Cornell that teaches necessary skills for industry, many of which are skills that get ignored in the core curriculum. We work in real-life sized teams where we're responsible for organizing a sizable amount of work, we work in interdisciplinary teams and need to communicate with non-technical peers, and have to document our thought processes and progress. That doesn't happen in other classes, because the assumption seems to be we'll get that experience in industry.

Students nearing graduation, such as this one, come to understand that the rich document cycles and teamwork expectations of the Games courses start them on their journey towards being agile, insightful, and self-assured pre-professionals.

4 TRACKING TEAM MEMBER EFFECTIVENESS

For the past three years, the Comprehensive Assessment of Team Member Effectiveness (CATME) online program helped us track team efforts and issues [1]. As of this writing, CATME has been used by over 100,000 students in over 2,000 institutions, and in over 80 countries [1]. Feedback can be private between students and instructors (our chosen method) or shared between team members. There is a plethora of outputs from CATME for users to explore. For example, Table 3 shows not only the fine-grained types of data that can be collected, but it also demonstrates how we know our annual pedagogical refinements, prompted by CATME feedback, are working. Students, individually, report upon team successes and challenges.

For example, significant assignment changes were made to the Architecture and Design Specifications cycle in spring 2016; the 2018 numbers show significant performance upticks. We interpret improving numbers for the Final Document Portfolio as evidence that our enhanced pedagogical approaches for fostering better teams is working. A closer look at Table 3 reveals interesting trends, too; in the middle of the semester, some teams report slightly higher team cohesiveness than at the end of the term. As instructors, we reviewed their private comments in CATME, and we came to understand that the stress of completing the course and game, along with their other academic obligations, made for a rocky end of semester in terms of team cohesiveness. CATME allows for unique windows into teamwork.

Table 3: Example CATME Outputs for 3152 course

Architecture and Design Specifications (mid-semester) by Year	C (mean)	I (mean)	K (mean)	H (mean)	% of students responding
2016	4.01	4.02	3.93	4.18	97
2017	3.92	4.15	3.85	3.97	98
2018	4.20	4.32	4.20	4.29	93

Final Document Portfolio by Year	C	I	K	H	% of students responding
2016	3.97	3.94	3.88	4.07	81
2017	3.87	3.97	3.79	3.99	80
2018	4.21	4.27	4.15	4.32	88
Whereas: C = Contributing to the team's work: scale 1 (low)-5 (very high) I = Interacting with teammates: scale 1 (low)-5 (very high) K = Keeping the team on track: scale 1 (low)-5(very high) H = Having relevant knowledge, skills, and abilities: 1 (low)-5(very high)					

The CATME system provides copious statistics for any researcher to investigate for particular classes, well beyond the Table 3 example. Aside from such birds-eye views of a course or project, the CATME system allows for incredible granularity as well as space for long-form student commentary, permitting instructors a window into team problems and triumphs, especially if confidentiality is promised by the instructor.

5 ALIGNMENT WITH ACCREDITATION & ASSESSMENT BODIES

University computer science programs in the US are familiar with accreditation standards for IGDA, ACM/IEEE, and ABET, providing measurable program outcomes frameworks. Accreditation and program review agencies challenge academic programs to think more expansively. As for communication efforts, we agree with The Joint Task Force on Computing Curricula Association for Computing Machinery and the IEEE Computer Society: "Effective professional communication of technical information is rarely an inherited gift, but rather needs to be taught in context throughout the undergraduate curriculum" [2].

There is an oft-stated challenge of providing solid communication skills to undergraduates such that they are prepared well for success in the workforce [1, 3, 4]. Employers want new hires to be well-versed in communication skills and team skills; indeed, beyond problem solving, those are core expectations for new employees in engineering, software development, computer science, and other related fields [5]. Students should be agile in creating strong communication artifacts including project management, proposals, pitches, internal team documents, test plans, user guides, app pages, presentations, etc. We strive to teach our students to work with confidence and speak with authority about their projects and work.

Other academic programs are decidedly working towards communication prowess and team skills for their Computer Science/Software, Engineering, and related degrees in the US [4, 6, 7] and elsewhere [8, 9]. Some have a separate course [7, 8]; others embed communication tasks into their engineering/CS classes [7, 10, 11]. Instructional depth, range, or style isn't mandated by ACM/IEEE, IGDA, or ABET, so the strategies and outcome vary widely. Experiments to incorporate communication and professional skills into engineering/CS include those within MIT [12], Georgia Institute of Technology [13], and Ohio University [14].

We provide below a high-level alignment with ACM/IEEE, IGDA, and ABET guidelines. For tables covering our specific course alignments with these guidelines, see <http://chec.engineering.cornell.edu/ecp-research/>, which may serve as models for other programs in developing alignments for their programs.

5.1 IGDA Curriculum Framework 2008

The International Game Developers Association posted a resource from its Game Education Special Interest Group in 2008 [3], and states its desire for students to have experience in teams, writing, presenting, and working in cross-discipline teams, noting “Fundamental proficiencies are often absent in graduates, and require special attention” [3]. Our strongest alignment comes with the section titled “3.8: Game Development” where the IGDA addresses workflow in teams, planning, documentation cycles, planning, many of the same game support documents.

5.2 ACM/IEEE 2013 Communication Guidelines

The ACM (Association for Computing Machinery) released the updated “Computer Science Curricula 2013: Curriculum Guidelines for Undergraduate Degree Programs in Computer Science” (CC 2013) in cooperation with IEEE and the IEEE Computing Society [2]. We align with the “Social Issues and Professional Practice” sections, indicated by “SP” therein. Communication ability is considered by the CC 2013 to be a core Knowledge Area for which “mastery experiences” should be provided. CC 2013 has language that covers communication skills including presentations, teamwork, and writing/documentation [9].

5.3 ABET Criterion 3

As with the other guideline sets above, the US’s ABET body provides a framework for assessing the teaching of engineering work. ABET’s “a-k criteria” [1] show that desired outcomes are more generally outlined than in the IGDA, for example. At the above URL, we provide a mapping that may be useful for CS programs and communication programs when working towards ABET accreditation.

6 SUMMARY

Spring semester of 2018 marks the eleventh anniversary of our integration of writing with game development. Agile and continuous development require that we (as instructors) revisit and revise the courses each year. The core feature of our approach is to make sure that the documentation always moves the development process forward, and CATME assists in our continuous assessment efforts. For all documents in the process, we identify for our students exactly why it is important to the agile cycles; we cut documents that don’t contribute to the process. By applying these simple rules, we believe that instructors can create highly effective and professional teams that are better prepared to meet demanding early careers in CS or related fields.

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Publish your undergraduate research!
A mandatory course for master students in engineering

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Conference Key Areas: How Learning Spaces Support Innovative T&L, Innovative Teaching and Learning Methods, Philosophy and Purpose of Engineering Education

Keywords: active learning, challenge based learning, liminal space

INTRODUCTION

During the curriculum redesign of a master course in engineering, it was decided to enhance the ability of students ...

- ... to express themselves effectively,
- ... to gain confidence in their research activities,
- ... to argue, reason and discuss scientifically,
- ... to evaluate the work of others and
- ... to align with scientific standards and engineering conventions.

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In short, a course was created with a simple assignment: Publish your research! In the following, we will relate our course model to existing approaches, set a perspective on undergraduate research and evaluate course results.

1 BACKGROUND AND EXISTING APPROACHES

With the completion of their bachelor thesis, engineering students have usually carried out and compiled a genuine piece of research. However, even with a thorough supervision, the exposition of results and arguments often remains limited to a small internal circle of stakeholders in a protected research environment and/or in an examination process. The students therefore miss the learning experience of being challenged by a broader audience of experts and peers. Such an advance into new and open terrain may look like trouble ahead but is often the doorstep to new advances in learning. This is well described by Meyer and Land [1] with the threshold concept of learning, which can ultimately “lead not only to transformed thought but to a transfiguration of identity and adoption of an extended discourse”. This transformation can be stimulated by the creation of liminal spaces. Walkington et al. [2] have shown that undergraduate research conferences are favourable opportunities to open such spaces, helping students to “reformulate their taken-for-granted frames of meaning by engaging in critical reflection, through a process of dialogue with others. Such dialogue is a central element of transactional communication.” Undergraduate research conferences like the National Conference on Undergraduate Research (NCUR) in the USA exist for a long time and have spawned successful offspring in other countries. They provide a suitable space for students to take a step beyond their classroom barrier, offer a guided (review) process towards high-quality scientific communication adhering to engineering standards and thus allow them grow confidence in their ability to sustain among peers.

At an institutional level, various approaches to learn and train the written and oral presentation of scientific work can be found. Commonly, the required skills of students are developed throughout continuous assignments to write lab reports, project documentations and, finally, the bachelor thesis. Ideally, the student develops her/his own style and skills with respect to authorship by learning from various staff members, but the learning process is rarely made explicit or guided. On the contrary, ambitious and valuable courses like “Writing your thesis” or “Presentations for engineers” exist, but are often offered on a voluntary basis and/or outside the faculty, see e.g. [3]. This can convey misleading messages with respect to developing a self-confident authorship. It implies that communication and presentation is only an add-on for either those with special weaknesses or special interests and may thus remain detached from the development of the student’s identity as an engineer.

Within computer science education, an integrated approach has been proposed by several researchers in the form of mini-conferences as a course model. This has been successfully applied in the past to both undergraduate and graduate courses [4, 5]. With our approach, we apply a similar model to a master course in engineering, assuming that almost none of the participants have published the research conducted

for their bachelor theses. In contrast to the courses described and referenced in [4] and [5], our students have already completed the research work that provides the necessary basis for paper writing and exercising communication and presentation skills [6, 7].

2 IDEA AND GOALS

For the development of our own approach [6], we argue that the emergence of scientific communication skills should not only be an explicit and integral part of the curriculum but must be developed as a competence from within the faculty. To achieve this, we expose all our master students to the basic standards of peer-reviewed research and provide the opportunity to present their own work on a conference-like level. For this, every master student has to take her/his bachelor thesis as a starting point and expose it to a full conference publication schedule during one semester. We therefore simulate an engineering conference which requires the student to actively prepare, revise and present her/his paper and a poster (see Fig. 1). Thus the publication process becomes a project with the student/author as the manager of her/his success, placing the responsibility for the associated learning experience into the hand of the student. Along the publication process, the students find out about current research in their discipline and become engaged in research discussions. According to Healy and Jenkins [8], this approach can be classified as research-led and research-tutored, as the research project itself, i.e. the thesis, has been completed before the course.

3 COURSE CONCEPT AND CONTENT

The course “Engineering Conferences” was developed for the curriculum of a master course within a medium-sized faculty of mechanical and process engineering (approx. 1500 students) of a medium-sized University of Applied Sciences in Germany. The course is mandatory and 6 credits according to the ECTS-scheme can be earned. The established language of scientific communication, English, is used as a means of instruction (EMI) throughout the full course, which is open to approx. 30 students and

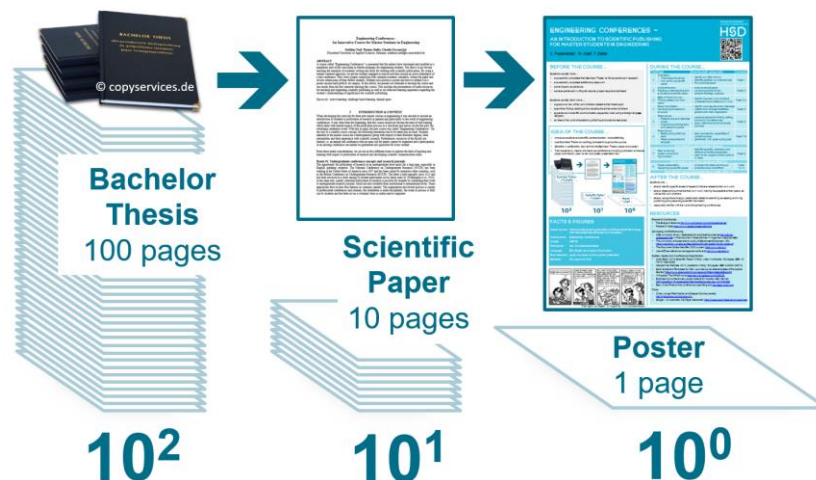


Figure 1. Reducing page numbers by two orders of magnitude: Evolution of key findings and the core message from thesis to paper to poster

can be booked every term. The underlying concept is a simulated engineering conference, with special emphasis on the upfront publication schedule including a full review process that employs the course participants as peers.

The detailed course outline is presented in Table 1. Special care was directed at the design of group work exercises: Students develop content and gain learning experience, with the lecturer standing aside serving as moderator (see exercises in bold face of column 3 in Table 1). As an example for these active learning exercise, the course starts with an “elevator talk” [9]: Each student has to explain the topic of her/his bachelor thesis to other students within two minutes. For most of them, it is the first time talking about their thesis topic in English in a very limited period of time and with the aim to convey a message. This deliberate push beyond the student’s comfort zone is turned into confidence by one or two repetitions.

To model the paper submission and review process, the free web-based conference management system EasyChair is used, which allows to set deadlines, upload papers, define roles such as authors, reviewers and chairs, organize reviews etc. This is not only easy to use for teachers and students but also a real conference standard. After

Table 1. Course Outline: Tasks and Exercises

Unit	Tasks	Exercise (bold face: group work)	Schedule
1	Orientation: ▪ The shape of science ▪ How to find a scientific paper	▪ identify own field of work ▪ identify position on science map ▪ find example paper	Week 1
2	Comprehension: Reading, understanding and evaluating a scientific paper	▪ “Elevator talk”: my thesis is about ... ▪ study example paper ▪ conduct a simple review ▪ present findings to group	Week 2
3	State-of-the-art survey: Finding related work and peers	▪ identify important work of others ▪ understand and relate to own work	Week 3-4
4	Paper compilation: Developing a thread and structure	▪ identify core results and/or message ▪ collect and arrange headlines, graphs and main arguments	Week 5
5	Paper layout / references: ▪ Referencing and reference styles ▪ Organizing a bibliography and referencing tools	▪ use example tool for finding, editing, and archiving references ▪ apply reference style to example sources	Week 6
6	Paper layout / style: ▪ Editing and publishing tools ▪ Paper style guide and template	▪ learn and test the capabilities of publishing tools ▪ get familiar with paper style guide	Week 7-8
Exam element: paper submitted (Week 8)			
7	Peer-review: Quality control and improvement	▪ identify elements, stakeholder, effects and defects of review processes ▪ peer-papers of other authors in class	Week 9
Exam element: two reviews conducted (Week 10)			
8	Poster presentation: Designing a scientific poster	▪ arrange information and layout ▪ evaluate story and effect	Week 10-14
Exam element: poster presentation day (public, Week 15)			

the paper submission, students are requested to conduct two blind reviews of papers submitted by their peers in class. This includes filling out a review form, which requires to state a reason for each rating and also the upload of the reviewed paper with the reviewer's annotations. If nothing else, the latter is an important and visual verification of the engagement of the reviewer with the papers. In real life, reviewers are volunteers, highly motivated, and usually concerned about their scientific reputation. This intrinsic motivation cannot be expected from all our students but at least some extrinsic motivation is installed, since the course rating is partly dependent on the quality of the reviews.

The last part of the course is dedicated to the preparation of the poster. The poster presentation day is the final event of the course and takes place in the main entrance hall of the faculty building (see Figure 2). While each student has to deliver a two-minute keynote on her/his research topic, the others are free to browse the final product of their peers or to answer questions of visiting faculty members and students. Both poster and keynote are assessed by the lecturers on the spot resulting in the final grade for the course.

Credits for the course are earned for the poster presentation (counts 60%) and the paper including two peer reviews (40%).

4 EXPERIENCE AND REFLECTION

Until now, we have organized and applied the conference concept in the form of a paper submission and poster presentation four times in successive semesters. Over a hundred participants in the mandatory course achieved an average course results of 91%. According to the anonymous self-assessment of the students, evaluated summer 2017, at least 70% of the participants noticed the improvement of their communication skills which can be seen as a success with regards to the goals set in the introduction and section 2. The review process and subsequent evaluation by the lecturers shows a high quality of the submitted papers. The goal to publish research according to international conference standards is met by about 50% of the submitted papers in the course.

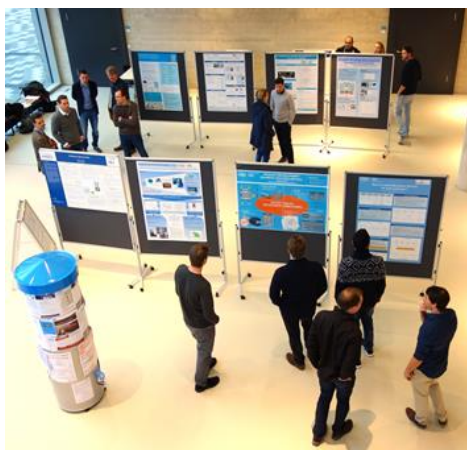


Figure 2. Poster presentation day

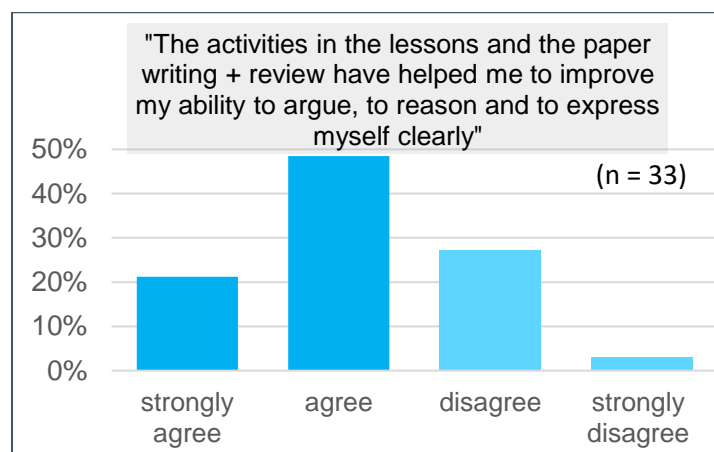


Figure 3. Evaluation of learning goals

The implementation of the course “Engineering Conferences” has led to a significant increase of activity among both faculty staff and students in social networks for researchers and scientists such as ResearchGate, thus increasing the visibility of research of our university. This effect is boosted by the final event of the poster presentations which vividly enhances scientific and informal exchange within the home faculty and its neighbouring faculty. The poster presentation is now an established bi-annual public event and it stands as one of the rare events in the curriculum where the result of learning is proudly made visible outside the classroom. In the course evaluation, students are very positive about this culminating event. They express personal satisfaction based on their success in delivering their research, which indicates that some of the engagement for a real conference can be captured.

However, the real conference remains the ultimate experience: Voluntary participation and a rigorous selection process are key drivers to self-motivation and “one-off” experience. Due to the course, we see a steep increase of interest among students to pursue their own research project with a focus to publish. With a local sponsorship of the Association of German Engineers (VDI) we are able to reward three conference participations per year for the best papers from the course. It has to be noted that not all students are happy with the effort required to master the course, especially those who are not interested in a research career. Despite the expressed improvement in effectiveness and precision with respect to communication in the engineering profession (see Fig. 3) the students do not yet realize this as a gain for a career in industry.

For the course preparation as well as during course delivery we make extensive use of the vast resources available on scientific writing practices and research communication. Here, we highlight two sources that have already appeared to be useful to a large community: Firstly, the survival guide on paper writing by Holst [10], salted with worldly-wise glimpses behind the scene and peppered with sketches by Jorge Cham, the maker of PhDcomics.com. Secondly, the compilation of the reference style required by the American Psychological Association (APA), provided by the University of Queensland Library [11]. It provides a precise answer, including examples, to the question of how to cite virtually anything. The following keywords are suitable to find more useful resources related to scientific publishing; they are loosely arranged in the order of increased caution required when employed in class: DOI.org, IMRaD-Style, JabRef, Shape of Science, ResearchGate, PhDcomics, SciGen, SciHub.

Eventually, we found ourselves doing research in teaching methods and scientific communication, resulting in a recursive learning – research – teaching experience. Since the course “Engineering Conferences” was our first genuine team teaching experience, we ourselves had entered liminal space and considerably stimulated our life-long learning adventure. How did this work out for our students?

From the beginning the students are pushed out into the open and exposed to active learning experiences such as group activity and, overall, to master their publication

process as their own project. This became especially apparent, when students were challenged to express their rationale, e.g. in outlining the main theme or thread of their work. A gain in literacy and thus confidence in their own work was observed from one lesson to the next whenever the student was willing to engage with her/his research. Many students openly expressed that genuine research on the work of others in the field was a first-time experience for them as a result of the course, and that they wished to have known about these findings during their thesis. We thus witnessed at various occasions that troublesome knowledge led to transformed thought and dialogue acted as a central element of transactional communication [2]. Such “magic moments” are likely to occur by opening liminal spaces, which small active learning elements can provide as well as the overall exposure to a conference situation.

5 SUMMARY

A master course module was designed, implemented, and tested with the goal to improve scientific communication skills of engineering students. As the name “Engineering Conferences” suggests, training is based around a mock-up conference, where students have to present the results of their bachelor thesis in a paper and as a poster. The combination of the following features distinguishes the course concept from similar approaches:

1. It has a storyline (conference participation) with a public finish (poster presentation day).
2. It engages undergraduate students as researchers and it turns the publication of their bachelor thesis into a project.
3. It is mandatory for all master students of the engineering faculty.
4. It is delivered by teachers/researchers from within the faculty, i.e. from “engineering native speakers”.
5. It can easily be copied and integrated into any STEM curriculum.

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The possibility of improving individual learning processes by a digital preliminary and introductory phase for civil engineering students

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INTRODUCTION

The German higher education landscape is dealing with the problem of dropping out of university without a degree for years [cf. 1,2]. Decisive for discussing this topic are the high numbers of university dropouts. For example, a recent study by the DZHW (German Center for Higher Education Research and Science Studies) shows that one in three undergraduates drop out of university without a degree in engineering (reference group: first-year students studying a Bachelor's degree at universities in 2010/2011) [1]. In a focused examination of the field of civil engineering, actually a drop out of the studies can be observed in 48% of the first-year students [1]. Other studies refer to similar figures on the European scale [2,3].

First of all students complete a complex drop out process before the final decision on disenrollment is made [1]. Besides the fitting problems regarding students' interest and study requirements, performance problems - especially in basic subjects (such as engineering mechanics (EM) or engineering mathematics) - are to be seen as a decisive factor within the various phases of this process [4]. A deepened examination of the performance problems point out that the critical motives are final failures in exams, a perception of too high study requirements or even self-doubts regarding the own suitability of the named subject [1]. Several studies [i.a. 5,6] justify the mentioned performance problems with a decrease of special expertise and mathematical knowledge among first-year students. However, in the introductory phase of the studies, there is not enough time to work on these knowledge gaps [7].

In general, the introductory phase in engineering courses can be attributed a central importance for the further success of the students during their studies. Figures show that already in the first semester, 42% of the drop-outs disenroll, in the following semester there are another 31% [1]. Henn & Polaczek [5] could already prove that students without study success in their first semester, describe the largest share of disenrollment at universities. Therefore, a direct connection between lack of study success in the introductory phase and the early termination of the studies can be constructed.

1 REFERENCE MODEL FOR QUALITY ASSURANCE

Heublein & In der Smitten [6] have adopted this problem and developed a reference model for quality assurance at faculties of engineering sciences. The reference model states that a variety of supportive measures at different times throughout the course of the studies can be helpful and improve the students success. Preventative measures can be used both in the preliminary phase (self-assessments and prep courses) and in the introductory phase (additional learning offers) (Fig. 1).

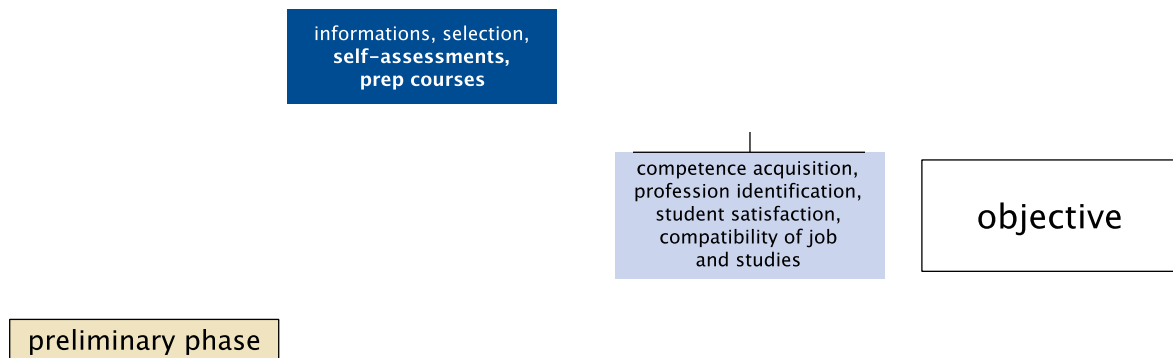


Fig. 1. Reference model for quality assurance in the course of the studies
(own representation in dependence on Heublein & In der Smitten [6])

Almost all universities are offering similar support measures for a long time, with the objective of making it easier for new students to begin their studies. However, the above mentioned offers are not very well received by the prospective and first-year students, further consideration of those who are absent indicate that these are mainly those who urgently need such assistance or offers [1]. So far, the question remains unclear whether such measures in general can cause any improvement or the type of content is inappropriate.

Approaches that embed these support measures into an online environment already exist. However, at present available online offers of the mentioned support measures (e.g. Studicheck¹, OMB+² or MathBridge³) only provide a few and mostly subject-unspecific topics. Engineering application contexts, such as the EM, remain completely untreated. So far, there are no relevant empirical findings regarding the effectiveness of such support measures.

As a result of the stated, the collaborative research project FUNDAMENT deals with this topic, the basic project idea is explained in the following section.

2 THE COLLOBORATIVE RESEARCH PROJECT FUNDAMENT

The support of individual learning processes in civil engineering studies by the use of digital higher education is the objective of the collaborative research project “Förderung des individuellen Lernerfolgs mittels digitaler Medien im Bauingenieurstudium” – FUNDAMENT (Improvement of individual learning success by the use of digital media in civil engineering). The collaboration of the University of Duisburg-Essen (UDE) and the Technical University of Kaiserslautern has developed a support concept that intervenes preventively in the preliminary and the introductory phase (Fig. 1). The support concept includes an online self-assessment (OSA) and an online prep course (OPC) in the preliminary phase; in the introductory phase additional learning opportunities are offered in the form of interactive online modules (IOM).

By using the OSA, an active engagement with their own interests and their fit to the content and framework conditions of the study program should be encouraged for the

¹ <https://studicheck.nrw>, accessed April 25th, 2018

² <https://www.ombplus.de>, accessed April 25th, 2018

³ <http://www.math-bridge.org>, accessed April 25th, 2018

prospective students. A feedback regarding the fitting of the own previous knowledge with the knowledge requirements of the favoured study course is also offered. The composition of the OSA is divided into two parts: first the determinants of the PPIK-model according to Ackerman [8] (vocational interest, intellectual commitment, crystalline and fluid intelligence) are tested using suitable instruments, while the second part focuses on previous knowledge. In addition to the mathematical basics (MB), which are relevant for civil engineering studies, natural science basics (NB) are retrieved. The NB are the fundamentals of physics needed in engineering mechanics. Prospective students will receive personalized feedback after completing the OSA, indicating gaps in previous knowledge. The implementation of the OSA took place in a moodle⁴-environment in combination with JACK⁵.

Downstream of the OSA an OPC is offered, which should serve to close the previously uncovered knowledge gaps. An OPC is an online prep course, also known as a bridging course, which normally starts a few weeks before the beginning of the studies with the objective of improving or deepening the school knowledge. As in the case of the OSA, there are hardly any empirical findings in terms of effectiveness, also the number of users is just about half of the prospective students [9]. The content areas are identical to those of the OSA (MB and NB). The OPC is based on the principle of learning by example [10] with informative tutorial feedback [11] embedded in an engineering context. The implementation also takes place in a moodle-environment in combination with JACK. JACK is a server-based system for executing computer-based tests with automatic feedback generation. Especially for exercises within the OPC, features such as parameterization, staged hints can be used as support and a detailed feedback evaluation.

Prusty et al. [12] discovered in a study of the introductory phase that new students have difficulties in understanding the key core concepts. So-called IOM could be helpful regarding this problem. Within FUNDAMENT, the IOM are understood as a "3-pillar concept", which is used in the EM1 and EM2 courses. The three pillars are learning videos (experimental videos to illustrate the core concepts and animated slideshows as teaching and learning support for calculating exercises), JACK exercises and online communication. Last-mentioned should strengthen the integration into the academic community. This is another major problem especially for programs with large numbers of new students and should also be regarded as a factor for the dropout [1].

3 METHODOLOGICAL APPROACH

The classic experimental and control group design is used to examine the effectiveness of the entire support strategy and the support measures (OSA, OPC and IOM) on their own. The students attending the EM1 (1st semester) or EM2 (2nd semester) courses in the previous conceptual design are assigned to the control group. If they use the integrated IOM in the mentioned courses, they are assigned to the study group (Fig. 2).

⁴ <https://moodle.org>, accessed April 25th, 2018

⁵ <http://s3.uni-duisburg-essen.de/jack>, accessed April 25th, 2018

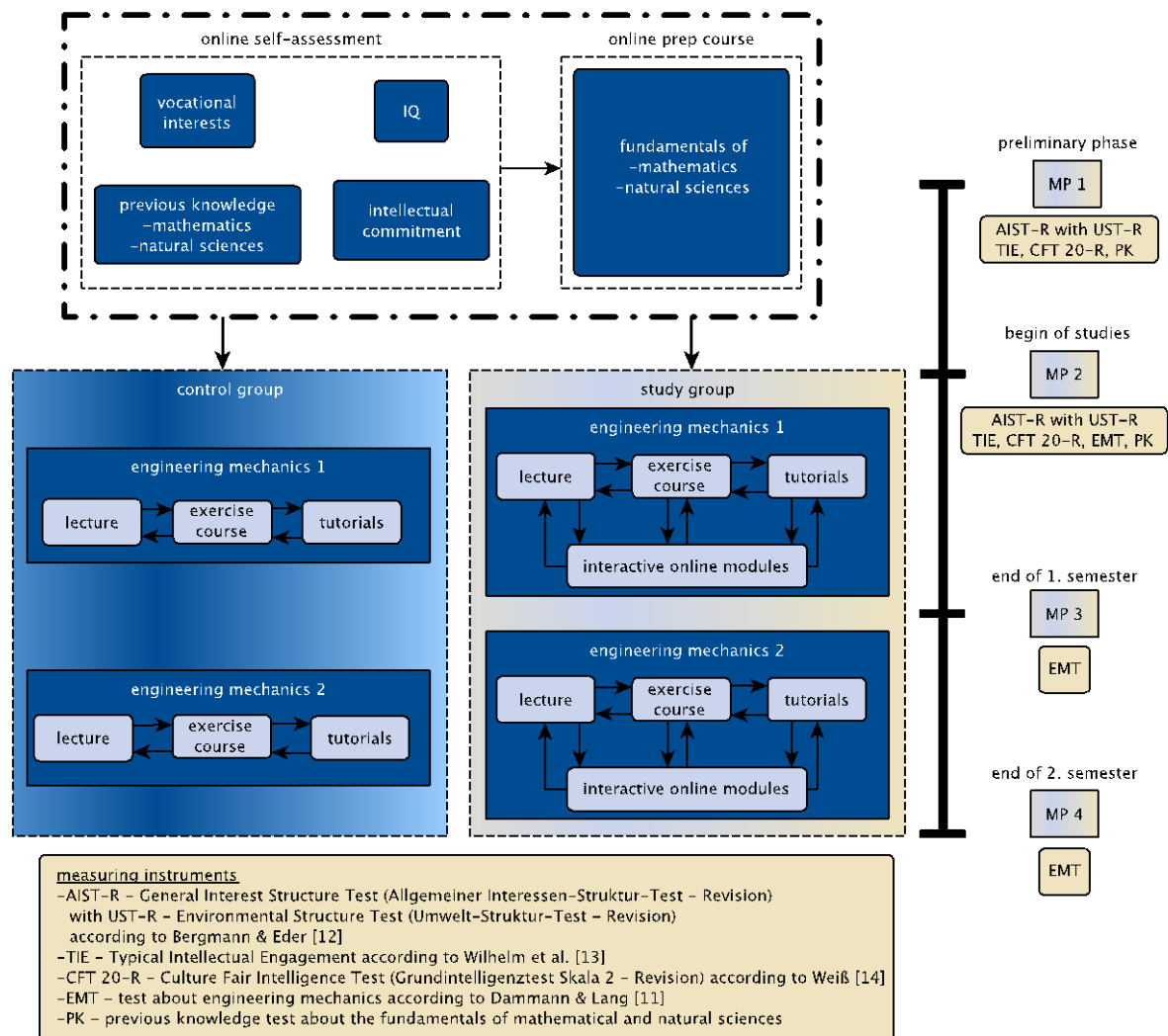


Fig. 2. Longitudinal design of the collaborative research project FUNDAMENT
(© Technology and Didactics of Technology – UDE)

The three online elements and the test instruments will be piloted from the winter term 2017/2018 up to and including the summer term 2018. Afterwards the data of the main study will be collected starting in the winter term 2018/2019 until the end of the summer term 2019. Both in the pilot phase and in the main study, the longitudinal collection of data takes place at four measurement points (MP) (Fig. 2).

With the help of the results achieved at the MP in the applied tests about engineering mechanics (EM, calculating ability and mathematical modelling ability) according to Dammann & Lang [13], the grade and the achieved credits, the effect of the support strategy is examined. Referring to the PPIK-theory, the construct of vocational interest is collected using the General Interest Structure Test (Allgemeiner Interessen-Struktur-Test – Revision AIST-R) along with the Environmental Structure Test (Umwelt-Struktur-Test – Revision UST-R) according to Bergmann & Eder [14].

The Typical Intellectual Engagement (TIE) is determined by a German-language questionnaire according to Wilhelm et al. [15]. Basic cognitive abilities are assessed

by using the Culture Fair Intelligence Test (Grundintelligenztest Skala 2 – Revision CFT 20-R) according to Weiß [16]. In addition, demographic data, but also information regarding the school career are collected.

4 OUTLOOK

The final stage of the pilot phase has begun at both locations. The online elements will be examined regarding their effectiveness on the basis of the collected data. Likewise, the data will be used to allow a revision of the elements in terms of the main study.

First evaluations of the individual MP indicate a low number of test persons. On a closer inspection of continuous data sets, over the previously collected data of MP1-3, only numbers in the single-digit range can be achieved. Despite an advertised test person compensation of 100 euro for the complete finalization of all four MP, a high drop-out can be assumed. This situation, which is unacceptable in consideration of the main study, is currently being analysed more closely and different approaches are discussed. For example, a readjustment of the survey to a paper & pencil-test would be conceivable, as well as an award of bonus points for the EM-exam.

ACKNOWLEDGMENTS

Special thanks go to the Federal Ministry of Education and Research (BMBF) for funding the collaborative research project FUNDAMENT (FKZ 16DHL1024 and 16DHL1025) within the framework of the guideline for the promotion of “Research on digital higher education” within the first funding line.

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Enhancing interdisciplinary hands-on education in the field of Magnetic Levitation Mobility and Signals Analysis and Control

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Conference Key Areas: Curriculum development, Engineering skills

Keywords: Engineering education, Interdisciplinary, Design-based learning, Challenged-based projects

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INTRODUCTION

Imagine a world with environmental-friendly, soundproof and safer modern trains. The second-year Design-based learning bachelor project *Signals and Systems* has introduced an interdisciplinary and hands-on approach to let students explore physics concepts of Maglev trains. This type of modern train is not resting on wheels but is levitated in a contact-free and friction-free way. The rationale to integrate interdisciplinary engineering approaches from Electrical and Mechanical Engineering domains is based on stimulating the application of trial-and-error methods in order to enhance out-of-the-box thinking. Physicists, however, apply a mathematical approach to analyze physical models using differential equations and Laplace transformation.

The integration of the interdisciplinary and hands-on approach in this compulsory project of the Applied Physics curriculum at the Eindhoven University of Technology (TU/e) is two-fold: first of all, we introduced more explicitly a limited number of engineering design steps also common to other disciplines, e.g. *analyse the problem, exploring graphic representation of the problem, or building a model*. Secondly, we also included interdisciplinary elements from Electrical Engineering, e.g. extension to the fully digital domain, Z-transform, and pole manipulation in the digital (z-transform) domain. In addition, the Mechanical Engineering input consisted of working in the frequency domain, recording a Bode plot of the open system, and optimizing control action.

In this project, we also have groups of students who carry out the DBL *Signals and Systems* project in the Innovation Space (InnSpace) at the TU/e university campus. This InnSpace location has been specially created to accommodate students' groups working on multidisciplinary collaboratively projects.

In this study, we explore to what extent interdisciplinary elements embedded in the DBL *Signals and Systems* project have influenced the quality of the students' final products. In addition, we examine whether the Innovation Space has encouraged students to work in a more creative and collaborative manner.

1 INTERDISCIPLINARITY IN ENGINEERING EDUCATION

1.1 Rationale for interdisciplinary education

Interdisciplinary education is becoming more and more an essential component of the curriculum of engineering studies and applied technical programs in higher education. The rationale to pay more attention to interdisciplinary in upper education curricula lies in the fact that the requirements of the industry are more demanding for newly graduates [1]. As the labour market is dynamic so are the developments of new products and equipment, technological processes and applications to meet societal, health, energy and economical demands [2]. These challenges in society claim for a broader approach to work in teams with experts from other disciplines *making use of tools, integrating information and data techniques, and using concepts or theories to solve complex problems* [3].

The need for interdisciplinary education becomes even more relevant as the expected knowledge and skills of both engineers and physicists are framed in accreditation frameworks [4]. This to assure that the output to the industry meets the expected requirements [5].

1.2 Theoretical considerations

Definitions on the concept of interdisciplinary in higher engineering education are numerous in the research literature [6]. The differences in the definitions lies in the models and focus of application in education. Interdisciplinary education is interpreted as a mean to teach students to solve challenging problems from multiple disciplines and perspectives [7]. Other modern approaches and supporters of interdisciplinary argue that this type of education is embedded in technological innovations in which interdisciplinary knowledge is essential to resolve complex problems in iterative loops in order to create joint solutions [8].

When applying interdisciplinary approaches into courses and projects to design interdisciplinary education, the level of integration varies by nature depending on different considerations [9]. From an interdisciplinary research perspective, interdisciplinary education can be implemented by applying gradually different knowledge sources (multidisciplinary, interdisciplinary and transdisciplinary) [10]; by the degree of collaboration among the disciplines [11]; by induction as a method to structurally apply in program design [12] or by the so-called design abduction [13]. Furthermore, prescriptive forms of designing education by constructive alignment can provide suitable means to design interdisciplinary education by focusing on the teaching and learning environments [14].

1.3 Innovation Space

The Innovation Space (InnSpace) concept is a rather new creation at the TU/e. The motivation to build such a creative environment was generated by models elsewhere such as the Design Factory at the Aalto University in Finland. Inspired by this model, the InnSpace at the TU/e aims at stimulating students to work on hands-on and challenging projects in multidisciplinary teams in a collaborative manner. The purpose is to create linkages with the industry, research organizations and businesses in order to generate an ecosystem of technological development. One of the main goals of this macro project is to create a community of students and support them in interdisciplinary engineering projects to generate prototypes together with staff and companies. In addition, the purpose is to *transform prototypes into products and services for society, creating new businesses and valorizing research at the university* [15].

The InnSpace at the TU/e is an open area in which students work in teams and interact with other groups. Students can work on experiments, make measurements, solder pieces or build own models in order to generate designs. The space contains meeting rooms and With this vision of interdisciplinary education and innovation in mind we selected a group of students to carry out part of the project in the Innovation Space. Our interest was to identify whether this innovative environment of the InnSpace would have an impact on students' final products.

2 THE DESIGN OF THE DBL SIGNALS & SYSTEMS PROJECT

2.1 Design-based learning and hands-on education

The aim of the DBL *Signals and Systems* project is to explore systems to maintain a Maglev train levitating by experimenting with repulsion forces between the magnets in the train and the electromagnetics in the track. The assignment is hands-on as students experiment with the levitation of a ball by measuring pull-up and pull-down forces. Students work through the open-ended design-based [16] project by exploring how a control system works, reviewing stabilization time and experimenting with calibration.

2.2 The interdisciplinary design of the DBL *Signals and Systems* project

Grounded in the theoretical considerations mentioned above and more specifically in Biggs & Tangs' constructive alignment theory, we focused on one of the elements of the model of teaching and learning in higher education, i.e. learning environment. Following the constructive alignment theory, we made more explicit a limited number of engineering design steps from engineering disciplines. The engineering design steps are taken from Mehalik and Schunn's taxonomy [17] and these are *analyse the problem, use graphic representation and build the model*. This taxonomy is validated and based on an empirical analysis of engineering design steps that take place in engineering disciplines. For the purpose of our study, we only applied however a few design steps of this taxonomy that fit the content and context of the DBL *Signals and Systems* course.

In addition, we also included Electrical Engineering (EE) and Mechanical Engineering (ME) interdisciplinary elements following Klein's approach on the degree of collaboration among the disciplines. In this regard from the Electrical Engineering field, we integrated topics such as the extension to the fully digital domain, Z-transform and the pole manipulation in the digital (z-transform) domain. With respect to the Mechanical Engineering field, we added elements such as the frequency domain, recording a Bode plot of the open system, optimizing control action from that viewpoint. Furthermore, students were to start with the system with open loop stable (upside-down configuration: electromagnet is below permanent magnet, pushing the permanent magnet upwards), optimizing and later extending this towards the "normal" configuration, with the electromagnet magnet above the permanent magnet, pulling it up, where the open loop is unstable, and an open loop Bode diagram cannot be recorded.

Moreover, following the open-ended approach of the design-based learning educational concept, the integration of the EE and ME elements has not been introduced in the form of a framed assignment. On the contrary, short introductory lectures have served to present new concepts on disciplinary topics in order to widen students' understanding on those. The open-ended character lies therefore in providing students with insights so that they are stimulated to further conduct experiments and analysis, carry out tests and based on results to apply iterations in the models. By doing so, students gather new information and facts in each design step and apply this new knowledge in order to generate and produce new insights [9].

It is worth mentioning that the rationale to integrate EE and ME disciplinary themes was not only based on including elements of these disciplines but also to stimulate a rather trial-and-error approach to problems and look for solutions. On the contrary, the physicists' approach follows rather linear process to analyze physical models using differential equations and Laplace transformation.

3 METHODOLOGY

3.1 Research methodology

The methodology we have applied in this study followed a triangular approach. In order to collect students' perceptions on the interdisciplinary elements in the DBL *Signals & Systems* project, we developed a structured Likert-scale questionnaire (1 to 5 scale). The majority of the questions for this survey were taken from a previous research study and has been readjusted for the purpose of this research. The questionnaire has been previously validated [16]. We also interviewed students, tutors and lecturers to identify interdisciplinary elements applied in exploring physics concepts and in delivering a proof of principle model system. Finally, we reviewed the students' reports in order to identify whether the interdisciplinary and hands-on elements have influenced the quality of the products, the approach taken towards solving the problems or the steps followed in order to solve the problem.

3.2 Participants

The participants in this study were second year bachelor students enrolled in the Applied Physics study program. The total number of students that followed the course DBL Signals & Systems was 146. For the purpose of this research N= 45 students took part in the study, N= 22 students conducting experiments in the Innovation Space location and N= 23 students working at the AP building premises. The selection of the groups involved in this study was done as follows: we selected four groups at random in order to collect perceptions and observe students' approach to solve the problems within the regular labs. In addition, four other groups were selected to carry out the project in the Innovation Space premises. The selection criteria to choose these four InnSpace groups were based on their progress shown in the first part of the course involving levitation of a ping pong ball emulating the levitation magnets of a train, and in particular representing the effectiveness of a configuration for a train and the system to keep the ball afloat. Likewise, the selection of the tutors was completely arbitrarily done as the tutors were previously randomly distributed among the groups.

4 RESULTS

4.1 Students' perspectives

We collected students' perceptions by a structured Likert-scale survey consisting of 12 questions. For the purpose of this study, we only present the results of the questions pertaining to the interdisciplinary character of the project (Q1 to Q3) and the questions related to the impact of the location, e.g. InnSpace or the regular lab premises (Q4, Q5 and Q12).

Table 1. Overview mean of groups with & without interdisciplinary elements

	Groups without interdisciplinary approach		Groups with interdisciplinary approach in Innovation Space	
	M	SD	M	SD
Q1	2.76	.99	3.31	1.04
Q2	2.90	.99	4.00	.69
Q3	2.65	.87	3.40	1.18
Q4	2.80	1.19	3.54	1.10
Q5	3.77	.75	3.40	1.25
Q12	3.76	1.09	3.22	1.02

The results in table 1 indicate differences in perceptions between the groups that have been exposed to the additional EE and ME interdisciplinary content within the Innovation Space and those that remained in the premises of the AP traditional labs. Looking at the results of some of the questions² (Q1, Q2, Q3) we perceive substantial differences in students' perceptions

² Q1 – The project is interdisciplinary (i.e. design steps from other disciplines, for instance in designing a solution); Q2 – The project is interdisciplinary (i.e. there are concepts or topics from other disciplines rather than only Applied Physics); Q3- The location, Innovation Space, has inspired me to work in a more creative and innovative manner; Q4 – The location, Innovation Space, has inspired me to work in a more collaborative manner; Q5- The project is open-ended, e.g. there is no one solution given, there are possibilities to look for alternatives, no specifications of the final solutions are given; Q-12 – The project represents a real-life problem as, for instance, I was working in the industry (question for students in the labs). Working in the Innovation Space resembles better the idea of working in a real-life project representing industry problems (question for InnSpace students)

related to the interdisciplinary character of the project, both in the design steps taken from other disciplines as well as the content provided. Regarding the perceptions on whether the location has inspired the students to work in a more creative and collaborative manner (Q4), results indicate that students working in the Innovation Space have a more positive opinion on the influence of this location in the way of working. This due to the fact that the premises at the InnSpace are open extensions in which students work around a table. This provides more opportunities for collaboration among the group members and with other groups as well. There is however little differences with respect to the open-ended character of the project (Q5) as the set-up of the course contains ill-defined aspects in the assignments. Finally, the question (Q12) on whether the Innovation Space resembles better the idea of working in a real life problem has not major impact on students' beliefs. Differences in results may be influenced by the fact that the four groups selected to carry out the project in the Innovation Space were chosen based on the quality of the mid-term results (i.e. groups managed to let the ball floating) they produced.

4.2 Analysis of reports

We selected specific criteria in order to compare quality of reports and appreciate whether essential elements of the design process and interdisciplinary education have been applied by the students. In the tables below we present an overview of the Innovation Space students and students carrying out the assignments in the labs. Some of the criteria on interdisciplinary cannot be used for comparison as the groups in the labs had not access to additional interdisciplinary education.

Table 2. Overview of students' Innovation Space scores

Criteria \ Groups	3	5	7	15
Criteria to make adjustments in the model, or optimize performance	+	++	+	+
Adjustments in the model, or optimize performance and validating the model and analysing	+	+	+	++
(More) iterations as a result of testing different models of EE/ME elements	+	++	++	0
Z-transform, and pole manipulation in the digital (z-transform) domain (EE)	+	+	+	-
Optimizing control action (ME)	+	++	0	0
Group's final grade	9	9,5	9	8,5

Table 3. Overview of students' scores in lab premises

Criteria \ Groups	2	4	9	11
Criteria to make adjustments in the model, or optimize performance	+	0	++	0
Adjustments in the model, or optimize performance and validating the model and analysing	++	+	+	+
(More) iterations as a result of testing different models of EE/ME elements	0	0	+	-
Z-transform, and pole manipulation in the digital (z-transform) domain (EE)	*N.A.	N.A.	N.A.	N.A.
Optimizing control action (ME)	N.A.	N.A.	N.A.	N.A.
Group's final grade	8	7	9	7,5

*N.A. Not applicable

From the lecturers' perspective, the Innovation Space groups with additional interdisciplinary input score roughly one point higher than the groups which remained in the AP building premises. However, it is worth mentioning that the InnSpace students were selected based on the quality they produced in the first weeks of the project. Furthermore, it is remarkable that the Innovation Space groups have certainly made more use of the additional interdisciplinary components. As a matter of fact and according to the lecturers' findings students have applied the Bode plot, used the low-pass filter as well as the discrete transformation among others. Surprisingly, students carrying out the project in the InnSpace mainly follow the physics approach during the project implementation and experimentation. Another observation by the lecturers is that the Innovation Space groups also had more possibilities to make use of the newly gained knowledge for instance through the experimentation with the disturbance of the light in the room (disturbing the optical sensor in the setup). In particular, one group even made a special box as this group certainly went deeper into their analysis to protect the floating ball from external factors such as light. Another annotation is that these groups also used more original display techniques and optimization techniques, e.g. 3-D plots from the poles, Ziegler-Nichols approach, etc.

The quality of the measurements and simulations is not very different between the AP lab and the InnSpace groups, but the quality of the analysis by the InnSpace groups is much better.

4.3 Students' observations and interviews

Semi-structured interviews with students carrying out projects at the InnSpace premises reflect similar findings regarding the working method. Students both in Innovation Space and in the traditional premises mentioned that the use of a trial-and-error approach is a logical process of testing how for instance the PID controller works when optimizing the system. In addition, the interdisciplinary components of the InnSpace assignment have not enhanced a different approach to work. The InnSpace groups recognize indeed the EE and ME components in the assignments and used for instance the theory on adaptive PID controller or linearization for discrete analysis although these have not been completely practiced by all InnSpace groups.

Reasons for this have to do with time constraints rather than with the assignment itself. According to the students, the influence of the interdisciplinary components has indeed enhanced the hands-on aspects of the project as it requires more experimentation with multiple ways of controller systems, the improvement of the systems, adjusting the frequency response and stimulates the options to use different methods. In terms of the engineering design steps, the fact that the InnSpace require more analysis and experimentation in designing the system and building the model implies therefore a deeper exploration of, for instance, how a low-pass filter works and the calculations of the values. This encouraged more iterations in building the model, for example, in making the system more stable with the use of lead-lag compensator. Regarding graphic representation, there is no difference between InnSpace and the other groups. The specific added value of the InnSpace is that the collaboration among group members and the communication with other groups has increased. Students have more possibilities to move around in the open space. This stimulates communication easily.

5 CONCLUSIONS

The implementation of the DBL *Signals and Systems* project has been an excellent opportunity to explore how interdisciplinary components can play an important role in education. Efforts made to embed these EE & ME components are obviously more evident in the InnSpace groups than in the groups working in the labs. Slight differences are also perceived in the analysis of the system and in building the model as the InnSpace groups studied and used additional theory, i.e. the Bode plot, used the low-pass filter as well as the discrete transformation and an adaptive controller in building the system. However, these steps are not commonly applied by all InnSpace groups. Likewise, although a different working approach was expected this has not been always obvious and students still use the physics way of conducting experiments by gaining first the insights from literature, using the linear process in analysing physical models and transforming these into differential equations to apply those in building a model.

The results of this project shows an interesting approach to introduce interdisciplinary as a vehicle to design challenging projects. We have gradually introduced content aspects from two engineering disciplines and observed that students make use of these disciplines in their designs. However, due to the fact that selected groups performed optimally in the first part of the project we cannot easily prove that the interdisciplinary aspects influenced the quality of results. This project opens up new venues for further experimentation to design interdisciplinary hands-on projects. Implications for further research imply adjusting the design and set-up of the DBL project *Signals and Systems* by, for instance, including more explicitly the engineering design steps from Mehalik and Schunn's taxonomy. This will reinforce the trial-and-error working method. It will also encourage a more in-depth approach to analyse, experiment and test while building a model. These adjustments in the assignment will ask as well for other forms to assess of students but also in teachers' and supervisors' attitudes in order to align the project more constructively.

Regarding the Innovation Space, this element depends strongly on the new premises being built at this moment at the TU/e. The vision of the Innovation Space is still under construction and the implementation of this ambition lies strongly on making a practical environment in which students can easily collaborate with students from other disciplines, create linkages with the industrial partners and foster creativity and innovation. This will immediately encourage the multidisciplinary vision of the Innovation Space.

6 ACKNOWLEDGMENTS

We would like to thank the second year bachelor students of the Applied Physics department for participating in this study. In addition, we would also like to thank the tutors who supervised the students for their input during the project and in this study.

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Students' View about Development of an Electronic Tool for Self-evaluation of Engineering Education as Thesis project

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Conference Key Areas: Engineering Skills, Quality Assurance and Accreditation, Innovation as the context for Engineering Education

Keywords: students view of education, quality, real life projects, IT development

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INTRODUCTION

The purpose of this paper is to give an overview of a student driven project that had the goal of designing and implementing a user-friendly application for managing e-form based surveys. The application was designed to be used as an electronical tool in an ongoing project exploring a practical approach to quality assurance through continuous self-evaluation and cross-sparring. Publicly available survey management tools did not provide the support for result analysis in the way that was needed in the project, which is why the clients wanted to develop a tool that was designed specifically for the needs of the project.

The task was undertaken by two final year students as a thesis project. The project was carried out in close cooperation with the clients, and feedback from the clients was utilized throughout the development process. The application was developed using modern web technologies and currently relevant frameworks to speed up the development. The paper will focus on covering the methodology used in the project as well as the application design.

1 THEORETICAL BACKGROUND

1.1 Node.js platform

Node.js is a popular JavaScript runtime that is widely used as a server-side platform to run JavaScript based web applications. The runtime is based on Google's V8 JavaScript engine, and it utilizes non-blocking event-driven architecture with the single threaded programming model. [1.] Node.js is different from other web development platforms for it can create its own server to handle requests and serve static files, and therefore programs written for the platform are not necessarily dependent on a separate server layer such as the Apache server [2].

One reason for the high popularity of Node is its capability to handle requests quickly, which has made it a preferable platform for fast and scalable web applications. The architecture the platform is based on makes it possible to run operations asynchronously so that slower operations do not significantly impair the performance of the whole application. [1; 3.]

1.2 Frameworks

Instead of just adding additional functionality to an application like modules and libraries, frameworks generally function as a foundation for an application. There are different kind of frameworks and some of them only provide a layout for the developers to build upon, whereas so called full-stack frameworks define entirely the technical implementation of an application. [4.]

In web development, frameworks can be split into frontend and backend frameworks. Backend framework is a component of the server side that is usually involved in the process of request handling. Frontend framework is part of browser side that usually affects how a web page is rendered and how it reacts to user interaction. [4.]

1.3 Sails framework

Sails is a backend framework for Node.js platform. Sails is built upon Express framework and it consists of multiple smaller modules. Sails contains large amount of functionality in itself, and it defines strict conventions for the development. Due to the enforced guidelines, the development with Sails is straightforward and the framework is considered to be highly user friendly. A major feature of Sails is that it makes it possible to utilize multiple different database solutions simultaneously with a Sails application by supporting relations between database models stored in different types of databases. With Sails database models are defined as

separate modules by specifying the attributes and model relations. The system allows for extensive customization of a model, and the database library will enforce the defined schema, and update or create a database table accordingly to match it. [4.]

1.4 Koa framework

Koa is backend framework based on Express developed by the same people, and it uses JavaScript generators to define middleware functions. Koa is minimalistic framework that is essentially a middleware-based HTTP (hypertext transfer protocol) server library. Generator syntax allows the code to be written in almost synchronous style which makes writing callback dependent middleware simpler and the code more readable. Suggested use cases for Koa include lightweight web applications and HTTP APIs (application programming interface). [4.]

2 SYSTEM DESIGN

2.1 Overview of the application

The application is an e-form based survey management tool, for managing, running and analyzing the results of surveys through a web client. The application is designed specifically for the surveys of the self-evaluation system used by the clients, but it can be used to run practically any kinds of surveys. The self-evaluation system used in the project is based on a specific set of questions and the statistics gained by comparing the answers of different answerer groups.

The questions of the self-evaluation system are multidimensional, meaning that the questions are evaluated using multiple sub questions that are also called criteria. A typical question of the system would be to evaluate the urgency and importance of an issue. In this case the issue is the question, and the urgency and importance are criteria used to evaluate the issue.

The flow of the application is such that users are expected to login or register to the application in order to gain access to all of its features. In addition to creating and answering surveys, users are able to manage groups and evaluations that are used in specifying a target group for a survey. The application offers a graphical representation of the results of survey, and additionally the results can be downloaded as a separate file.

Each user of the application is attached to a group or groups that represent the user's background, like for example whether a user is a student or a teacher. Answers to a survey are grouped based on the answerers' groups, so that the answers immediately reflect the discrepancies between each group's answers. The target group of a survey is defined by so called evaluation group that consists of multiple user groups. Evaluation groups can be used multiple times, making it simple to run multiple surveys with the same target group.

To make recreating a survey simple, surveys can be saved as templates for future use. When creating a new survey, user can select any existing template as foundation for the survey so that all the questions of the template will be immediately available in the new survey. All the questions attached to templates are also separately available for importing when editing an existing survey.

Answering to a survey can be done in two ways. Users that have registered to the application can see and access all ongoing surveys matching their user groups. Surveys can also be distributed by sharing a survey specific link that can be used to quickly answer the survey without registering.

2.2 Modeling

In this section, the word model is used to refer to a database model that defines a structure for data being stored to a database. The modeling started by defining the minimal components needed to create a tool for survey management. This included the models for containing information about the users, surveys, questions, and answers. The system was extended by adding the group and evaluation models to fulfill the requirement for more detailed result analysis, and a surveySession model to combine the answers of a single user. The models and their respective relations can be seen in *Fig. 1*.

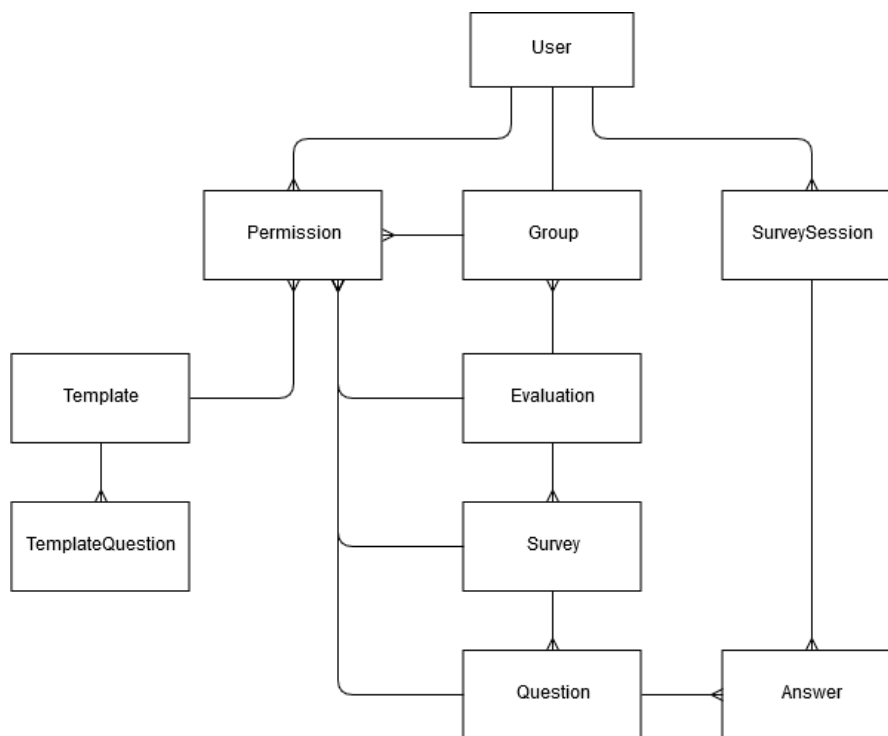


Fig. 1. The models of the application and their respective relations.

The evaluation model represents the target group of a survey, and it contains one or more groups. The evaluation attached to a survey specifies which groups are able to participate in the survey. The evaluation model was added so that target groups could be easily shared between surveys and recreating a survey with the same target group was simple.

The major question in designing the question model was how to implement the support for multiple sub-questions. It was evaluated whether the question criteria should have its own model, but to keep the questions self-contained it was decided to implement the criteria as a JSON field of the question model. The criteria field is expected to be an array of criteria objects, and a particular structure that can be seen in *Fig. 2*, was designed for the criteria objects.

```

{
  "title": "Importance",
  "description": "",
  "type": "scale",
  "options": { "min":0,"max":5 }
}
  
```

Fig. 2. An example of a criteria object.

The keys “type” and “options” of a criteria object are used to define what kind of question the criteria represent. The two criteria types currently supported are linear scale and multiple

choice. In the client side, the criteria type defines the type of input element rendered for the question, and the options contain the information used to customize the input. For a scale type, the options contain the minimum and maximum values for the input, and for a select type, the options contain the selectable choices, and their respective values. These criteria types were selected, because the questions of the client's evaluation system can be expressed using these two types. The criteria structure was something that the developer team wanted to leave as flexible as possible, so that additional types of criteria could be easily added later on.

2.2.1 Ownership of records

In the beginning, to restrict access to the instances of models that users can interact with, these models contained an owner attribute defining the one user allowed to modify a specific record. The owner attribute was commonly set when a record of a managed model, like a survey or a group, was created. But since the application was originally designed to be used on organizational level, it meant that multiple users would need to access the same records. The owner attribute was removed in favor of a new Permission model used to create ownership defining relations between the user model and any of managed models. Permission model contains the ids of the user and the target instance, and name of the target model. With the Permission model, multiple users can have access to the same managed record. The Permission model was further extended by adding a new attribute defining the allowed operations. With predetermined values for each type of permission, the attribute is used to define whether a user has the permissions to view, edit or delete a specific record.

The tradeoff that comes with the high customizability is that checking the ownership of managed record always involves an additional database query. This also means that retrieving records from the database based on permissions requires the queries going through an extra table. Creating new records also becomes more complicated as it must be guaranteed that no instance of a managed model gets saved without also saving at least one permission record pointing to it. Preventing the database from ending up in an inconsistent state was achieved by wrapping the two insertion operations inside a transaction, meaning that if either of the operations fails, the database will be reverted back to its original state.

2.2.2 Templates

To address the requirement for being able to quickly recreate surveys, two additional models were implemented. The idea is that the new models work as counterparts for the survey and question models, so that a survey can be alternatively saved with its questions as a template and template questions. In the application's current state, templates are considered as public property, and anyone creating a survey has the option to choose an existing template to use as the foundation for the new survey.

2.2.3 Survey sharing

For easier distribution of surveys, a convention for sharing them was developed. The system is based on a new link model built around the idea of a unique key used to access a particular survey. The model is also used to specify which group of the related survey's evaluation the users accessing the survey this way will represent. Alternatively the decision can also be left for the users. A survey can have multiple link objects for different groups at the same time, so that the distribution can be customized to a greater detail.

2.3 Initial technologies

Node.js was selected as the platform for the application, because everyone in the developer team had previously worked with it, and it was suited for the goal of building a modern scalable web application with a large number of third-party modules available.

It was decided early on that a framework was going to be used as a foundation for the application to speed up the development, because time and manpower for the project were limited. To maximize the development speed, Sails was selected as the main framework for the application, because it provided a set of clear guidelines for development, and all the functionality needed to immediately start designing the actual application logic.

2.4 Changing the technology stack

Later in the development it became clear that Sails was the cause for the major problems the team was dealing with. A lot of time was used to create workarounds for the Sails related issues, and in the end, it was decided that the initial product would be finished using the original stack and Sails, but once delivered to the client, another version of the application would be developed with new frameworks for the backend implementations and database operations. The initial version became a test run for the concept, and any features needing to be reworked would get an overhaul in the next version which would replace the original one in production once finished. After delivering the initial version by the deadline, the schedule to develop the next one was more open-ended.

For the final version Koa was selected as the backend framework, because Koa was highly configurable and didn't enforce any strict conventions like Sails that had previously added a limiting effect to the development. Adopting Koa meant redesigning the entire server component, but this way it could be customized for the application's needs.

Due to the high amount of functionality in the front end, React was adopted to the project. React is a library for implementing frontend scripting, and the goal with it was to simplify and increase the maintainability of views that had large amount of scripting attached. The idea of adding SPA (single page application) like functionality to application was considered but dropped in favour of preserving the existing backend logic.

The major task in changing the backend solution was to design the server component and the model system, which were this time not provided directly by the frameworks. Once the foundation was implemented, changing the old code base to use the new system was fairly straightforward.

3 DEVELOPMENT

3.1 Methodology

The development process happened in close cooperation with the clients, and there were meetings about the project every couple of weeks. The meetings were used to inform the clients about the progress made in the development, and because the initial design and requirements for application were relatively loose, time was also spent on polishing the design together with the clients. Since the clients were actively involved in the development process, it was phased so that there were milestones set between every meeting with the goal of having something new to show the clients.

In the early phases of the development certain features were prioritized to create an early working version of the application, so that it would be possible for the clients to actually test the application and better assess the current direction of the development. The feedback from the clients was used throughout the development process to shape application. The production environment for the application was also set up yearly in the development, so that a working version was always be available for the clients for testing purposes.

3.2 Outcome

The application was successfully created in the given period of time, and the survey management part was built successfully to meet the requirements of the client, and the application can be effectively used to create and distribute surveys with multidimensional questions.

The way the users and answerer groups are linked together underwent multiple design changes during the development, and in the end, it was not highly approved by the clients, because of its complexity. The concept of answerer groups was tied so tightly to the application design, that despite it being heavily simplified, it makes the flow much more complex compared to other available survey management tools. The goal of having the application easy to use, was not met in this regard, and should the application be further developed, the enhancement of the usability should one of the priorities.

4 CUSTOMER SERVICE IN REAL LIFE PROJECT

Ever since the early phases of the project, working versions of the application were made available, so that the clients were able to manually test the application during their own time or the regular project meetings. The meetings also included presentations of the application usage and core concepts. To better support the demonstrations and testing, a user manual for the application was created and maintained during the project.

4.1 User guide of the system

The user guide is a documentation used to cover all the essential features of the application, and how to effectively use it. The guide covers everything starting from getting started with the application to detailed descriptions for all of its different views. Because the application design was gradually finalized during the actual development process, the guide had to be frequently updated to cover all the features of the application. *Fig. 3* contains a snippet taken from the user guide describing the view used for editing a user group.

In the edit group page you can:

- Add users to a group
- Remove users from the group
- Give users administrator permissions
- Assign users to an evaluation
- Remove users from an evaluation

Adding users

To add users to a group, start typing the name or username of the user you wish to add in the **Add users to the group** field. When you find the user you are looking for, click it or press enter when the user is highlighted to select it. If the user is not found, it means that they have not signed up.

When all users you wish to add are selected, click the **Add** button next to the search field to add them to the group.

Fig. 3. A snippet from the user guide.

During the project meetings the latest version of the guide was often given to the clients to test if they would be able to properly operate the application only using the guide as a reference. This method of testing often generated practical feedback about both the guide and the application itself, and the method was by far one of the more effective ways of assessing the helpfulness of the guide and the general usability of the application. The long term goal was that an average user would be able to fully utilize the application in survey management just by reading the usage guide.

4.2 Technical documentation for further development

In student driven projects the technical documentation of the delivered artifact is especially important, because the maintenance and any possible further development is likely to be undertaken by different people than the students who originally created it. Without a proper documentation the further development of an existing system is greatly hindered if no one from the original developer team is present, and ultimately it may even lead to the abandonment of the whole application.

In this project the technical documentation is largely built inside the application itself. The flow and the methods are designed and named to be immediately understandable to anyone who has any experience in programming. The documentation system of the programming language is used to clearly express the function signatures, and all the complex functions are associated with comments explaining the general usage and implementation of the function. *Fig. 4* demonstrates how a function used for adding permissions to managed records is documented inside the application by describing its signature and usage.

```
/**
 * Grant one or more rights to a user.
 * @param {User} user the instance of the user record to whom these rights
 *   will be granted
 * @param {Array<string|Number>} rights to allow either as strings or direct
 *   bitmask values
 * @returns {ManagedModel} this instance of chaining
 */
allow(user, ...rights) {
  if(!(user instanceof User) && !user.id) throw new Error('User must be an
    instanceof user or have an id')
  if(!(user instanceof User)) user = new User(user);
  this.permissions.push(new Permission()
    .to(user).for(this).allow(...rights));
  return this;
}
```

Fig. 4. An example function from the application.

The application is based on currently popular frameworks, which is why the developer team refrained from creating a comprehensive technical guide for the application, for to understand the technical implementation of the application, it should be enough to read the general principles of the major frameworks used in the implementation, and go through the conventions and comments found in the actual code base. Instead of explaining the details of the application, the technical documentation focuses on covering on how to get started with the development, and the details of the production environment used to host the application. The documentation gives an overview of the technical implementation, and points out the relevant technologies a developer should be acquainted with to fully understand the details of the implementation. The documentation also contains a step by step guide for setting up the development environment for the application, and a detailed explanation about running the application in production environment.

5 FINAL REMARKS

From a student's perspective the project was an intriguing opportunity to put the skills acquired during courses to a test. Working together on projects with other students is something that almost every course contains, but creating an actual tool for a specific use case in cooperation with a client made the process more challenging. The project required thinking outside the box and combining all the different skills learned during studies, as it was not enough just develop the application and get it up and running. This kind of software project requires taking a multitude of other things into consideration, like how the maintenance is going to be handled and what kind of documentation the users are going to need. All of these things are at least familiar practices or concepts from the courses, but having to apply them to real life project is not always simple, and often requires doing some additional research on the subject.

The project itself was a convenient subject for a thesis, because it was a complex project and it included a lot of different technologies as well as both practical and research oriented work. This made it possible to fine tune the angle of the thesis making it possible to focus on covering the implementation of certain components of the application, or taking a more theoretical approach through covering the research work and design decisions made during the development. The complexity of the project also made it a valid subject for thesis for multiple students, because the subject could be narrowed so precisely that theses would not overlap significantly.

Working closely with a client is an interesting way of working, and it provides both unique benefits and challenges to the development. Having a constant source of feedback is highly beneficial, but it may also prove sometimes to be counterproductive, for it may cause the specifications for the product's features to suddenly change, or introduce new requested features in a rate that can't be sustained. An influx of changes to the design is never desirable, and this emphasizes the importance of having a clear design to follow as early in the development as possible. However, changes and improvements to the design are still a necessity throughout the development if the aim is to create the best possible product, but for the development process to be straightforward, it is best if the changes are kept minimal.

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Development of entrepreneurial education for engineers

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Conference Key Areas: University-Business cooperation, Engineering skills, Curriculum Development

Keywords: Entrepreneurship, Engineering education, Mentor

INTRODUCTION

Enterprises are fundamental for the societies. They offer employment and the state gains tax assets based on salaries paid to employees. Most enterprises are micro enterprises or small and medium-sized enterprises – SMEs – and they are growing more than the big ones. A big part of the SMEs are technology-based. In Finland 70 % of the industrial companies produce and sell innovative products [1]. It is necessary that also SMEs achieve and export competitive products. Especially the successful technology products are important. Generally spoken, the trade balance should be positive. A country and its companies should have more sales than purchases. New, vital, technology-based businesses are needed to make it possible. Therefore new capable business-oriented engineers are needed. The role of universities of applied sciences is important because they educate engineers, who are the main professionals especially in SMEs, who develop products and business. This is the basis to the fact that universities of applied sciences need to offer more education especially in entrepreneurship to engineering students.

The main focus in engineering education is on technology but it is not enough to have capacity to carry out the product development and the production. Additionally the products must be taken to the market. From an idea to the market there is a long multiphase pathway to pass. To arrange this complex chain of actions, an enterprise is needed. In technology-based industry, the convenient background for an entrepreneur is engineering degree. S/he has an adequate education in order to understand the technology that fulfills the needs of clients. Still, additionally, understanding of the technology market and business is needed.

This research report includes a literature review about entrepreneurial education of engineers. Also, the result of questioning to engineers who have taken the engineer degree is presented. They have given a statement about the education and made proposals to improve it. It is rare to find this kinds of research reports. Additionally, this paper discusses the characters of potential engineering students and the educational approach of the universities to train successful entrepreneurs of the technology field.

This research is a part of series of small researches to prepare a wider research about entrepreneur skills, education and achievements of engineers graduated especially from a university of applied sciences.

1 GENERAL

1.1 Technology-based companies

All the start-ups do not survive up to a stable growth stage and therefore there should be a large number of start-ups so that some of them would continue their existence for a longer time. The companies have to survive the start and first years after finding an idea and the first development stage. In most cases the engineers are trained to implement technical product development but not enough to take care of the marketing and the entire business. Capable entrepreneurs are the ones who make it happen. They are economic visionaries fueling economic growth [2]. A large part of successful enterprises are based on technology products or services and they are important because they have possibilities to design, produce and market the products to export. The role of engineers as professionals and managers of those companies is crucial. Many research reports discuss the technology aspect of the engineering education but a minority discusses the entrepreneurial education. On the other hand a general business education that is not focusing on any specific industrial sector is a popular subject in researches. Concerning the technology-based companies, the more advanced the used technology is, the more often the founder of the company is an engineer.

1.2 Role of engineers

During the last decades the need to offer entrepreneurial education for engineers has been discussed more and more. Universities of applied sciences have a big role in teaching engineers to work in SMEs. They can become entrepreneurs immediately after their graduations or after a period as an employee in a business of another entrepreneur.

Often a technology-based business produces and sells physical products. In order to have a successful product, good ideas have to be found. These ideas are evaluated and the best one is chosen. The process is long from the idea to the product that provides profit on the market. It includes many different phases. The idea is further processed in product development. Thereafter it is ready for production. Simultaneously the marketing is planned and prepared. Once the product has been launched on the market it still is under constant further development based on reactions and needs of customers. Additionally, during this process many details of management and leadership as well as legal issues and contacts with public administration have to be taken care off. Normally, in universities the education of this process is divided into different subjects and disciplines. It means that different students are educated for different stages of the pathway of the product process – engineers for technology stages and students of marketing and economics for other stages. In traditional education one person does not learn the entire holistic chain which is needed in real business. This is the main problem in education and causes difficulties in setting up and developing technology-based companies.

The big companies have better chances of employing people who have been trained especially to certain special tasks because there are enough special tasks for full time professionals. In SMEs and especially in starting start-ups the entrepreneurs has to take care of everything. They have to know what special knowledge is needed and where it can be acquired. They have to be able to communicate with other specialists effectively. In this

case the holistic general education is better but at the same time there has to be a strong technological base in order to understand the technology of the product and production. Also, it is necessary to understand the situation of the client who is often using the product in a technical environment. A suitable person for this position is a business-oriented engineer who has been educated in the right way.

1.3 Role of universities of applied sciences

The role of universities is to provide the companies in the area with professionals who possess right skills and knowledge. That is why the universities have to be aware of the circumstances where the graduated engineers will work as entrepreneurs. Universities of applied sciences are very suitable players in educating entrepreneurs into the technology industry. The main focus is not on preparing students for a researcher career but more on practical design and production. The mental attitude is to achieve practical results effectively. The amount, method and content of the entrepreneurial education of a university depend on its strategy. Because traditionally the focus is on technology, there has not always been attention and interest to include entrepreneurship in the curricula. The universities of applied sciences have good possibilities to take a bigger role in developing entrepreneurship in their operating areas. Business-oriented engineering education does not need necessarily to lead to entrepreneurship but it is also good if it leads to an entrepreneurial attitude mode to work inside a company as an employee. This kind of behavior has been widely called intrapreneurship.

2 OBJECT AND METHODOLOGY

The purpose of this research was to find grounds for entrepreneurial engineering education and to suggest means to enhance it. Firstly the characters of successful young entrepreneurs are discussed. The second topic is to conduct an inquiry to engineers who have graduated from universities of applied sciences and academic universities into the perception of their education according to the readiness to the entrepreneurship. The research has been made from the point of view of an experienced engineer. The third topic is how to arrange a convenient entrepreneurial education inside the engineering education in a university of applied sciences.

The approach of this research was to make a literature review and to make an inquiry and an interview directed to engineer-entrepreneurs who have graduated from universities of applied sciences. Also, the extra-curriculum events are presented that have been realized in Oulu University of Applied Sciences as well as experiences of them.

In this report proposals for entrepreneurial education in universities of applied sciences are presented. This study is a part of the study series which have been made from different points of view to the entrepreneurial education in Oulu University of Applied Sciences (OUAS). It is a continuation to the paper presented in SEFI2015.

3 LITERATURE REVIEW

3.1 Traits of nascent entrepreneurship

Nascent entrepreneurs are people who are actively trying to set up their own businesses. Determination of these people is not easy. Characteristics of an entrepreneur have been presented in several research reports. Creativity, innovativeness, tenacity, risk-taking, team

building capacity, customer orientation, contact with marketing, project engagement are often mentioned [2], [3], [4], [5], [6].

The features can be classified into human and social capital. Human capital is e.g. creativity, innovativeness, tenacity, risk-taking. Social capital is a capacity to get in contact with other people and to work with different kinds of people. Team building capability is important in entrepreneurship. St-Jean et al [7] have written about the differences based on psychological, sociocultural and economic factors influencing entrepreneurial intentions.

Young entrepreneurs use bootstrapping and effectuation mechanisms to compensate the lack of knowledge, experience and financial capital that more experienced entrepreneurs have in use. They also benefit of social support from their parents and other entrepreneurial family members and friends. They are active in participating all kinds of small-scale ventures and senior managers of the established companies are arranging access to additional opportunities. By using their creativity, energy and originality the young entrepreneurs acquire the experiences and the contacts they need for their next development steps to develop their entrepreneurship. Social skills are important when supporters are looked for especially in the first stage along the pathway towards a skilled and successful entrepreneurship. According to Cannone et al [8], young successful entrepreneurs are investing heavily on their social capital to countervail the effect of the young age.

Dietz et al [9] have discussed the management of the complexity. Surroundings of the enterprise is changing continuously and the entrepreneur has to react to that. This situation is connected to the ability to tolerate uncertainty, and surely asks for tenacity.

An entrepreneurial engineer has been discussed by Elia et al [10]. Human capital means that s/he is capable of matching technology innovation with business challenges and societal development, assuring economical, technological and environmental sustainability.

Garsia et al [6] address to design work as a positive skill for an entrepreneur. That approach enables entrepreneurs to be pro-active, consistent and reliable, rather than just exploratory and reactive. Design possesses instruments that allow framing, development, co-designing and prototyping complex intangible projects. In their education engineers learn this kind of way to work. They have got used to thinking analytically.

3.2 Education of entrepreneurship

The manner to arrange engineering education has developed along a century. When the great technology inventions appeared and technology was taken into use in bigger scale, the need for the technological engineering skills has been obvious. The need for new technological products has been urgent. Production has been a bottleneck. Later, during and especially in the end of the 1900's the businesses have faced an increasing global competition. That has caused a need to find new competitive products in order to obtain revenue. The marketing effort has become more important than before. Still, in these days the engineering education promotes for students wage-employment rather than self-employment like Wani et al [2] have stated in their report discussing techno-entrepreneurial workforce.

In most universities in the engineering education the entrepreneurship has been superficially dealt with. This is understandable because the focus is on technology and normally the educators have a long experience as technology experts in companies but only a few have

an entrepreneurial background. According to a research [11], 5 % of the teachers of OUAS have pursued an entrepreneurial career. In many cases the teachers and university managers who have the same technology background are developing the education and naturally the focus is on technology. In the strategy of the university the development of entrepreneurship is mentioned. The first steps are taken e.g. by offering one basic course in entrepreneurship for all students. Additionally, there is a possibility for students to develop their business ideas in the business incubator where the entrepreneurship is profoundly dealt with.

Baumol [12] has discussed in his report the level and direction of education in the USA and compared it with the education in other countries. He presents that the level of subjects like physics, mathematics, technical and scientific disciplines of the American students in elementary schools and high schools is clearly at a lower level compared with some European and Asian countries. Yet, American students make more dissertations and the attitude and ability to make start-ups is higher. This is a paradox but Baumol [12] presents that maybe the educational approaches that provide effectively the mastery of the extant body of intellectual material actually tend to handicap a student's ability to "think out of the box" and prevents to find new groundbreaking ideas and breakthrough approaches.

3.3 Attraction of entrepreneurial education

How the interest in the entrepreneurship can be aroused? Fellnhöfer et al [13] have studied the influence of the role model on perceived entrepreneurial desirability and feasibility. They have found that embedding entrepreneurial role models in education promote entrepreneurial activities. When students have a possibility to become acquainted with real entrepreneur's careers, it creates a positive awareness. Furthermore, the development of the right identity can be achieved with the help of the relevant peer groups. Also, they have stated that in addition to the entrepreneurial knowledge and skills that have been studied in a traditional way, the creation of the entrepreneurial identity is essential for the acting as an entrepreneur. The authors have noticed that entrepreneurial education contributes the entrepreneurial feasibility. Hence, as a conclusion it can be said that a role model of an experienced and successful entrepreneur connected to entrepreneurial education is an essential combination to stimulate the right attitude. According to a questionnaire to bachelor students of engineering, 31 % have a serious intent to found an enterprise in the future [11].

4 ENTREPRENEURIAL EDUCATION IN OUAS

In the strategy statement of OUAS entrepreneurial education is mentioned. It means that all curricula include at least one basic course in entrepreneurship. The size of the course is two credits. Additionally, a business incubator is available. If a student has an idea, s/he can make a business plan of it. The scope of the subject is 10 credits.

Every year a business idea contest Kickstart is arranged. There students can present their business ideas and receive guidance to develop them further. The next step is the choice of 10 best ideas which are prepared to be presented to the jury. The members of the jury are from businesses and banks. After a short presentations the best idea is chosen and awarded with 1500 euros. As a result of this extra-curriculum education principle, a few promising start-ups have been found. They are in a growing stage and they have received a significant risk financing for the further development and growth. A part of the entrepreneurial education is a yearly realized entrepreneur afternoon where former graduates from OUAS present their career paths as entrepreneurs. Students have been very interested in those events and they have had an opportunity to discuss the interesting matters with the entrepreneurs. These

events have caused demand to participate in the studies in the business incubator. The entrepreneurs have had a very positive attitude to meet students and to tell them about entrepreneurship. A phenomenon of the role model presented by Fellnhöfer et al [13] has been easily seen.

An international project to develop innovation and entrepreneurial education together with enterprises is being prepared. The idea is that student groups in universities in different countries carry out a product process from the idea to the market. The groups will be guided together by university teachers, business professionals and entrepreneurs. The aim is that students get a realistic and holistic impression of the innovation process and of the entrepreneurship.

5 QUESTIONING AND INTERVIEWS

5.1 Questionings to entrepreneurs

The questioning was directed to 12 entrepreneurs who have an engineering degree. They had 1 – 30 years experience of the entrepreneurship. The interviewees reacted positively to the entrepreneurial education to the engineering students. They thought of the society as a whole and they expressed that the region and entire society needed more new enterprises to provide economic welfare. The first of the main findings was that the entrepreneurs emphasised economics, business strategy, management and marketing as useful entrepreneurial subjects as part of engineering education. Entrepreneurs were asked about the number of student who should be trained to the entrepreneurship. All of them mentioned that an entrepreneurial education should be offered to 100 % of the students. That would be important even though students would not act as entrepreneurs but would work as intrapreneurs in companies owned by someone else.

The second finding was the willingness of entrepreneurs to participate in the planning and executing of the entrepreneurial education supporting the actual teachers. According to the opinions of the questioned entrepreneurs, the engineering education should include case presentations carried out by active entrepreneurs. They are ready to come and present their companies and their experiences to students. The third interesting finding was that the share of 30 % of entrepreneurs and business development professionals proposed the mentoring of young nascent and active entrepreneurs and the presentation of the role model of an SME-entrepreneur. Also, it came out in the interviews that most of the contacted professionals emphasized the encouragement of the nascent entrepreneurial students to continue the studies towards the entrepreneurship.

5.2 Business development organisations

The proposal of the representatives of the local business development organisations was that it is beneficial to present to students the companies that are for sale. The experienced entrepreneurs want to give the companies to younger generations. There are a numerous micro and small enterprises for sale. By becoming acquainted with them, the nascent entrepreneurs learn practical issues about business.

6 RESULTS AND PROPOSALS

In the following the proposals to develop the entrepreneurial engineering education are presented. They are based on the literature review, the questioning of entrepreneurship and the interview that was made to the entrepreneurs and to the business development specialists.

According to the former research, 31 % of the engineering students already have had a business idea in their minds but they have not made any actions to start a start-up [11]. In order to identify the nascent entrepreneurs and to support their path to the entrepreneurship, a clear organized system needs to be developed. In the beginning of the studies events can be arranged together with entrepreneurs where the identification can take place. Thereafter, they can be activated and encouraged to participate in the tentative entrepreneurial courses. [14]. In the later education it is important to offer firstly solid skills and knowledge about technology, secondly a formal set of activities to found a start-up, and thirdly it is convenient to strengthen the human and social abilities and personal attributes such as risk perception and self-efficacy [14], [12].

The best alternative is a separate study line for the entrepreneurially oriented students. For them it is advantageous to learn the entire product process, the chain of actions which is needed on the pathway from the idea up to the market. It is not only technology that is needed but also actions in management, marketing, financing, strategic decisions, etc.

Normally, the development of curricula and education methods are realized by teachers. Because the entrepreneurs are ready to support in this work, it is beneficial to create a collaboration method. Also, when recruiting teachers the entrepreneurial background of the candidates is worth taking into consideration. Connected to the collaboration with entrepreneurs, the mentoring of the entrepreneurially oriented students is one effective mean to support the emerging business career as also Hulsink has discussed [14]. In this connection it is possible to present to students the role model of senior entrepreneurs as well.

The conclusion of the research is that the role of the universities is important when the know-how of engineers to create and manage technology-based companies is developed. In engineering education it is possible and worth realizing the motivation of the nascent entrepreneurs together with entrepreneurs who have made engineering degree.

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Communication Skills in Engineering Education: A Fundamental Aspect of Information Processing

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Conference Key Areas: Engineering Skills, Curriculum Development, Educational and Organizational Development

Keywords: Communication Skills, Engineering, Information Processing

INTRODUCTION

From an early age, each individual develops a capacity to process information as a result of their biologically primary abilities. Biologically primary abilities are those which an individual is born with, or innate abilities (e.g. information processing and innate communication), while biologically secondary abilities are those which can be acquired and developed through education and training (e.g. engineering language) [1]. As a child matures into adulthood, there is an increase in the complexity of the information that they are presented with, and therefore must process. However, as each individual's development differs, they will not utilise the same methods to process this information. Similarly, individuals will not use the same means of communication.

Communications may be verbal, visual, written, or non-verbal [2] and each of these may be internalised (understood) or externalised (explained). Individuals' capacities to communicate vary significantly. Again, if childhood is taken as an example, each child will begin to talk, draw, paint, write, etc. at different stages of their childhood. As

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that child matures, their skills will advance through the development of various biologically secondary abilities. However, in order for these skills to develop, an individual must be able to internalise and externalise communications effectively to support the processing of information.

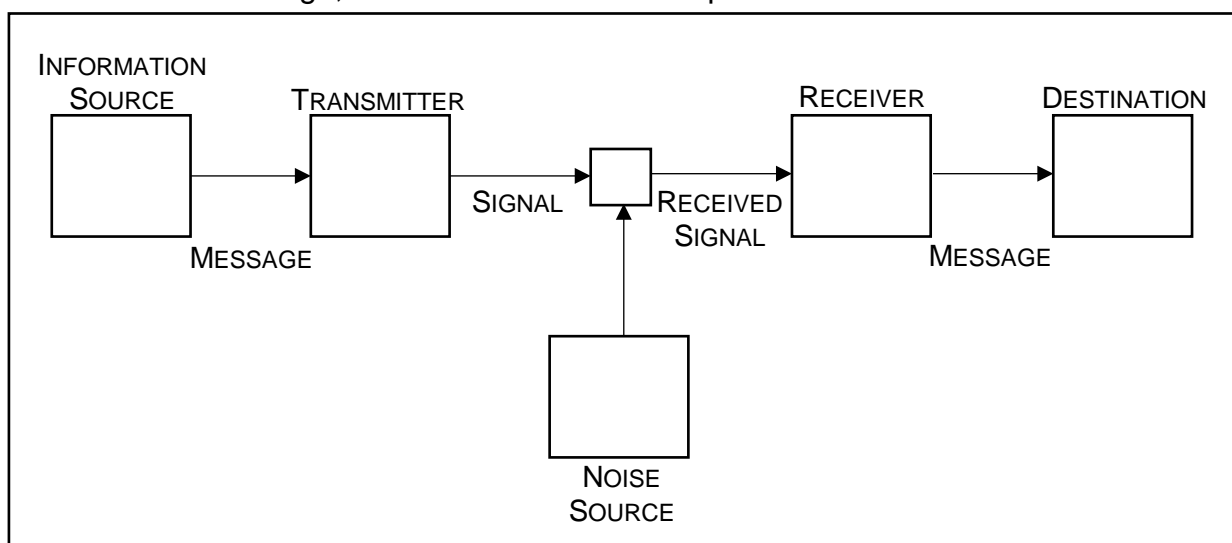
Information processing capacity is a vital part of our day-to-day and professional activities. No more so than in the engineering profession. Engineers are often presented with extensive amounts of information and must determine a solution based on the information provided to them. When considering an engineer's capacity to process this information, we must explore how the information is communicated to them and how it comes to be understood. Engineers must understand verbal, visual, written, and non-verbal information that they are presented with and draw meaning from these communications [3].

Information processing is a vital part of this process for engineers. Information processing and communication skills provide an engineer the capacity to understand the complex problems they are presented with. These capacities also provide engineers with a means of expressing their solutions to problems [3][4]. Effective information processing is not possible without effective communication skills, highlighting the importance of biologically primary and secondary abilities operating in tandem in the engineering profession. The relationship between communication skills and information processing is explored throughout this paper and the importance of understanding this relationship for student learning in engineering education.

1 COMMUNICATION SKILLS

An individual's ability to communicate ultimately determines how they progress developmentally. If an individual is lacking in an area of communication e.g. verbal or visual, they may be unable to understand certain other communications or express themselves, therefore hindering their capacity to progress. Understanding the role of the individual in the communication process is central to supporting their development. An individual may internalise (understand) or externalise (explain) the information communicated. The individual's role in communication has also been described as transmitter and receiver through earlier works [5], as illustrated in Figure 1.

Individual's knowledge, skills and abilities develop at different rates due to a number



of such as *Fig. 1. The Shannon-Weaver model of communication [5]* factors,

behavioural, environmental, or personal determinants [6]. While an individual may not be proficient with particular means of communication, they can sometimes compensate with other communications. For example, if an individual is not proficient with written communications, they may compensate with their verbal communication skills. This is sufficient for day-to-day interactions, however, issues may arise throughout their educational experience.

1.1 Communication Skills in Education

Throughout the educational experience, be it early, second-level or third-level education, content is communicated to learners through a variety of means. Internalising communications is a fundamental aspects of learning [7], as well as information processing [8]. An educator may present information visually (e.g. on the board/using models), verbally (e.g. explanation), written means (e.g. notes), or non-verbal (e.g. demonstrations) means [2]. They may also use a combination of these methods of communication to deliver content. However, if a student is not proficient in one of these areas, they may experience difficulty with the education and learning experience, therefore contributing to issues with performance.

The externalisation of communications is an area of particular importance in education in terms of assessment. For example, a person may be extremely intelligent, however, if they are not an effective written communicator they will experience a significant scholastic disadvantage. Similarly, if an individual excels in visual communication, such as sketching, and experiences difficulty with verbal communication, they may struggle if asked to verbally present and explain their visual solution. As noted by Albert Einstein, "Everybody is a genius. But if you judge a fish by its ability to climb a tree it will live its whole life believing that it is stupid". This emphasises the key role that communication skills play in education and assessment.

Communications are a fundamental aspect of all disciplines in third-level education as learners begin to take greater responsibility for their own work. The development of proficiency in communication skills is of particular importance in third-level engineering education programmes as a result of the unique role that communication skills hold in the engineering profession [3][9][10].

1.2 Communication Skills in Engineering

Communication skills are fundamental to the engineering profession as they allow engineers to effectively develop and present their solutions to problems and designs [3][4]. The engineering profession converses in its own unique language consisting of innate communication skills (biologically primary), and engineering communication skills (biologically secondary), for example parametric modelling. This language combines the use of verbal, visual, written, and non-verbal means of communication to describe their solutions to problems to others [2][3][4][11].

For an engineer to effectively understand a problem or a brief, they need to be conversant in all means of engineering communication and have the capacity to internalise this information [2]. This may entail the understanding of technical knowledge, visual representations of information, or verbal descriptions of the brief. If an individual experiences difficulty in internalising these fundamental details, they may encounter problems when developing a solution [4]. Also, if a problem must be solved in a group dynamic, they may experience difficulty in communicating their design to the other members of the group [12], resulting in frustration and a possible lack of motivation to solve the problem.

A range of communications may be used by engineers to externalise their solutions. For example, engineers often use parametric modelling software, working drawings or sketches to visually communicate their solutions [3][11]. Verbal and written communications may also be used to support these visual communications. If an engineer cannot process the communications presented to them, this will contribute to issues with the development of problem and design solutions [2][4], which may have significant practical implications, e.g. structural failure. This highlights the importance of considering information processing capacity in engineering education approaches to support students internalising and externalising communications.

2 INFORMATION PROCESSING

Information processing is the gathering, interpreting and synthesis of information to support decision making [13]. Each individual has a different capacity to store and retrieve information [14]. While some may be highly efficient in processing information, other individuals may experience greater difficulty. As information processing is a biologically primary ability, its capacity cannot be directly developed.

Through cognitive psychology, in order for information to be successfully processed, it requires the combination of memory capacities, which are responsible for the storage and retrieval of information [13][14][15]. Figure 2, presents the Atkinson and Shiffrin structure of the memory system for information processing [16].

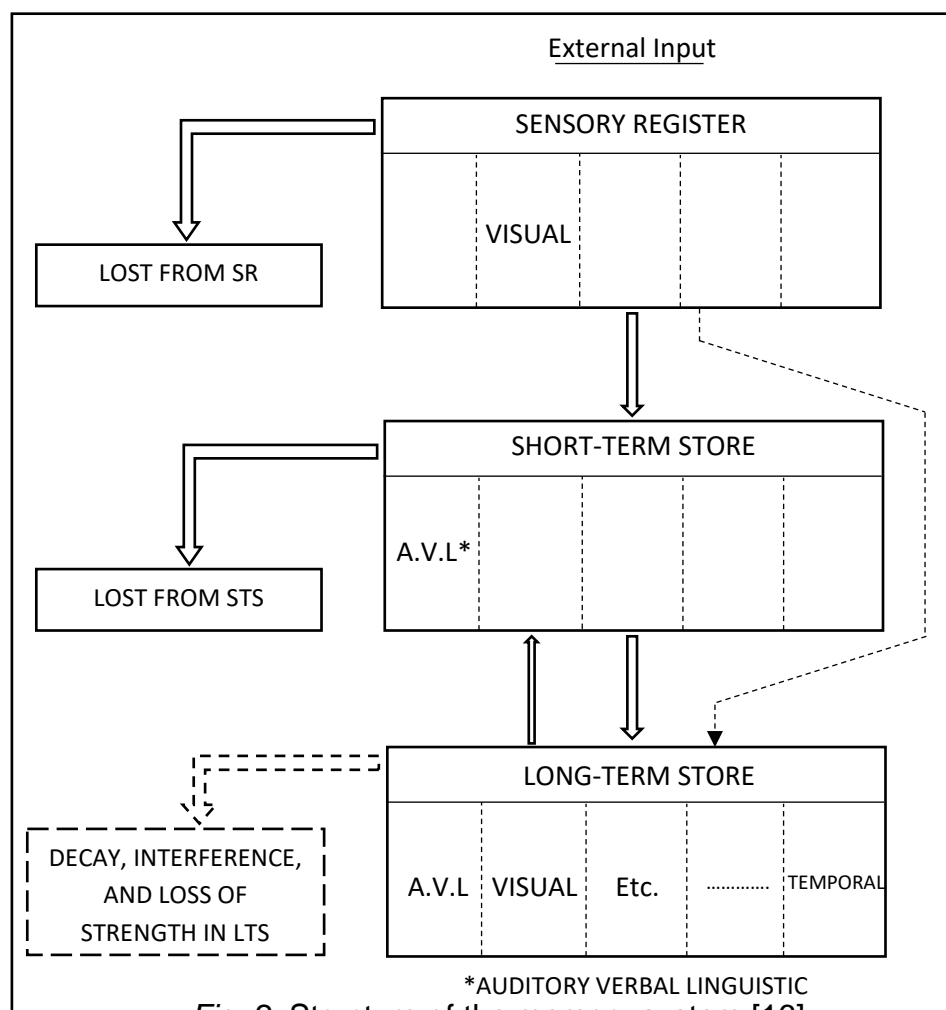


Fig. 2. Structure of the memory system [16]

Sensory memory, short-term memory and long-term memory play a fundamental role in information processing [14][16][17]. Sensory memory is the initial stage of the information storage process. The information must be addressed in sensory memory in order to progress to short-term memory [14][16][17]. Short-term memory is also referred to as working memory or conscious memory and is used to understand stimuli and thoughts [14]. In order for this information to be retained, there must be organisation and repetition. The information is ultimately stored in the long-term memory [7][14][16][17]. Throughout the presentation and understanding of information, the collective and synchronous nature of information processing places demands on sensory, short-term, and long-term memory [7][13][14][15][16][17]. The demands that are placed on an individual's memory during this process result in limitations in their capacity to process the information effectively [14][15][17].

2.1 Limitations in Information Processing Capacity

An individual roughly has the capacity to complete two tasks at a time due to the demands placed on the brain to process [17]. When an individual is presented with a number of factors to process, limitations in information processing capacity can occur. There are a number of areas in the brain that cause these limitations.

Sensory memory has a limited capacity to transfer information onto the next stage (short-term memory) for processing and storage, and experiences limitations in a number of ways [14][15][17]. The first limitation is the time it takes for the brain to consciously understand what is seen in visual short-term memory (VSTM), secondly, the restricted capacity of VSTM to hold information, and thirdly, choosing a response [17].

Considering the vast number of decisions that an individual has to make throughout a day, they may experience these limitations on a number of occasions. Regardless, of an individual's profession, there will be significant demands placed on their information processing capacity [13][14][15][17]. However, if we view this in the context of the engineering profession, and the large volumes of information processed when problem solving, it is clear that engineers may frequently experience limitations in processing capacity throughout the problem solving process.

3 THE ROLE OF COMMUNICATION SKILLS AND INFORMATION PROCESSING IN ENGINEERING EDUCATION

Although communication skills and information processing are central to all educational disciplines, their role in engineering education is significant for a number of reasons. Effective innate and acquired communication skills, and information processing are fundamental for engineers to succeed in their key technical roles e.g. understanding and processing complex information, communicating to and with others, and problem solving. This emphasises the need for effective acquired communication skills to be developed throughout engineering education to support the processing of information. Therefore, upon graduation, students will be equipped with the skills necessary to support them in adapting to the changing landscape of the engineering profession as it advances. Efforts now must be placed on a practical approach to developing these core skills within engineering education.

Educational frameworks such as Problem-Based Learning and Project-Based Learning are often implemented in engineering education as they provide students with an applied experience, similar to that experienced in the engineering profession. As problem solving is central to engineering, it is important that students in engineering

education engage in experiences to support the development of problem solving ability. In order for students to acquire the skills necessary for effective problem solving, educators must consider the complexities of the underlying capacities which lead to solutions. Therefore demanding that the relationship between the biologically primary abilities, innate communication and information processing, and biologically secondary, acquired communication skills, is examined and the implications of this relationship on problem solving in engineering.

Communication, information processing and problem solving are each initiated by an external input or information source. Consequently, if one considers that the information an individual stores through processing consists of verbal, visual, written, or non-verbal communications, we can see that communication skills are a fundamental aspect of information processing. When presented with a problem, innate and acquired communication skills, and information processing are necessary to support the identification of key points of the problem so that they may progress to problem exploration. Likewise, throughout problem exploration, solution development, and presentation, communication skills and information processing are utilised continuously throughout the process, as presented in Figure 3.

Capitalising on the natural relationship that exists between communication skills,

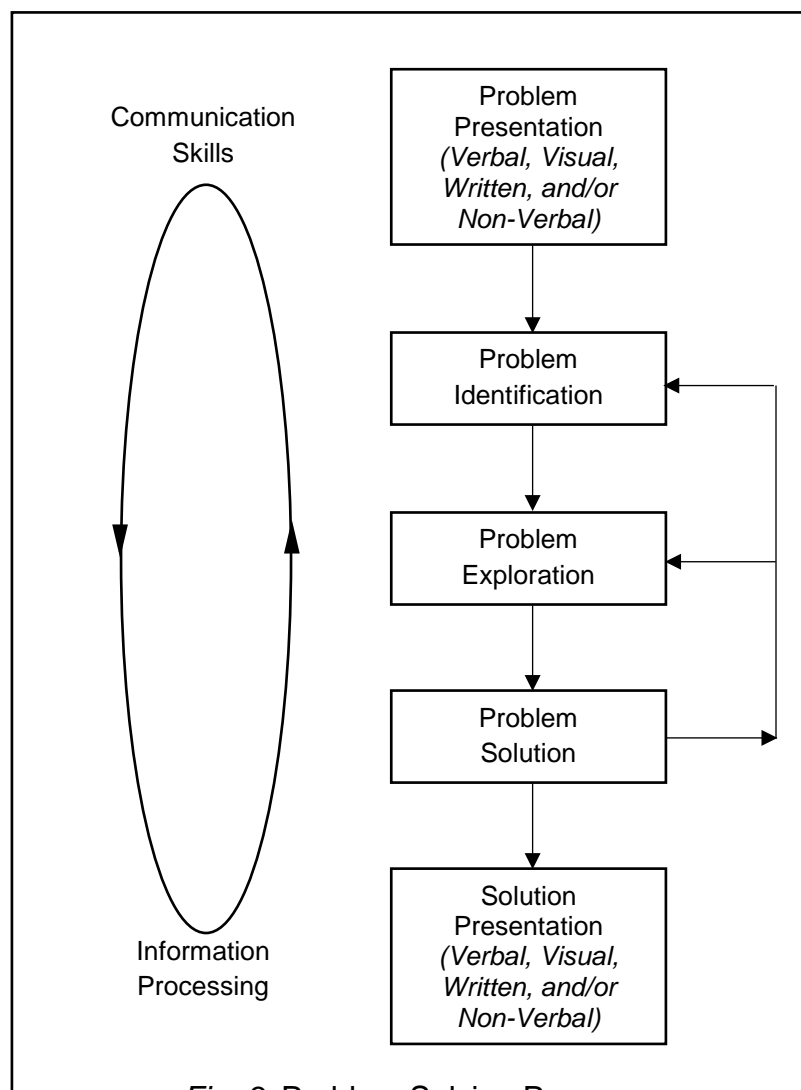


Fig. 3. Problem Solving Process

information processing, and problem solving, may scaffold the development of

discipline-specific communication skills within problem- and project-based engineering education approaches. The development of discipline-specific communication skills through engineering education is critical to supporting students in becoming effective communicators and succeeding in their future engineering profession.

4 SUMMARY

It is clear that communication skills, both innate and acquired, and information are central to the engineering problem solving process, and therefore must be considered in the educational approach taken to develop problem solving skills [2][9][10][18]. Much research has highlighted the deficiencies in communication skills of engineering graduates and interventions used to develop these skills [2][18]. However, these skills require continued attention and development as the engineering profession evolves in order to meet societal demands [9][10].

Beyond the engineering profession, communication skills are a fundamental aspect of information processing. To process information an individual requires communication skills, likewise, the understanding of communications requires information processing. This presents the concept that a co-dependent relationship may exist between communication skills and information processing. Should this be the case, there may be significant implications for the acquisition and development of communication skills in engineering and engineering education programs. As engineering curricula seek to achieve an integrated educational and learning experience, the authors suggest that capitalisation on the natural relationship between communication skills, information processing, and problem solving may support the consolidation of knowledge, skills, and abilities in engineering education.

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Spatial Ability in Engineering Education: Working Towards an Integrated Learning Approach

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Conference Key Areas: Engineering Skills, Curriculum Development, Educational and Organizational Development

Keywords: Engineering Education, Spatial Ability, Engineering Skills

INTRODUCTION

Engineering is a collaborative and complex activity which demands the use of a broad range of skills and perspectives [1]. The desired attributes of an engineer have long been the focus for engineering educators and will continue to be discussed throughout the progression of the profession as a result of its dynamic and evolutionary nature. Despite the progression of the profession, biologically primary and secondary abilities will always be necessary for engineers to perform in their key roles such as problem solving. Biologically primary abilities are those which an individual is born with (innate) and do not require direct development [2], or cannot be directly developed such as information processing [3]. Biologically secondary abilities, such as domain-specific communication skills [3], can be acquired through education and training [2] and are therefore the core focus of education programmes.

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As the desired attributes of an engineer continuously evolve, engineering education focuses on developing knowledge, skills, and abilities through educational programmes to support students in consolidating these three elements. While biologically primary skills such as information processing and communication skills are central to information being understood [2][3], biologically secondary abilities, such as technical knowledge and transversal skills, may be fundamental to achieving an integrated learning experience whereby knowledge, skills, and abilities may be truly consolidated.

Technical knowledge and skills encompass a broad range of abilities such as science and engineering fundamentals, applications, and practice [6][7]. Similarly, there are a broad range of transversal skills used in the context of engineering education, such as discipline-specific communication, creativity, and problem-solving [1][6][7]. Spatial ability, a transversal skill, is the focus of this paper.

Spatial ability has been attributed to the successful acquisition and development of both technical and transversal engineering skills [4][5][7][8][9][10][11][12]. Therefore, spatial ability is a fundamental element to consider when aiming to achieve an integrated teaching and learning experience in engineering education. Although spatial ability is an innate ability, spatial skills are biologically secondary abilities and therefore may be developed to support and compliment the innate spatial ability of an individual. Throughout this paper the role of spatial ability and spatial skills to support an integrated learning experience being achieved through engineering education is examined.

1 ENGINEERING SKILLS

The concept of technical knowledge and skill is utilised to classify abilities such as science and engineering fundamentals, applications, and practice [6][7][16][17]. Through the literature, transversal skills are referred to as 'soft', 'non-technical' or 'life' skills [4][6][7][16][17], among a range of other terms. Throughout this paper they will be referred to as transversal skills. In the context of engineering education, transversal skills include discipline-specific communication, creativity, critical-thinking, discipline-specific problem-solving, and spatial ability/skills [6][7][16][17].

The requirement for technical knowledge and skill in engineering is irrefutable [1][5][6][7][16][17]. These abilities are important for engineers to successfully perform in their key technical roles. However, in a rapidly advancing engineering world, these skills are not sufficient for an individual to succeed in the profession [1][16][18]. As the role of engineering is evolving, individuals in the profession and those wishing to enter it require a knowledge of both the technical and transversal aspects of the discipline [1][5][16].

The transversal skills outlined as important requirements are extremely broad as noted in a number of studies [4][6][7][8][16]. Through investigations exploring desired engineering knowledge and skills, the magnitude of the transversal skills desired for engineers became apparent as they varied from communication, critical thinking, innovation, leadership and honesty, problem solving, reasoning and teamwork [1][4][5][7][8][16].

In past engineering education structures, there was little importance placed on these transversal abilities. Transversal skills were seen to be of little importance to the success of an individual in the profession as an in-depth technical knowledge was favoured for the types of problems that engineers faced during this time. Through the

evolution of the profession and education, transversal skills and their acquisition have become an area of greater importance [1][5][16][18].

2 SPATIAL ABILITY

Spatial ability is defined as the capacity of an individual to successfully mentally manipulate visual patterns [13]. It is also described as “the ability to generate, retain, retrieve, and transform well-structured visual images” [14]. Examples of these visual images include mental rotation, and the mental folding and unfolding of objects [20]. As earlier noted, spatial ability is an innate ability and therefore may not be directly developed. However, spatial skills may be developed to support an individual’s innate spatial ability when performing spatially orientated tasks. There are a range of measures available for the analysis of spatial skills such as the Mental Cutting Test (MCT) [21] and Purdue Spatial Visualisation Test and Rotations (PSVT: R) [22].

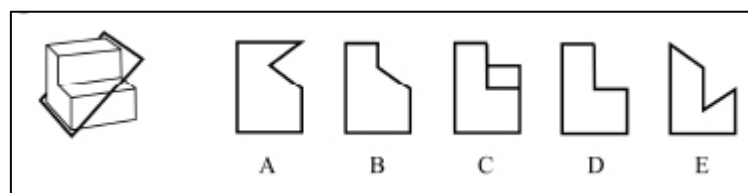


Fig. 1. Example of question on the MCT

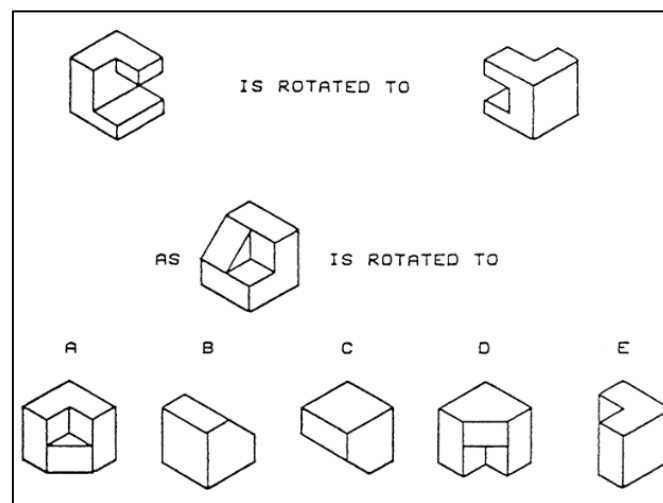


Fig. 2. Example of question on the PSVT:R

It has been established that spatial ability and skills play an important role in success in STEM fields [12][15][19][23]. This perhaps is to be expected as spatial visualisation, an element of spatial ability, which involves the manipulation of 2D and 3D models, is a means of visually communicating [12]. This is a fundamental aspect of a number of STEM disciplines, particularly engineering.

2.1 Spatial Ability in Third-Level Engineering Education

Spatial abilities have been explored as neglected talents in education [10]. This is of great importance when one considers the role of these competencies in the engineering profession. Disciplines of engineering, such as mechanical engineering, are perceived as highly spatially orientated disciplines, while there is also recognition that all disciplines of engineering are spatially demanding [23]. The skills acquired and developed throughout engineering education programs are fundamental to the success of graduates in the profession [1][4].

The aim of education is to provide students with domain-specific knowledge [24], skills and abilities. The acquisition of such a broad range of competencies requires an individual to be proficient in the internalisation and externalisation of communications, and information processing [3]. However, spatial abilities are also important to this process for students of all engineering disciplines. Information is often communicated through visual means in engineering and engineering education e.g. through the use of parametric modelling software. Therefore, spatial abilities, such as retention or mental manipulation [13][14], are necessary to understand the information presented to support the acquisition of knowledge, skills, and abilities.

The development of technical and transversal knowledge and skills through engineering education is fundamental to students succeeding in the profession upon completion of their studies [1][4]. Through the development of capacities which support the consolidation of information, such as spatial and communication skills, engineering education programmes will move towards achieving an integrated learning experience for engineering students.

3 ACHIEVING AN INTEGRATED ENGINEERING EDUCATION EXPERIENCE

An integrated education and learning experience requires the coming together of knowledge, skills, and abilities for the consolidation and understanding of information. Past engineering education programmes placed a greater emphasis on a deep technical knowledge, with lesser importance placed on skills and abilities, resulting in a fragmented approach to engineering education. Over time, a transition has occurred whereby engineering education frameworks have been moving towards an integrated educational experience, as illustrated in Figure 3 below.

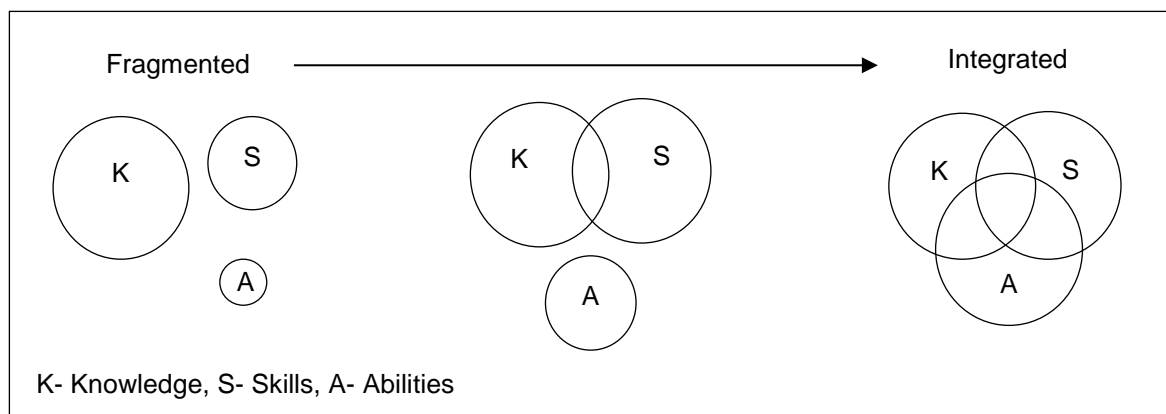


Fig. 3. The evolution of attribute dominance in engineering education

Due to the nature of the engineering profession and the advancements in both technology and the complexity of engineering problems, the development of skills and abilities through engineering education has become an area of increasing importance [1][16][18]. As educational approaches have advanced, engineering skills have risen in importance and have begun to converge with engineering knowledge, illustrating the emphasis placed on these competencies in engineering education programmes.

While abilities have increased in importance, they still often do not receive the same emphasis as knowledge and skills. However, in order for an integrated experience to be achieved, greater emphasis must be placed on developing abilities as they are pivotal to the consolidation of knowledge and skills. For instance, if an individual cannot effectively communicate, problem solve or spatially reason, they may not be

able to consolidate the knowledge and skills that occur throughout their education and learning experience.

3.1 Spatial Ability and Integrated Education

Although an integrated educational experience may be provided for students, this does not mean that integrated learning takes place. In order for this experience to be translated into learning, the underlying skills that support the processing and understanding of information must be developed. Though communication skills and information processing are central to understanding information [3], consideration must be made for the fact that engineering is a highly spatially orientated profession [23].

Spatial ability is central to the acquisition and development of both technical and transversal knowledge and skills [4][5][7][8][9][10][11][12], while also playing an important role in problem solving [25]. Knowledge and skill acquisition, and problem solving are core elements of engineering and engineering education programmes. Due to the role of spatial ability in fundamental factors of engineering education, the development of such a competency may support an integrated education and learning experience being achieved.

The development of biologically secondary abilities such as domain-specific knowledge and skills [24] is the fundamental focus of education. As earlier noted, spatial ability cannot be directly developed as it is an innate biologically primary ability. However, spatial skills, as biologically secondary abilities, can be developed through education and training to support an individual's innate spatial ability. This is a core element that must be considered in the context of engineering education, due to the role of spatial ability and skill in engineering practice.

Spatial skills may be developed in a number of ways throughout engineering education due to the spatially orientated nature of the discipline. Problem solving is a central element of engineering education programmes such as Problem-Based Learning and Conceive, Design, Implement, Operate [26]. The problem solving experience provides an organic opportunity for spatial skills to be developed in a practical context through engineering education.

Students may be encouraged to sketch, produce a physical model, or a parametric model [9] to support them in reaching a solution. Engagement in such an experience provides the student with the opportunity to generate, retain, and retrieve visual imagery. In this context, the completion of the sketch or model supports the development of the student's spatial skills, complementing the underlying spatial ability to reach a solution. Completing a task of this nature also requires the student to call on their knowledge, skills, and abilities to reason about the solution. Leading to an integrated learning experience being achieved whereby knowledge, skills, and abilities are consolidated through the completion of a spatially orientated task.

As problem solving is utilised in a number of engineering education programmes to bring together knowledge, skills, and abilities, achieving an integrated education and learning experience would require minimal structural change to existing curricula. Rather, the focus would be placed on capitalising on the natural relationship that exists between engineering and spatial abilities and skills. Through placing a greater emphasis on elements such as sketching and modelling throughout the problem solving process, educators may ensure the knowledge, skills, and abilities are consolidated and that students have a complete understanding of the complex

relationships that exist between objects and space in engineering e.g. forces, machine processes.

As the engineering profession and engineering education evolve, it is pivotal that core skills such as spatial skills are developed to support students succeeding in the profession and adapting to future changes. Therefore, it is vital that an integrated learning experience is achieved through the delivery of an integrated educational approach so that engineering graduates may successfully perform in their future roles.

4 SUMMARY

Spatial skills play a fundamental role in the engineering profession and in the acquisition and development of technical and transversal knowledge and skills. In order for engineering graduates to be successful in the profession, an emphasis must be placed on the development of fundamental abilities and to support the consolidation of learning experiences. Spatial skills are extremely important in engineering education and to success in STEM disciplines as they support students capacity to be creative, innovative and problem solve, each of which are highlighted as key desirable attributes of engineers by prospective employers and professional engineering bodies [1][6][7]. While there has been considerable progression in the approach taken to third-level engineering education, this progress must continue to ensure that graduate engineers are provided with the opportunity to be successful in the engineering profession.

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Dynamic Behaviour of Coupled Systems

A new course for second year's engineering students on modelling and simulation techniques in Matlab SIMSCAPE for describing dynamic behaviour of complex systems

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Conference Key Areas: curriculum development, engineering skills, discipline-specific teaching and learning

Keywords: dynamic systems, modelling and simulation, Matlab Simscape, design challenges

INTRODUCTION

In modern design assignments engineers need to take an integrated approach during which the choice of materials, statics, dynamic behaviour and thermal aspects need to be taken into consideration. By the introduction of a redesigned curriculum for Mechanical Engineering at Fontys University of Applied Science a new course is introduced in the second year in which students will learn, using a predefined design case, how to take a system wide approach by taking mechanics and thermal and material aspects into account. Modern software tools and system design tools will be used to iteratively come to an optimal design solution.

Students work on several assignments during which knowledge on different subjects such as Matlab Simscape/Simulink, working in the frequency domain, designing for statics, dynamics and thermal behaviour will be explored. In the end the student will be able to use these elements combined in order to come to an integrated optimized system model and design solution of a given design case. The students present their

results in a detailed design report explaining all the steps taken to come to their optimized solution.

At Fontys University of Applied Science, the V-cycle (see *Fig. 1*) is an often used methodology in product development. The system wide approach, aimed for in this new course might become very useful, especially in the concept phase of the V-cycle, in future projects and even in professional life. [1,2] That's why the introduction of such a course is widely supported by teachers, members of the board of recommendation and companies in and around Eindhoven.

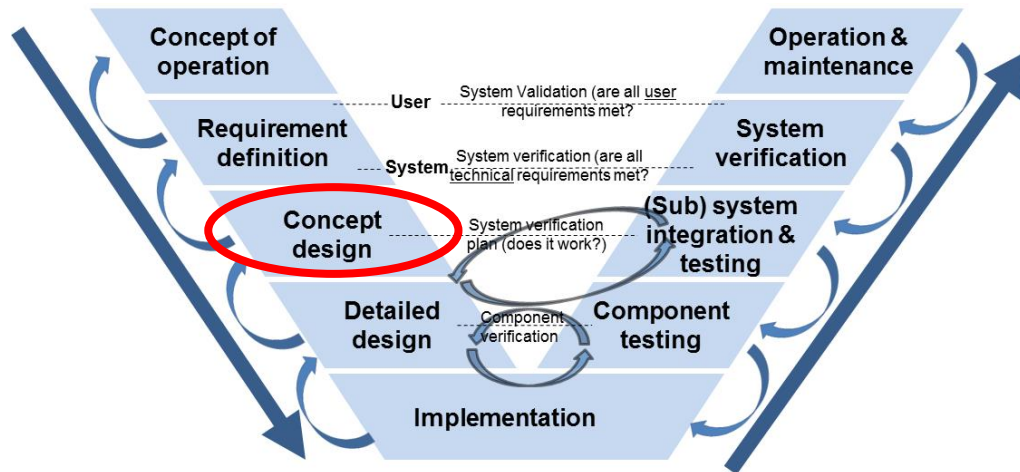


Fig. 1 A schematic representation of the V-cycle

In the first version of the new course in the previous academic year, students worked on designing a wingbox for an airplane wing by studying the effect of material choice and thickness on several aspects of the behaviour the wing. The results and experiences of teachers and students on this approach of system design are presented in this paper. A system model obtained by the students for this design case shows knowledge on fundamental engineering skills, student's creativity and enthusiasm for the approach on design thinking. Based on first experiences, a list of recommendations and future improvements for the course is formulated.

1 COURSE CONTENT

Groups of 2 students work on several assignments during which knowledge on different subjects such as Matlab Simscape, working in the frequency domain, designing for statics, dynamics and thermal behaviour will be explored. In the end the student will be able to use these elements combined in order to come to an integrated optimized system model and design solution of a given or chosen design case.

1.1 Learning objectives

In the development of the course, all different disciplines within the Mechanical Engineering department are asked to come up with their discipline specific wishes for such a course. Combining and summarizing all the input, resulted in a list of learning objectives as a starting point:

1. From a given design problem, the student is able to identify different design aspects and translate these aspects into design questions
2. The student is able to translate the design questions into an integral simplified system model(s)
3. The student has knowledge of working in the frequency domain and is able to use tools (such as Fast Fourier Transformation and/or Laplace transformations in order to predict the behaviour of a design)
4. The student is able to use appropriate simulation tools in order to translate the system model into a computer model that can be used to simulate and define design parameters
5. The student is able to make an integral optimized system design using the system and computer models.
6. The student is able to describe and summarize all design aspects into a professional report.

The pre knowledge required for the course is first years theory on statics, mechanics of materials, thermodynamics and practice on mathematical modelling in Matlab Simulink.

1.2 The design challenge

The students are asked to design the wingbox of an airplane wing using a systems based approach, meaning that they need to optimize for static, dynamic and thermodynamic (optional) requirements. For the sake of simplicity, the geometry (i.e. internal chord lengths, length of the of the wingbox, weight of the engine, etc., see Fig. 2) is already given to the students as a starting point for their design.

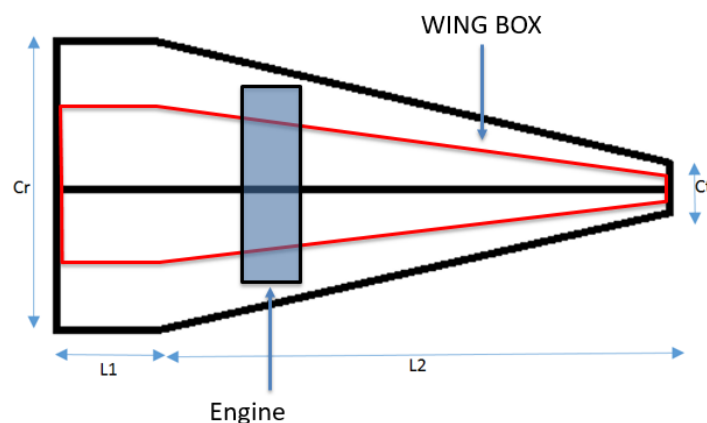


Fig. 2 Schematic representation of the wing, the wing box, the position of the engine and all typical length scales.

The wing structure must be strong enough in order to withstand the various loads which act on the wing. It should also meet stiffness requirements in order to dampen the vibrations as subtly as possible which might be caused by the dynamic loads during flight operations, for instance: a wind gust or a turbulence. In addition to the information mentioned above, the wing structure must also meet weight requirements in order to keep the flying costs at a reasonable level.

The design challenge gives freedom to optimize two characteristic design parameters in order to meet the above requirements: the *panel thickness* of the wingbox and the *material* of which the wingbox is made. [3]

1.3 Course contents

The first version of the course consists of three parts:

1. *The static design.* Students use their knowledge from first year's mechanics classes to study the static properties of the wing. They draw a free body diagram (FBD) and make plots of the bending moment, the shear forces, the normal stresses and shear stresses in order to determine where on the wingbox the maximum stresses act. This information is used to optimize for the panel thickness and material choice such that the wingbox can withstand the maximum stresses (taking into account a 1.5 safety factor) and the maximum deflection is calculated for the obtained design.
2. *Exercises in Matlab.* In a few basic exercises students get a first impression on building *physical* models using Matlab Simscape. The students learned how to build *mathematical* models based on differential equations in Matlab Simulink in a first years course on modelling and simulation. By adding Matlab Simscape to their skills, it offers opportunities to build models for more complex systems than they were used to so far. The basic exercises cover a model for a mass-spring-damper system, a double pendulum and an introduction and exercise on Fast Fourier Transform (FFT)
3. *The dynamical model.* A lumped parameter model for the wingbox is built in Matlab Simscape. The students make their own choices on how to set up the model using the standard building blocks available in Matlab Simscape (Multibody). In practice, it results approximating the wingbox by several solids connected by torsional springs. Based on the panel thickness and material properties obtained in the static design, students should be able to calculate spring constants and approximated damping constants. Once the lift force is added to the wingbox model, students can draw conclusions from graphs on the dynamic motion of the wing and elaborate on typical frequencies that occur according to the FFT analysis.

Note: the thermodynamical part is skipped in this first version of the course to prevent from creating an overload of work for students within the available hours (in total 3 ECTS) and to step by step develop the course instead of everything at once.

2 RESULTS AND EXPERIENCES

The course has had its first year in practise and some of the results are shown here.

2.1 A student's example

As an example, in *Fig. 3* a graphical three-dimensional representation of a model build in Matlab Simscape by two students is given. As a material they opt for an alunium alloy, 2014 UNS A92014, and a panel thickness of 11.5 mm. [4]

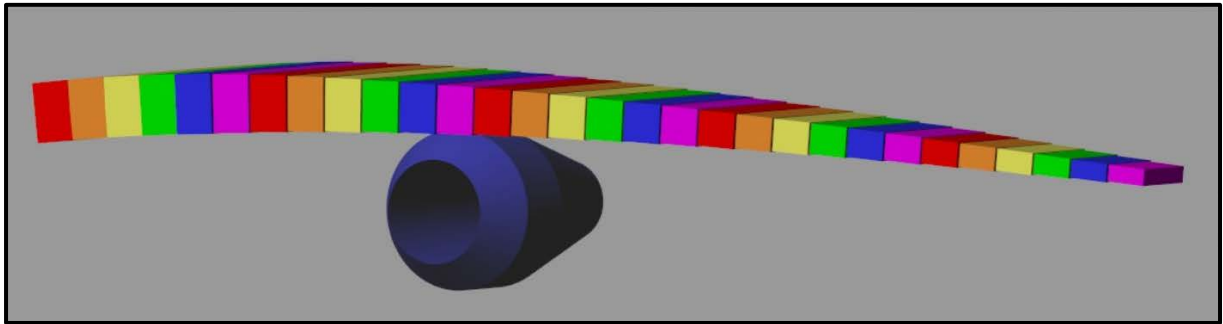


Fig. 3 A lumped model build in Matlab Simscape by students to study the dynamic behaviour of the wingbox.

These students chose to build up their model from 35 solids, each one connected with the previous one by a torsional spring. In *Fig. 4* a snapshot of a part of the model in Matlab Simscape is shown. *Part 1* represents a single solid with the mass of the solid and the typical dimensions as input parameters. The *Revolute Joint* represents the torsional spring with a calculated spring constant and an approximated damping constant as input parameters. It outputs (optional) the relative angle and angular acceleration, which can be plotted. Attached to the solid *Part 1* is an *External Force and Torque*, which represents the lift force that acts on the wing. The lift force is calculated within the Matlab Workspace using a script file. The connection points *Conn1* and *Conn2* connects the solid to his neighbouring ones. Some of the result of running the Simscape model can be found in *Fig. 5*. In the report, the students have reflected on the effect of slightly changing spring constants on the resonance frequency and the influence of adding a random noise signal to the lift force (simulating the effect of turbulence).

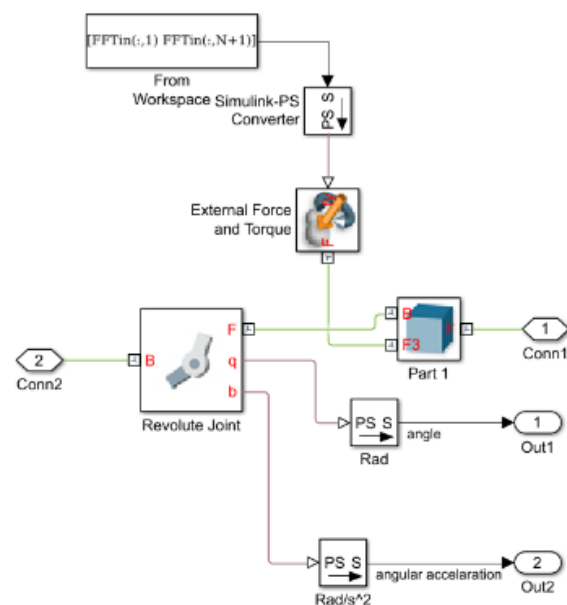


Fig. 4 A snapshot of the building blocks in Matlab Simscape used to model a single solid of the wingbox.

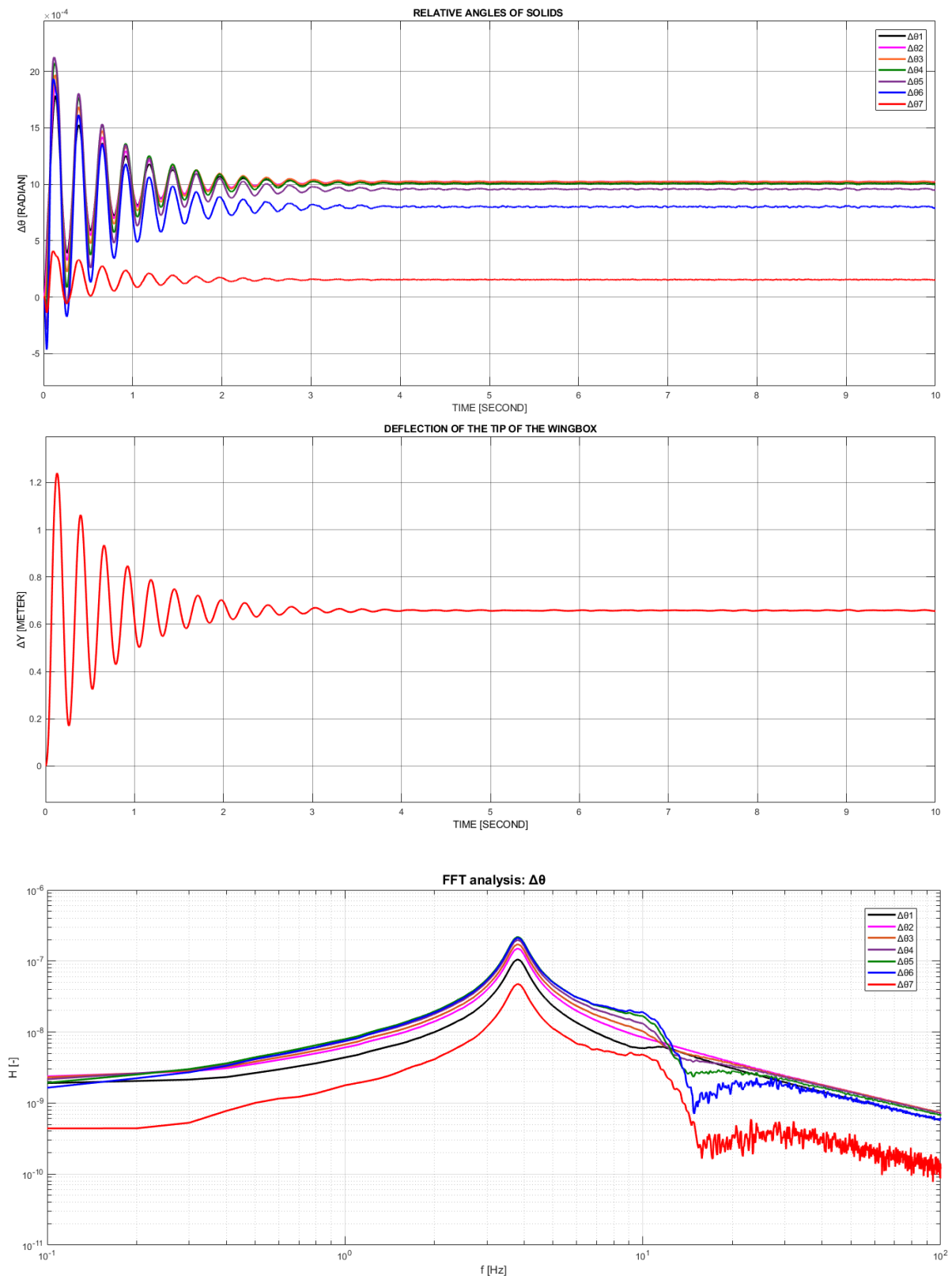


Fig. 5 Simulation results from Matlab Simscape (i) The deflection of the tip of the wing with respect to the fuselage (ii) the relative angles between solids at each 5 m of the wing (iii) the FFT corresponding to the relative angles showing a resonance frequency of 3.8 Hz

2.2 The results

In *Table 1* the passing grades are shown for the first generation of students that have followed the new course. The course was taught to three classes of which two were in Dutch and one in English (international students). In the end, 76% of the students passed the course. Remarkably, none of the international students passed for the regular exam. From evaluation with students it appeared that this was due to miss-communication, multiple deadlines at the same time and poor translation of the course manual. For the second attempt extra guidance is offered for these students.

Overall, the reports delivered by the students show great creativity and usefulness of such a design tool. The passing grade in the end is satisfactory and gives reason to continue the course and develop it even more.

Table 1 Passing grades (per class and total) for first attempt (regular exam) and second attempt (resit exam)

	NUMBER OF STUDENTS	FIRST TIME PASS (#)	FIRST TIME PASS (%)	SECOND TIME PASS (#)	SECOND TIME PASS (%)	TOTAL PASS (%)
CLASS 1 (dutch)	39	27	69	3	8	77
CLASS 2 (dutch)	34	13	38	15	44	82
CLASS 3 (english)	25	0	0	16	64	64
TOTAL	98	40	41	34	35	76

3 FUTURE ADAPTATIONS

Based on the first experiences with this new course and feedback we received from both teachers and students, a few adaptations and additions are formulated.

1. *Changing the order the main parts of the course.* The course started, just after the summer break, with calculations by hand on the static behaviour of the wingbox. The students find problems to recall on how to perform these calculations, getting back in working mode again after the holidays and consequently create a certain backlog. The result is a motivation drop immediately at the beginning of the course. Next time, the course starts with the basic introduction exercises into Matlab Simscape to make the first few weeks more easy going and fun.

2. *Simplifying the Matlab scripts.* The Matlab scripts provided to the students contain a lot of options to test and verify the influence of the design parameters on the dynamic behaviour of the wingbox. Although students are experienced in using Matlab Simulink, there's hardly now knowledge on script writing in Matlab. This makes it hard for them to understand what is written down in the script. Therefore, stripping down the scripts to a minimal level is essential.
3. *Adding a thermal component to the design challenge.* The first version of the course only focusses, for practical reasoning, on the static and dynamic components of the design challenge. The thermal component is added in the newer version. This is done by introducing the concept of deicing of a wing to the problem. For deicing, heat from the engine is blown under high pressure to the leading edge of the wing to provide ice from arising on the wing. This is typically affected by the choice of material and the thickness of the wingbox panels and therefor a good addition to this design challenge.
4. *Adding the option of a two degrees of freedom motion.* The dynamic motion of the wing is now restricted to motion in vertical direction, the so called plunge of the wing. For students who need some more challenge, also rotation about the elastic axis of the wing might be added. This is referred to as the pitch motion of the wing. The combination of pitch and plunge is often studied in the phenomenon flutter and so this extra option adds some more real issues to the actual design challenge.

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Application of Topic Modeling for Analysis of Open Feedback by Students in International Design Project

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Conference Key Areas: Assessment, Quality Assurance, Curriculum Development.

Keywords: Topic modeling, open-ended survey, student feedback, multinational collaboration.

INTRODUCTION

Open-ended questions are a common option to collect feedback from students after they have participated or performed an assignment. There are benefits and issues with this type of assessment, but certainly there is value in their utilization. The expectation is to get feedback that will provide information that serves to define specific interventions in order to improve the offering of the task being assessed. With the goal of having more objective information being extracted from the students' feedback, Topic Modeling has been applied to the data collected.

Topic modelling is a data analytics approach that results in the identification of topics or themes in the textual datasets provided as responses to open-ended questions. The approach is an iterative algorithm that utilizes frequencies and probabilities in the dataset to extract the requested number of topics. This approach was applied to the responses provided by students participating in a multinational engineering design project collaboration, where basic like-dislike-suggestion questions were given at the end of their participation. The collaboration was done over the course of several weeks with engineering students from different countries in the Americas and Italy.

Demographic data was as well collected from the students, and the application of topic modelling approach is segmented based, mainly, on geographic location. Preliminary results from the analyses indicate that there are some specific topics being identified, particularly on the dislike side, which can be considered as expected challenges when multinational teams work on a given task. Such results will be considered to define interventions in future offerings of this collaborative project.

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1. GENERAL

Assessment of any activity, academic or otherwise, is always recommended in order to have a better evaluation of the actual offering of the activity. Because in an assessment of an academic activity an objective is to take a look at the process followed for such activity, in many situations there is a need to have open-ended questions. These type of questions will give to the person providing feedback more freedom to mention specific aspects or issues of the activity being evaluated. Such capability for feedback is not easy to accomplish when a numerical survey, with specific questions that are graded based on a scale, is used as assessment tool. Open-ended questions do offer such capability to provide feedback on aspects that are not included in a scale-based survey, but the disadvantage is that it is not easy to extract and use the feedback that is being provided. But this disadvantage is no way demerits the value of such assessment options.

Global engineering collaborations have become a fundamental component in current product design activities. In fact, because of the growing complexity of today's products, their development requires to integrate knowledge and skills across disciplines and organizations resulting in a high levels of collaboration between diverse parties. Working on a collaborative environment provides the advantages of having complementary resources, information and ideas that compensate for the limitations of a design done individually. The expected result is a product that could not have been achieved by any individual acting alone. A main catalyst that has increased collaboration in engineering design projects is the growth in Information Technologies (IT), in particular communication and computational capabilities. These developments improves the capabilities for sharing information across teams of designers located around the world, and provides the infrastructure necessary for an integrated and distributed engineering environment [1]. However, working on multi- or inter-disciplinary projects is inherently challenging, and effective collaboration may require new ways to share information. These challenges "include aspects such as differences in language, culture, education, and government regulations, as well as teams working across different time zones around the world" [2]. As result of these challenges, there is a growing demand for professionals who are able to effectively and efficiently communicate and collaborate with partners from different countries and cultures [3].

It is evident that there is an educational challenge regarding training experiences offered to students so that they acquire the skills necessary to operate in an interdisciplinary and intercultural collaborative environment. As a result, many engineering programs are incorporating educational experiences to better prepare students for the global working environment. Multinational collaborative projects are a good example of such experiences used to promote the development of global competencies in students, combined with the additional technical knowledge of a particular discipline. These projects are characterized by having teams geographically dispersed but working on a common design project. A multinational collaborative project involving students from the US, Latin America and Europe [4] is the one considered in this study. A main reason to implement this project comes from the notion that while international projects offer new opportunities for diversification and expansion, they also introduce risks because of cultural, administrative, geographic, marketing, and economic differences between the organizations involved [5]. Therefore, students must be prepared also to understand and deal with these challenges, and proper feedback needs to be utilized to assess these activities.

2. BACKGROUND

It is essential to have assessment of those collaborative experiences in order to define proper interventions that improve the overall benefits for the students. Direct feedback from participants is the most acceptable vehicle to collect evaluation data. At the same time, in order to avoid any bias in such evaluations, open-ended questions are a better option to get feedback from participants. For this report, data was gathered via an online survey that collected information on three main areas: demographics, motivation of students, and direct feedback. Analyses of the motivational aspects of the survey have been previously reported [6, 7]. The objective in this report is to extract important trends in the open feedback provided by the engineering students participating in a multinational collaborative project, indicating any specific dominant demographic factor.

A collaborative network of institutions from the Americas and Italy has developed and implemented collaborative multinational design projects as part of academic experiences for their students. The main goal of these projects is to foster international collaboration and to offer an opportunity to the students to develop professional skills through international teamwork effort in the solution of a design problem. However, a real challenge of this practice has been to create an effective interaction among the students participating in this type of projects and to maintain the flow of information, and students' engagement in the project and in their learning [8]. The multinational collaborative project used in this study follows the parallel projects approach in which teams from different countries work on the same design project, and clusters of collaboration are formed for the international teams to exchange information and enrich the final conceptual design. Clusters are created in such a way that teams formed on each participating institution are paired with teams from other countries to enforce exchange of information and collaborative work. The interaction of the students is expected to take place using the formal means of communication; additionally, teams are allowed to use informal means of communication to keep the interaction active during the project. The projects last for eight weeks and teams are required to interact for at least five weeks including four scheduled video-conferences.

3. PROPOSED APPROACH

To identify trends in the responses by student participants to feedback open-ended questions is the objective of this study. Those trends will be based on the use of a data analytics approach to investigate any possible relationship between text answers and some of the demographic factors collected in the surveys. The specific analytical approach is topic modelling, and its application is by means of utilizing an implementation in R-language, with the corresponding links to the data analytic routines. Topic modeling is a non-supervised technique to cluster documents in different groups about a specific theme or topic. The idea behind this technique is to group related words like student, homework, teacher in a chosen topic, like university. There are different techniques such as Latent Dirichlet Allocation (LDA) [9], Term Frequency, Inverse Document Frequency [10], and Non-negative Matrix Factorization. More specifically, the Latent Dirichlet Allocation algorithm for Topic Modeling assumes that documents are generated from a mixture of topics. Thus, given a set of documents, the LDA algorithm iteratively infer the topics that can be extracted for a specific theme. LDA uses a document-term matrix representation of all documents and words in a corpus. Then, taking into account the k number of topics, this matrix is decomposed into two matrices, a document-topics one and a term matrix. The former represents the probability of a document belonging to a given topic k . The latter models the probability of words to be in that given topic k . Subsequently, the weights in the matrices are updated taking into account the proportion of words in documents that

are assigned to the topic k and the proportion of topics overall documents that come from word w . These steps are repeated until convergence is accomplished in the process, resulting in the identifications of topics or themes represented by the documents (i.e., survey responses) provided. In this cases the user has the option to specify the number of topics k to be identified, which is usually based on establishing a balance between quantity of topics and their importance.

Similarly, another data analytics technique applied in this case is Sentiment Analysis, or opinion mining, which is an approach that attempts to determine whether an opinion, expressed in written text, is positive, negative or neutral, with respect to specific entities/factors or characteristics [11]. These entities may be products, services, organizations, individuals, events or topics [12]. Nowadays, the Sentiment Analysis tasks are typically performed by corporations or businesses looking for relevant information for their stakeholders. Companies collect and analyze massive amounts of textual data, generated in, for example, social networks and surveys with the intention to identify specific trends or conclusions that support the mission or objective of the corporation/business. In academic institutions, an approach such as Sentiment Analysis can be used to evaluate the perception or the motivation of students concerning development or implementation of specific task(s) in a course, or even for a new course or field of study. In fact, at the end of a semester, some lecturers perform a survey to capture feedback related to the appropriateness of the task or topic/course implemented. Sentiment Analysis can be performed in two ways:

- using supervised machine learning methods
- using dictionaries

The first method uses a well-known machine learning technique called classification. The classification needs a labeled corpus, i.e., a set of positives and negatives documents and, a classification algorithm “learn” from using this labeled corpus to predict the class (positive/negative) when a new document without class arrives. A lot of articles have been published involving the application of this method [13, 14]. The idea behind the second method is to use two, or more, dictionaries. One of positive word(s) and the other one containing negative word(s). This approach starts parsing each word in each document and comparing it with words in both dictionaries. If a word in a document matches with a word in a positive dictionary, the positive sentiment index of the document counts as plus one. The strategy is the same for negative words in the document. Finally, for each document, the number of positive and negative words in the document are compared, and the sentiment (positive or negative) is obtained. This method has been presented and applied in several reports in the literature [15], and in the present study these approach is utilized to deduce the polarity embedded in the responses to open-ended questions in the administered survey.

4. RESULTS

This study is based on data collected during the international collaboration that took place during the Fall 2015 semester. In this instance, 54 international teams from seven different institutions representing six countries were grouped in 12 clusters. Six clusters had five international teams and six clusters had four international teams, as illustrated in *Table 1*. The project undertaken by all clusters consisted on the design of an appropriate workspace for prototyping with hand-tools. The following requirements were defined for the project: the workplace was to accommodate up to four people working simultaneously; workers with various types of disabilities should be able to use the facility; workbenches were to be utilized for prototyping and tools/materials storage; workbenches were to be installed in 34 m² room with the footprint of the workbenches limited to a maximum of 50% of the room space.

Table 1. Distribution of country teams in clusters.

Cluster	BR	CH	EC	HO	IT	US1	US2	Total
1		2	1			1	1	5
2		2	1			1	1	5
3		2	1			1	1	5
4		2	1			1		4
5		2	1			1		4
6		2	1			1		4
7		2		1	1	1		5
8		2		1		1	1	5
9		2		1		1	1	5
10		2		1		1		4
11		2		1		1		4
12	1	2				1		4
Total - Teams	1	24	6	5	1	12	5	54
Total - Participants	4	49	33	28	4	52	15	185
Total - Respondents	3	1	0	19	2	50	12	87
% Respondents	75	2	0	68	50	96	80	47

BR: Brazil; CH: Chile; EC: Ecuador; HO: Honduras; IT: Italy;
US1: United States (University 1); US2: United States (University 2)

The survey administered after students participation had five demographics questions and three open-ended questions, in addition to IMI-based questions [6, 7]. The first five questions allowed characterization of the population participating in the study. The last three question provided the feedback for assessment and intervention purposes. The total number of students participating in the collaborative effort as well as the feedback exercise was 185, with 95 responses captured online at the end of the semester, but only 87 of them considered as valid responses, i.e., 47% response rate. The main demographic data collected was: a) location, b) class standing, c) gender, and d) ethnicity, with one additional question is related to their enrollment in the collaborative effort. The three questions included in the questionnaire to capture the appreciation of the students are open-ended and the answers by the students were given in text format (online). The questions are the following ones:

1. What did you like most about the collaborative project?
2. What did you like least about the collaborative project?
3. What would you recommend to improve the collaborative experience?

The datasets from these questions were used in the analyses presented in this study, basically the application of the Topic Modeling and the Sentiment Analysis approaches to the textual data of the surveys. The first step is to take a look at the actual data collected based on demographics. Exploring the dataset to analyze the number of answered surveys corresponding to each of the demographic factors, such as standing, gender, and ethnicity. *Figure 1a* illustrates information regarding class standing, where the largest group represents first-year students; *Figure 1b* illustrates the breakdown based on gender, the participants were 83% male and 17% female; and *Figure 1c* illustrates the ethnicity of the participants, indicating that the largest group is #5, which represents Caucasian ethnicity. Based on these results, and as well taking into account recommendations for the Topic Modeling using LDA algorithm, it is decided to perform a grouping based on ethnicity, which implies that the results will be a good reflection of US student population and non-US population, since there is high level of correlation between ethnicity #5 and a participant being from a US academic institution.

Performing Topic Modeling to the complete dataset, and selecting the identification of three topics (*Table 2*), results in positive responses regarding the international experience (country), the global teamwork (team), and the concept (idea); with negative responses related to communication, time, and work level; and suggestions related to timing and communication. Once the analysis focuses on the #5 group (*Table 3*), again the positive indicates the international experience and global teamwork, and diversity of ideas; with negative responses related to language (not communication in general), and timing; and suggestions related to teamwork, language and timing. For the non-#5 group (*Table 4*), the positive responses related more to the international experience and people involved, with negative responses on specific communication and timing, and suggestions on collaboration, communication and timing.

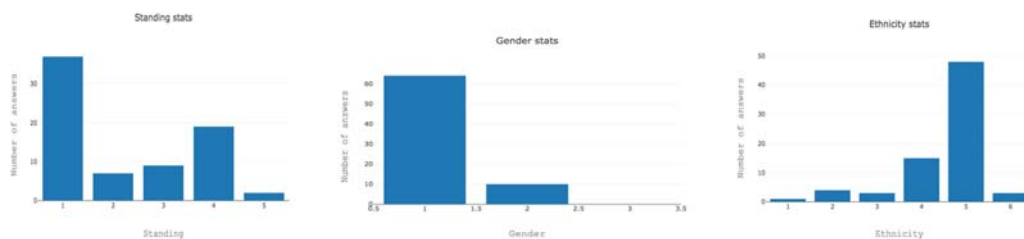


Figure 1. Breakdown of participants based on a) Class Standing, b) Gender, and c) Ethnicity.

Table 2. Topic Modeling based on answers by all participants.

	Topic1	Topic2	Topic3
Q1	country people different	student meeting team	working idea liked
Q2	team communication would	time group work	team working hard
Q3	time work group	team working communication	group team time

Table 3. Topic Modeling based on answers by ethnicity #5 (Caucasian).

E5	Topic1	Topic2	Topic3
Q1	idea different country	team working international	different working project
Q2	project working different	team language time	group time meeting
Q3	team project group	time meeting language	time hard group

Table 5 shows the results of the Sentiment Analysis, which has been accepted as valid tool for analysis of text, showing value ranges from negative to positive, and zero being

neutral in a 10-point scale. These results, overall and split groups, indicate a positive sentiment but with most values close to the neutral point. The only negative is in Q2 for the non-#5 group, where communication (language) was previously identified. It is of interest to indicate that similar trends are observed when the grouping is based on geographic location, as it can be observed in the last column in Table 5 (G=6); which is the expected results based on the stated initial assumption between ethnicity and geographic location.

Table 4. Topic Modeling based on answers by ethnicity other than #5 (Caucasian).

E/5	Topic1	Topic2	Topic3
Q1	people sharing country	liked student diff	meet like different
Q2	contact voice call	team work country	team meet time
Q3	project group voice	team work country	team meet every

Table 5. Sentiment Analysis based on answers to the survey.

	E#5	E=5	All-E	G=6
Q1	1.269	0.750	0.932432	0.750
Q2	-0.115	0.187	0.081081	0.180
Q3	1.130	1.111	1.117647	1.111

5. CONCLUSIONS

In this work, analysis of end-of-participation open feedback is analyzed. The feedback is provided by students participating in an international engineering design project, and it is in text format as answers to open-ended questions regarding basic like-dislike-recommendation sequence. The use of a Topic Modeling algorithm results in the identification of themes (topics) that can be extracted from the text provided for each one of the three open-ended questions. The text answers were grouped based on ethnicity, which is highly correlated to location, due to the relative percentages represented in the collected responses. Topic Modeling with an LDA approach provides useful information, presenting that:

- for positive aspects (i.e., international experience, global collaboration, and concept) the two groups have similarities, and are reflected in the overall topics extracted
- for negative aspects, the communication and timing themes are common, with specific indication that language is an issue for non-US participants
- for recommendations, there are similarities in both groups, and basically are directed at addressing the negative aspects (i.e., communication and timing).

The Sentiment Analysis indicates an overall positive feeling, but with an index close to neutrality.

These results indicate that even when all students appreciate the international collaboration experience, there were some issues that need to be addressed. In terms

of communication, which is an expected challenge particularly for entry-level students, the intervention that is suggested is to make participants more aware of this, and other, issues when the project is introduced, thus expecting more understanding from the students. On the issue of timing, the intervention that is suggested is to have better logistics, offering more flexibility to the students to have less constraints in terms of meeting sessions. Future offerings of this experience will implement the interventions suggested here, with the goal of having a more positive global collaboration.

6. ACKNOWLEDGEMENTS

The authors would like to acknowledge the participation of faculty members that worked in this collaboration project, mainly by including the project into their courses, thus having students participating in the project, and requesting their participation on the surveys. Specific faculty are: Carlos Saccheli, from Universidade Federal de Santa Catarina, Brazil; Sheila Lascano, from Universidad Tecnica Federico Santa Maria, Chile; Jorge Duque, from Escuela Superior Politecnica del Litoral, Ecuador; Jared Ocampo from Universidad Tecnologica Centroamericana, Honduras; Roberto Vigano, from Politecnico di Milano, Italy; and Uladeslau Ivashyn, from The Pennsylvania State University - Brandywine, USA. Additionally, faculty that provided assistance with the analysis presented here: Miguel Nunez del Prado and Hugo Alatriza Salas from Universidad del Pacifico, Perú.

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Professional Licensing/Register and Mutual Recognition of Academic Qualifications in the Washington Accord Jurisdictions*

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Conference Key Areas: Quality Assurance and Accreditation

Keywords: Engineering Education, Washington Accord, Licencing, Accreditation

INTRODUCTION

The Washington Accord was signed originally more than 25 years ago with the intention to facilitate the mutual recognition of education qualification for registering or licensing professional engineers to practice in the signatory's jurisdictions [1]. This paper seeks understand how the mutual recognition actually works inside the Washington Accord and identify which signatories are able to follow the intent of the Washington Accord.

This review is timely due to the recent admission as signatory of ICACIT (Peru) and the possible entry of three other accreditation systems from Latin America (currently as provisional members), where the register/license processes differ from those analysed in this research.

1 BACKGROUND

1.1 Washington Accord and the International Engineering Alliance

The International Engineering Alliance (IEA) is a global organization with 37 members from 28 countries around the world. The IEA comprise seven international agreements. Three of

* This work was sponsored by IEEE. Opinions expressed in this article are the author's – not IEEE's or any of the organizations mentioned in the paper.

them for the recognition of engineering educational qualifications (Educational Accords) and the other four for recognition of professional competence (Competence Agreements).

The Washington Accord (WA) is a multi-lateral agreement between bodies responsible for accreditation or recognition of tertiary-level engineering qualifications within their jurisdictions who have chosen to work collectively to assist the mobility of professional engineers. The WA was originally signed in 1989 and is the oldest of the IEA Educational Accords.

The WA acknowledges that accreditation of engineering academic programmes is a key foundation for the practice of engineering at the professional level. Currently there are nineteen signatories and five organisations, who hold provisional signatory status

1.2 Licensing/ Register Process

The licensing is defined as the process by which a governmental agency grants official permission to persons meeting predetermined qualifications to engage in a given occupation and/or use of a particular title [2]. The register/licensing process usually requires three basic elements:

- Academic Qualification: educational qualifications are almost always required as a pre-requisite to demonstrate being considered for a license. In most jurisdictions, this qualification is a bachelor degree and in some jurisdictions, a master degree may be required. In many jurisdictions, licensing bodies rely on accreditation agencies to ascertain that a candidate for register/licensure possesses the required education, and most will allow graduates of accredited programs an easier path to register/licensing than others [3].
- Experience: usually candidates for a license are required to demonstrate that they have worked and performed successfully as engineers for a certain period of time before they apply for a license.
- Examination: there are a plenty of evaluation tools used by licensing bodies to assess the competence of candidates for a license. In some jurisdiction, candidates shall pass a series of standardized technical exams. In others, there is a more individual review process including an evaluation of work portfolio and interviews by peer committees. A common practice is assess in two moments: (1) after graduation for recognition of educational qualifications and (2) after complete a certain period of years working in the engineering field to demonstrate the competence for an independent practice of the engineering.

2 FRAMEWORK OF LICENSING/REGISTER PROCESSES

To understand the diversity of registration, licencing and regulatory models, a framework was establish using the criteria below and show in table 1. The information was collected through literature and websites review and consultation with Washington Accord signatories.

- a. What academic qualifications are required for Licensing/Register?
- b. How many stages and titles does the process include?
- c. How much experience is required?
- d. What kind of examination is included?
- e. There is a relation between the licensing process and accreditation?
- f. What protected title(s) and authority are provided?

Table 1. Accreditation and Registering Bodies Associated with the IEA

Jurisdiction	Academic qualification required	Stages	Experience (years)	Examination				Linked w/ accreditation	Protected Title
				Academic Qualification	Self-Assessment	Industry review	Professional Interview		
Australia	Bachelor degree	1	5	Yes	Yes	Yes	Yes	Yes	Chartered Professional Engineer (CPEng)
Canada	Bachelor degree	2	3 - 4	Yes	-	Yes	-	Yes	Professional Engineer (P.Eng.)
China	-	-	-	-	-	-	-	-	-
Chinese Taipei	Bachelor degree	1	-	Yes	-	-	Yes	Yes	Professional Engineer
Hong Kong	Honours degree	2	4 - 6	Yes	-	Yes	Yes	Yes	Engineer (Ir.)
India	-	-	-	-	-	-	-	-	-
Ireland	Master degree	2	4	Yes	-	Yes	Yes	Yes	Chartered Engineer (CEng MIEI)
Japan	Bachelor degree	2	4	-	-	-	Yes	Yes	Professional Engineer (P.E.Jp)
Korea	Bachelor degree	1	6	-	-	-	Yes	Yes	Professional Engineer
Malaysia	Bachelor degree	2	3	-	-	Yes	Yes	Yes	Professional Engineer (Ir. / P.Eng)
New Zealand	Bachelor degree	2	-	-	Yes	-	Yes	Yes	Chartered Professional Engineer (CPEng)
Pakistan	Bachelor degree	2	5	-	-	-	-	Yes	Professional Engineer (PE)
Russia	-	-	-	-	-	-	-	-	-
Singapore	Bachelor degree	1	4	Yes	-	Yes	Yes	Yes	Professional Engineer (Er. / Engr.)
South Africa	Bachelor degree	2	3	Yes	Yes	Yes	Yes	Yes	Professional Engineer (Pr Eng)
Sri Lanka	Bachelor degree	2	8	-	Yes	Yes	Yes	Yes	Chartered Engineer [CEng (Sri Lanka)]
Turkey	Bachelor degree	1	-	-	-	-	-	No	Mühendis (Engineers) / Yüksek Mühendis (Higher Engineer)
UK	Master degree	2	-	-	-	Yes	Yes	Yes	Chartered Engineer (CEng)
USA	Bachelor degree	2	4	Yes	-	-	Yes	Yes	Professional Engineer (PE)

3 ANALYSIS OF THE MUTUAL RECOGNITION

The diversity of registration, licencing and regulatory models is identified as a major factor in inhibiting recognition of Accord graduates for registering/licensing. Three categories are identified to classify the regulatory models in the Washington Accord jurisdictions.

- *Signatories that are registering/licencing bodies:* A body with accreditation and registering/licencing responsibilities, in signing the Accords, agrees in terms of the Preamble and Clause 1(b) of the Accord to afford graduates of programmes accredited by other signatories the same benefits toward registration or licencing as graduates of programmes accredited in their jurisdictions. Most of these are also members of an IEA competence agreement (i.e. APEC Agreement) and operate an international register.
- *A separate registering/licencing body:* Unless a relationship exists with the jurisdiction signatory, this body may not automatically recognise programmes accredited by other Accord Signatories as meeting its educational foundation. Such a body may be a member of an IEA competence agreement and operate an international register.
- *Jurisdictions without a national licensing system:* Each state or territory has its own licensing body, establishing its own procedures and requirements for granting a professional license. In these cases, the accreditation agency usually has no authority or influence to guarantee mutual recognition.

While the Washington Accord states that each signatory will “make every reasonable effort to ensure that the bodies responsible for registering or licensing professional engineers to practice in its country or territory accept the substantial equivalence of engineering academic programmes accredited by the signatories to this agreement.” This research shows that only twelve of the nineteen signatories guarantee the recognition of accredited qualifications and two may grant it depending on the state licensing boards. Table 2 show for each Washington Accord jurisdiction, the signatory, the registering or licencing body (indicating whether it is affiliated to the IEA or not).

In third category, the cases of Canada and United States are particular because both countries has institutions which make recommendation for admission to the practice of engineering, however each state has its own agency responsible for granting licenses [4][5]. Even more interesting is the considerably variation of registration policies from state to state in USA.

In particular, in the United States, registration policies vary considerably from state to state. To illustrate, the states of Mississippi, South Carolina, South Dakota and Utah recognize the graduates of the Canadian Engineering Accrediting Board (CEAB), the states of Texas, Idaho and South Carolina recognize the programs accredited by signatories of the Washington Accord. Moreover, the state of Illinois does not necessary recognize graduates of programs accredited by ABET even when this is a common practice for the other states [6].

4 BEYOND THE RECOGNITION TO ENTRY TO THE PROFESSION

The Washington Accord signatories has no duty to provide additional benefits other than to ensure that the agencies responsible for licensing in their country or territory accept the substantial equivalence of the academic engineering programs accredited by the signatories of the Accord. Nevertheless, several signatories make efforts for recognition of academic qualifications before higher education institutions of their country to continue postgraduate studies; however, they recognize their autonomy in the admission process. In this group, Turkey and Taiwan stand out. MUDEK (Turkey) and IEET (Taiwan) through negotiations with

Table 2. Accreditation and Registering Bodies Associated with the IEA

Jurisdiction	IEA-affiliated Bodies			Non-IEA-affiliated Bodies	Mutual Recognition
	WA Signatory	Registering/ Licensing Body	Body Operating IPEA or APEC Register	Registering/ licensing Body	
Australia	Engineers Australia			–	Full recognition
Hong Kong	Hong Kong Institution of Engineers (HKIE)			–	Full recognition
Ireland	Engineers Ireland			–	Full recognition
New Zealand	Institution of Professional Engineers New Zealand (IPENZ)			–	Full recognition
Pakistan	Pakistan Engineering Council (PEC)			–	Full recognition
South Africa	Engineering Council of South Africa (ECSA)			–	Full recognition
Sri Lanka	Institution of Engineers Sri Lanka (IESL)			–	Full recognition
UK	Engineering Council (EngC) (CEng licenced to Institutions)			–	Full recognition
Malaysia	Board of Engineers Malaysia (BEM)		Institution of Engineers Malaysia	–	Full recognition
Canada	Engineers Canada	–	Engineers Canada	Provincial/Territorial Registering Bodies (15)	May require additional learning or examination
China	China Association for Science and Technology	?	–	?	Full recognition
Chinese Taipei	Institute of Engineering Education Taiwan	–	Chinese Institute of Engineers (CIE)	Ministry of Examination R.O.C	No recognition
India	National Board of Accreditation	–	Institution of Engineers India	Each municipality	No recognition
Japan	Japan Accreditation Board for Engineering Education (JABEE)	–	Institution of Professional Engineers Japan (IPEJ)	Ministry of Education, Culture, Sports, Science and Technology	No recognition
Korea	Accreditation Board for Engineering Education of Korea (ABEEK)	–	Korean Professional Engineers Association (KPEA)	Ministry of Employment and Labour (MOEL)	No recognition
Russia	Association for Engineering Education of Russia	–	AEER	–	No recognition
Singapore	Institution of Engineers, Singapore (IES)	–	Institution of Engineers, Singapore	Professional Engineers Board (PEB)	Full recognition
Turkey	Association for Evaluation and Accreditation of Engineering Programs (MUDEK)	–	–	Turkish Union of Chambers of Engineers	Full recognition
USA	ABET Inc	–	NCEES	State Licencing Boards (54)	May require additional learning or examination

different government bodies, they have ensured mutual recognition for WA graduates to pursue postgraduate studies in the universities of their countries.

On the other hand, there are two singular cases. In Canada, CEAB establish in its accreditation criteria a process for recognition of WA studies in Canadian universities [7]. Likewise, in New Zealand WA degree holders are eligible for additional points under the Skilled Migrant immigration category [8].

5 CONCLUSIONS

Mutual recognition within the Washington Accord is not uniform. However, in some cases it goes beyond recognition for the practice of engineering for example: student mobility, postgraduate studies or even migration of professionals. Notwithstanding, this should not undervalue the worth of the Washington Accord, as a preeminent group of quality assurance organizations that has developed output standards for engineering programmes and a consensus on best practice in programme accreditation and anticipate needs in global engineering education. Therefore, it brings value to graduates and education providers by assuring that engineering accreditation system applies standards substantially equivalent to the Accord Graduate Attribute exemplar [9] as well as best practice in accrediting programmes.

Finally, indicate that the mutual recognition is not a problem unique to the Washington Accord. The EUR-ACE Accord, signed in November 2014, seeks to extend recognition of graduates for both registration / licencing and qualifications recognition purposes, also by agencies making “every reasonable effort” to ensure such recognition in their home countries [10]. Accord that may be subject of study for a future research.

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Engaging Engineering students into active collaborative learning

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Conference Key Areas: Innovative Teaching and Learning Methods, Discipline-specific Teaching & Learning, Engineering Skills, The teacher as a supervisor,

Keywords: Mathematics in Engineering Education, Assessment and Evaluation Strategies/Approaches, Teaching & Learning Experiences in Engineering Education, Collaborative Learning

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INTRODUCTION

Nowadays a number of transversal competencies are expected to be achieved in addition to the specific competencies of each subject. In order to facilitate this goal, instructors in general should transform themselves and their classes from a direct teaching/learning dichotomy into a kind of coaching and blended teaching/learning.

After having developed a methodology involving many facets of blended learning which include flipped learning as an integral part of tackling theoretical principles, problem solving and computing sessions, we have gone into a further blended methodology that facilitates and requires punctual collaborative learning while getting ready for relevant moments of evaluation in a first year Mathematics subject of Aerospace Engineering at Technical University of Valencia (Valencia, Spain).

The procedure developed consists in adding a task of selected exercises that the students are required to bring solved so that they may use them while solving some appropriate multiple choice tests based on the exercises of the task and including some slight difference. Students answer to this test individually and immediately after within small groups.

In this paper we present the activities undertaken which in a natural way help to develop some transversal competencies such as critical analysis, scientific and technological communication and collaborative working in addition to the pursued specific mathematical competencies. We analyse the students' opinion about the collaborative learning applied in the subject and discuss the results and questionnaire used to get the students' opinion.

1 THE SETTING

1.1 The subject

Mathematics I is a compulsory and annual subject with 12 ECTS of which 75% correspond to Theory / Problems (TP) sessions and the remaining 25% to lab practices (LP), taught in the first year of Aerospace Engineering [3] at the School of Design Engineering (ETSID) of the Technical University of Valencia (UPV).

One of the main competences that students must acquire in the Aerospace Engineering degree is the resolution of mathematical problems through the subjects of the Department of Applied Mathematics, Mathematics I being the first of them.

There are two different groups: one is High Academic Performance (ARA) which involves 51 students, with teaching in English, and the other one which involves 77 students, called NARA, with teaching in Spanish. Both groups follow the same methodology in Mathematics classes and there is no difference in topics, assignments or exams, just the language as means of instruction and communication.

The professors of the subject encourage collaborative learning among students throughout a number of activities related to the specific competencies that they must acquire within the subject. This collaborative learning facilitates the continuous assessment of students and allows them to customize their improvement needs in particular cases.

The methodology is extended to other mathematics subjects of this degree and in general to all those related to Science, Technology, Engineering and Mathematics (STEM).

1.2 About collaborative learning

Collaborative learning is given when two or more people learn something together, benefiting from the knowledge, resources and skills of the other group members, while evaluating their ideas, resources and skills, [4-6].

Therefore, in collaborative learning, students are involved in a common task in which each individual is both teacher and student, developing the critical capacity to discuss or refute ideas and at the same time offer knowledge. We can say that the objective of this methodology is to seek understanding, meaning or solutions or to create an artefact or product through group collaboration.

Collaborative learning provides a different approach to the traditional teacher-student relationship in the classroom, not without controversy since some authors question the possible benefits that can be obtained [7-8]. The activities that can be included in collaborative learning are wide, and include among others, collaborative writing, group projects, joint problem solving, debates, study teams and other activities. Also the possibility of planning the activities for the realization inside the classroom or outside it, or the high adaptability in difficulty and length must be added [9-12]. In some approaches, this collaboration arises in an unplanned way and can be closely related to cooperative learning. Some faculty members design work in small groups around specific sequential steps or tightly structured tasks. In some collaborative learning environments, the student's task is to create a clearly delineated product; in others, the task is not really to produce a product, but to participate in a process, an exercise in response to the work of others or to get involved in the analysis and creation of meaning.

1.3 Our approach to collaborative learning

Our approach is developed within a process of continuous evaluation, based on a significant increase in the number of control points of the evaluation of the subject, and is framed as part of the process of achievement of specific and transversal competences. The traditional form of evaluation is through individual tests, but in the process, collaborative and even cooperative learning can take place.

Collaborative learning has been designed taking into account that the fundamental objective is to maintain or increase the acquisition of specific competences in Mathematics, while developing the analytical and critical spirit of the students and their specific communicative competences in Mathematics.

Collaborative learning is facilitated by the realization of classroom activities that are the final phase of preparation of the subject before traditional individual exams are conducted. Little weight in the evaluation is given to these activities prior to the exam (15% of the general theoretical assessment / problem solving) by evaluating individual and group tests based on assignments that are made public 2 weeks before the traditional exam.



Fig. 1. Students doing the individual test



Fig. 2. Students doing the group test

The assignments are designed with different levels of difficulty and to be worked initially individually. The tasks can be consulted during the individual test. We can see the students doing this test in Fig. 1. Once the individual test is finished, the students are required to collaborate within a group of up to four students to analyze the options they consider valid and obtain their opinion on the correct answer, as can be seen in Fig. 2. During this test, the students cannot consult their individual assignment in order to encourage a critical analysis of the answers of their classmates and their own answers, and avoid the simple comparison of results. That is, we encourage the development of other key competences, such as oral communication skills related to scientific and technological language, leadership, critical thinking and the ability to adapt to other environments that face other opinions.

During the group test, the students, unable to use the results of their individual tests, must defend their opinion simply by using their oral communication skills and their mathematical competencies, without the support of solved exercises that can simplify their point of view by pointing out a result.

In this way, the possible deficiencies and strengths of their specific mathematical competences arise while they have to use their communication skills to ask or defend their selected answers when speaking with their peers. This facilitates collaborative learning through lively discussions among students immediately after working introspectively each of them in the proposed exercises.

This methodology implies a greater involvement of the student in the achievement of the objectives of the course given that he can obtain continuous feedback of his level of achievement, while receiving help to direct his efforts in those specific areas of the subject that require more practice or deeper learning.

Increasing the number of control points implies the increase of the immediate perception of the results and of their level of acquisition of specific competences, motivating the student and channelling their efforts towards a homogenization in their levels of acquisition of the subject's competences. The collaborative discussion of their results among them facilitates the development of transversal competences such as critical analysis, problem solving and communication, among others.

Finally, the early detection of students with more difficulties makes it possible to complement their activity to achieve the final objectives of the subject.

Clearly, the objective is not only an increase in the number of control points of the continuous assessment, but facilitating and encouraging the collaboration among the students so that they increase and develop both the specific competences of the subject and others of transversal type.

The specific objectives of our methodology can be summarized in:

- Facilitate collaboration among students as a group while increasing their evaluable control points. This should not imply saturation with more activities, but adapt them to collaborative learning.
- Integrate collaboration as a self-assessment and diagnostic procedure
- Encourage the active participation of students in the design of their curricular adaptation.

2 RESULTS AND FEEDBACK

The results and the rates of return are good since the study group obtained very high cut marks, and less than 10% of the students have problems to follow the course. Despite this low rate, it is necessary to have procedures capable of detecting situations in which students have problems of follow-up, and also offer solutions to correct possible deficits that arise.

By comparing the notes obtained by the students in the individual exam and the group exam (subtracting the group note from the individual one), we can draw several conclusions. On the one hand, the difference is always positive, which means that to date, the group qualifications are always higher than the individual ones, which reinforces the hypothesis that the group activity improves the students' performance and that the interaction between them can be considered a positive factor in their learning process.

On the other hand, if in each group we calculate the difference between the individual grade and the group grades squared and add these values, and divide by 400 (which would be the maximum possible value) we obtain the group efficiency. The values obtained in the course are shown in Fig. 3.

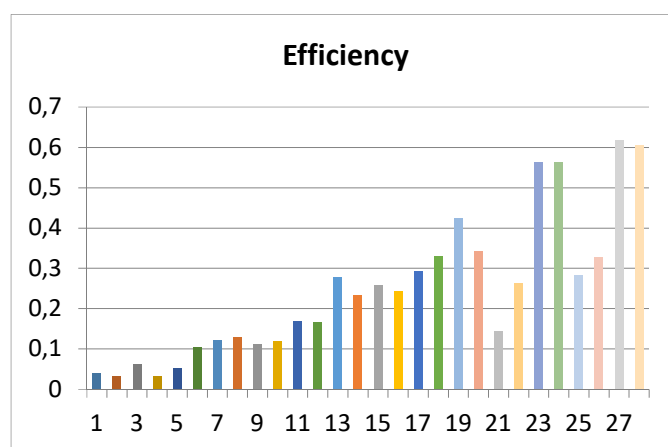


Fig. 3. Group efficiency calculated from individual and group grades.

These data may help to carry out a gamification process (rewarding the most efficient teams according to the grades obtained) or even to reinforce transversal competences.

In order to obtain the opinion of the students of the methodology followed, the opinion of the students about this work system was requested. Specifically, the students were asked to answer some questions. The declarations and the distribution of the answers are shown in Table 1 and Table 2.

*Table 1. Concerning the **individual test** I think that:*

	ARA	NARA	Total
I get aware of my level of competence and they influence my learning process	10 (20%)	19 (25%)	29 (23%)
I do not change my perception of what I know, and they influence little on my learning process	19 (37%)	25 (32%)	44 (34%)
I would rather not do them as they do not influence on my learning process	22 (43%)	33 (43%)	55 (43%)
	51	77	128

*Table 2. Concerning the **group tests** I think that:*

	ARA	NARA	Global
I get aware of my level of competence	6 (12%)	4 (5%)	10 (8%)
I usually learn something	21 (41%)	32 (42%)	53 (41%)
They do not influence on my learning process	9 (18%)	20 (26%)	29 (23%)
They add little value but I like doing them	6 (12%)	12 (16%)	18 (14%)
They are a loss of time	9 (18%)	9 (12%)	18 (14%)
	51	77	128

The tests that are carried out during the individual and group part are of multiple choice and require a lot of attention and reasoning to distinguish the correct answer from the four possible answers provided for each question.

In general, we can notice that the students have a positive perspective of the collaborative part of each exam and a negative one of the individual part. This can be understood if we bear in mind that the first part is closely related to the previous task and this involves hard work.

When the collaborative part comes into play, interaction with peers is fun and helps them clarify and correct ideas, and have a positive appreciation. Apparently, they are not fully aware that the whole environment helps them achieve mathematical competencies while practicing

with others. The final stage of collaboration makes sense in our environment once the individual performance has taken place in the first instance.

Maybe they would like to omit the individual part, but the information they would get from the experience would not be the same. In order to improve the perception of students in the individual test, instructors should make them aware of the relevance of this internal vision that allows for further collaborative work based on their personal introspective work.

3 SUMMARY AND ACKNOWLEDGMENTS

Due to their situation in the first stages of their studies, we have considered important that while students achieve specific mathematical competences, they do so by facilitating the development of other transversal competences such as scientific communication, collaboration with partners, thinking critical, all of which prepares them for their continuing education and lifelong learning.

The collaborative work developed in class facilitates a deeper achievement of specific competences. Students should be aware that this collaborative work is carried out once they have achieved some mathematical competence and a personal critical thinking that allows them to communicate and discuss with their peers. The relevance is not in the test itself or in the collaborative work, but in the mathematical and key competences developed and achieved in the process that should become evident in the mathematical competences that they will demonstrate to have achieved in the subsequent individual exams.

The authors thank the support received from the "Educational Innovation Project, PIME2016 A20, Vice-Rector for Studies, Quality and Accreditation, Universitat Politècnica de València (Valencia, Spain)".

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The use of digital learning technology to minimize problems caused by heavy budget cuts on teachers

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Conference Key Areas: Innovative Teaching and Learning Methods, Engineering Skills

Keywords: Introductory Mathematics, Mathematical Competencies, Digital Learning Technology, Digital Assessment, Maple, MapleTA.

INTRODUCTION

In this paper we report about a large scale teaching experiment conducted at a large introductory mathematics course which took place in the academic years 2016-2017 and 2017-2018. The experiment was initially forced by external needs: Due to general budget cuts we (the course managers and authors of this paper) received a tough assignment: To reduce working hours for external teaching assistants with one third - without compromising the teaching quality. Of course that seemed impossible, but we had to try. We were not offered any time for pilot projects etc., we had to find a solution that could be implemented soon and for all 1100 students at the same time. Thus, the budget reduction gave rise to a course redesign problem: How could we over short time reorganize a large course in order to reduce the number of contact hours between teaching staff and students whilst maintaining the quality of learning and teaching.

Since we did not want to cut in the scheduled teaching time, the only way we would have a chance to resolve the redesign problem was through extended use of technology. But what kind of technology should be chosen and how should it be used? We knew, as stated in a thorough OECD-report, that technology does not necessarily improve learning: "The

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connections among students, computers and learning are neither simple nor hard-wired; and the real contributions ICT can make to teaching and learning have yet to be fully realized and exploited" [1]. Accordingly, it was clear to us that we should pay close attention to the way in which we would implement a new digital tool, and that it should be carefully based on an analysis of local needs and conditions. We found that this could be done in three steps: 1) First we had to get an overall status of the mathematical competencies that we want the students to obtain during the course and find out where teachers are needed the most, 2) next we had to analyze how the use of digital tools could actually support the current learning goals, and 3) finally, in the implementation, we should not underestimate practical constraints such as numbers of students, available classrooms, ICT- infrastructure and network connections. In the paper we will describe how we took these steps, completed a new informed course setup/redesign and how we have evaluated our efforts.

1 MATHEMATICAL COMPETENCIES, WHERE ARE TEACHERS NEEDED?

1.1 The concepts of mathematical competence and competencies

With the now famous KOM report from 2002 it became clear for many educators that teaching and learning mathematics should be regarded in a much broader sense than it was common previously where the main focus often was on trivia knowledge and procedural skills. Now the goal for mathematics teaching on all educational levels from primary school to university should rather be obtaining mathematical competence defined as "the ability to understand, judge, do, and use mathematics in a variety of intra- and extra-mathematical contexts and situations where mathematics plays or could play a role" [2]. In 2013 it was confirmed that these ideas still are highly relevant, not at least on technical universities, when the SEFI Mathematics Working Group (MWG) adopted the concept of mathematical competence as a foundation for the group's new curriculum framework [3]. As stated by the principal editor of the framework (B. Alpers) there were mainly two reasons for this:

"On the one hand, it emphasizes the ability to apply mathematical concepts and procedures in relevant contexts which is the essential goal of mathematics in engineering education: to help students to work with engineering models and solve engineering problems. On the other hand, it explicitly recognizes that competence requires a solid base of knowledge and skills reflecting the strong opinion of many "practitioners" engaged in the MWG" [4].

In order to make the concept of mathematical competence more operational it is differentiated into eight specific competencies ([2], [3] and [4] for detailed definitions):

1. Thinking mathematically
2. Reasoning mathematically
3. Posing and solving mathematical problems
4. Modeling mathematically
5. Representing mathematical entities
6. Handling mathematical symbols and formalism
7. Communicating in, with, and about mathematics
8. Making use of aids and tools

In the next section we will analyze the status regarding mathematical competencies for the course in question in this paper.

1.2 How are the mathematical competencies reflected in the course Math1?

The course, which is the subject of this paper, is a first year course in mathematics, Math1, at a technical university (Technical University of Denmark, DTU). It counts 20 ECTS points, and it is obligatory for all bachelor study programs at the university. Inspired by ideas behind the Danish KOM report [2] the course from the very beginning back in 2001 combines different approaches to the teaching and learning of mathematics. It contains four teaching elements, each of them having its own evaluation form testing different competencies. We list the four elements here together with a tentative list of the most relevant competencies involved:

- Standard teaching with lectures followed by group exercises covering 2/3 of the total teaching time. Mathematics is built up linearly, step by step. The outcome is evaluated in two individual written exams. Competencies involved: 2, 3, 5, 6.
- Seven homework assignments distributed throughout the academic year focusing on mathematical subjects just been treated. The students are expected to unfold, explain and visualize the mathematical concept and methods. Corrected, commented and evaluated by Teaching Assistants (TAs). Competencies involved: 2, 3, 5, 6, 7.
- Seven thematic exercises given throughout the academic year focusing on mathematical subjects just treated. Examples: Modelling electric networks by using systems of linear equations or modelling forest fire by vector fields. Evaluated by a quiz which tests that the exercise has been worked through. Competencies involved: 1, 3, 4.
- A large four-week group project-exercise at the end of the course where several main topics are brought together in order to investigate a real-world problem. The group report is evaluated by TAs and followed by an oral examination. Competencies involved: 1, 2, 3, 4, 5, 6, 7. The idea and design of Math1 project-exercises is described in [5]

As shown here, each mathematical competence is unfolded in at least two of the four teaching elements, and we find that the elements play together in a fruitful way. Please note, however, that there is one missing: We have omitted competence number eight (aids and tools) from the analysis of the competencies involved in the course since. The reason for that is that the meaning, amount of use and influence of aids and tools have changed dramatically through the last decades, i.e. since the KOM report. This is especially the case in Denmark where CAS tools like Maple, TI Nspire or GeoGebra are fully integrated in the high school teaching and at universities and often allowed in homework papers, reports as well as in exams. CAS means "Computer Algebra System". The core characteristic of a CAS is it can calculate and reduce symbolic algebraic expressions, but must CAS can also be used for numeric calculations and advanced visualizations or even animations.

Today technology is (at least in Denmark) a part of all teaching elements, and here we would like to emphasize the intensive use of CAS. CAS supports and potentially expands the meaning of the above mentioned competencies and the opportunities for acquiring them. But, on the other hand, it has gradually turned out that CAS can weaken the acquisition of elementary skills, cf. B. Alpers's remark above about the need for "a solid base of knowledge and skills reflecting the strong opinion of many 'practitioners' engaged in the MWG". Recently a Danish governmental mathematics commission for high school reported that

“there is agreement in the Commission that the way CAS has been involved has had a negative impact on students' development and possession of basic skills”. [6] An earlier report from the Danish Ministry of Education stated that university teachers in general are worried about “the students' deficient handling of formal expressions.” [7]

We conclude that in the center of the new competence field integrated aides and tools a new deficient area has arisen. It is a new problem that we have to address and that commits reconsideration of the teachers' role in relation to the competencies. Where teachers on the floor are still highly important in the introduction of new subjects, in the feedback and evaluation of homework and in the supervision of project work, we found that the new need for consolidating elementary skills more easily can be resolved by mainly using digital tools. Since basic skills usually are introduced in the standard part of the teaching, we found that our chance to reduce working hours spent by TAs without compromising the teaching quality had to be pursued by a redesign of the weekly schedule for the standard part of the teaching which is the subject of next section.

2 REDESIGN OF THE WEEKLY TEACHING SCHEDULE

2.1 Before and after

As mentioned in the section above, we found that the budget cuts should be realized within the standard part of the teaching. We did not want to fire any of the external TAs, but where the TAs before the budget cuts appeared in class twice a week they now only appear once. Hence we had to address three fundamental questions in our course redesign:

1. How can we qualify and optimize the total effort made by the teachers
2. How can we motivate the students to attend sessions without TAs around and take advantage of “learning by peers”?
3. How can we improve the learning of basic knowledge and skills?

Now we will discuss these questions by referring to the before-after teaching schedule as shown in Figure 1. The course had and still has two meeting sessions for the students a week, a Long Day and a Short Day. Before the redesign of the weekly schedule the two days, except for the length (a full day program versus a half day program), had the same structure and goal: A new topic was introduced in the lecture (in big lecture halls) and afterwards the topic was explored in group exercises supported by teaching assistants (in class rooms).

The redesign implicated a new understanding and distribution of the curriculum. As the result of our considerations, we came up with one “topic of the week” which has to be introduced at Long Day. The roles for the lecturer as well as the teaching assistants have accordingly changed. On Long Day the teachers now have to focus on the big picture, the ideas and perspectives for the whole week. We present fewer worked examples but the ones chosen are essential for the attempt to prepare the students for group-work on Short Day without help from the TAs. The Short Day starts with a short lecture, a recap or pep-talk which includes investigating special cases etc. The group exercises, which follow the lecture on Short Day, provide extended online help (hints and results) and they focus important details from the weekly topic including elementary skills from the weekly topic.

Weekly schedule 2015-16			Weekly schedule 2016-17-18		
	Long Day	Short Day		Long Day	Short Day
08:00		Lecture: Topic 2	08:00		Lecture
09:00			09:00		Group exercises without TAs
10:00	Lecture: Topic 1	Group exercises with TAs	10:00	Lecture: Topic of the week	Weekly Test
11:00			11:00		
12:00			12:00		
13:00	Group exercises with TAs		13:00	Group exercises with TAs	
14:00			14:00		
15:00			15:00		

Figure 1. Weekly schedule before and after redesign

A crucial point in the new design is the Weekly Test that intends to give the math teaching week an elegant, effective and motivating conclusion by using digital assessment. We now explain this further.

2.2 The concept of The Weekly Test

To give the new weekly schedule an elegant, effective and motivating ending we had to find a professional digital assessment tool, and we chose Maple T.A. Let us here stress that Maple T.A. can be used in teaching independently from Maple (as a CAS) but its functionality includes the Maple kernel which gives the teacher the opportunity to ask complex and varied questions. Our main principles for the test can be summarized as:

- The students are not allowed to use any electronic mathematical tools since the overall subject is the basic skills of that week.
- The students are allowed to discuss the problems in their working groups. The 10 problems are randomized so that they include different parameters for different students. Consequently the students can discuss the methods but not share the results.
- The problems are graded by the Maple CAS kernel so that it is possible to pose more complex and open questions (as mentioned above).
- The students obtain one bonus point to bring to the final exam if they have more than 60% correct in the first attempt in the classroom in the last hour of the class.
- The test reopens later in a home version allowing for several attempt for further training, especially for students who did not “pass” the classroom test, they now have a chance to obtain a half bonus point.

- The final written exams have a Maple T.A. part with a set of problems selected from the weekly tests. Thus, the problems in the exam are regarding the math identical with the ones that have been on the agenda for the weekly test but they will contain new parameters etc. to prevent the students from just memorizing the result. This means that all “canonical” basic skills once more are fully on the agenda in the exam and that the weekly test not only has a summative purpose, but also a formative.

We now show two typical MapleTA problems.

Example 1:

Given a matrix A and a diagonal matrix D :

$$A = \begin{bmatrix} 5 & -6 \\ 0 & 7 \end{bmatrix} \text{ and } D = \begin{bmatrix} 5 & 0 \\ 0 & 7 \end{bmatrix}$$

State an invertible matrix V such that: $V^{-1} \cdot A \cdot V = D$

(A matrix $\begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}$ is written in MapleTA as `<<1,3>|<2,4>>`)



$V =$  

Figure 2. A typical MapleTA problem in Math1

The problem shown in Figure 2 is to find a quadratic 2x2 matrix that can diagonalize a given 2x2 matrix A . There are infinitely many solutions and the upper triangle in A is randomized within some limits.

Example 2:

An open surface F_r is given as the curved part of the surface of a cone of revolution with the height $h = 5$ and base radius $r = 1$.
We think of the cone as being placed with the base centred at the origin and standing on the (x, y) - plane, and with the vertex pointing in the positive direction of the z -axis.

A vector field is given by the expression:

$$V(x, y, z) = (7 \cdot y, 4 \cdot x, x^2 + y^2)$$

Compute the total flux in through the curved part of the surface of the cone.
(Hint: Put a bottom on the cone and use Gauss' Theorem).

Flux(V, F_r) = Number

Figure 3. A typical MapleTA problem in Math1

The problem in Figure 3 is to calculate the flux of a given vector field through a geometrically given surface. We expect the students to find a parametrization of the surface (there are infinitely many solutions) and the vector field is randomized within some limits.

2.3 The choice of tool, local constraints, drawbacks and how they were addressed

As mentioned above it was necessary to give the new weekly schedule an elegant, effective and motivating ending and the solution was the Weekly Test. We chose Maple T.A. since it gives us the possibility of asking many types of questions with a high degree of complexity, e.g. questions with randomized parameters and infinitively many correct answers which will be evaluated by the Maple kernel. We had one more specific reason for choosing this tool: Maple (CAS) had for many years been a fully integrated part of the teaching. Especially we avoided a classical hurdle in introducing digital assessment: That you have to teach a new input language with rules that can cause noise in the testing results (do you need to write the multiplication sign? Etc.) In our course we are teaching Maple with pure text programming and we use the same language for input in Maple T.A. tests. Subsequently an error is an error no matter if it is in the language or in the math.

When you use digital assessment for credit-giving tests and there are no teachers around, you should expect some cheating! For instance you can cheat by using Maple CAS for solving the problem, and then cut and paste the result into the MapleTA form. To avoid this we introduced the MapleTA facility Proctor Mode where you have to invoke full screen before you enter the test, and if you leave full screen, your answers are submitted immediately and you cannot reenter the test without help from an official. To make this setup work we had to improve internet connections and to have some elder student around as technical support.

3 FINDINGS

3.1 Attendance to the teaching sessions

In the ninth week of the semester we conducted a questionnaire survey where we asked the students about their study behaviour, experiences and attitudes in the previous week, that is semester week eight. One section of the questions was about attendance and here are the results (45% answered):

Table 1. Attendance to the teaching

About Long Day (with TAs):	Yes	No	Total
Did you attend the lecture Long Day	401	130	531
Did you attend the group exercises Long Day	490	43	533
About Long Day (without TAs):			
Did you attend the lecture Short Day	406	125	531
Did you attend the group exercises Short Day	504	29	533

We conclude that surprisingly the attendance on Short Day (without TAs) seems at least as high as on Long Day. This applies to both lectures and group exercises and shows that we have succeeded on one crucial point: To make the students attend that part of the scheduled teaching where we had removed the support of present TAs.

3.2 Motivation in relation to activity type

The questionnaire also asked the students about their experience of motivation in week eight in relation to the four most important teaching activities during a standard week: Preparation for the classes, the two lectures, the group exercises on Big Day (supported by TAs) and the

group exercises on Short Day (without TAs) including the Weekly Test. We asked the students to put the activities into a priority order. In Table 2 we show how many first priorities, second priorities etc. each of the activities obtained (41% answered).

Table 2. Popularity of teaching activities

Type of activity	1. priorities	2. priorities	3. priorities	4. priorities
Preparation	24	39	63	290
Lectures	153	113	139	35
Group ex. Long Day	146	160	101	31
Group ex. Short Day	167	106	108	54

We notice that the group exercises on Short Day, again rather surprising, got most first priorities. This fits well with the high attendance on that day and indicates that we have succeeded in one more important ambition: To develop class room teaching without present teachers which the students experience as highly motivating.

3.3 Conceptual understanding versus basic skills

Finally, the questionnaire also asked the students about their self-evaluation regarding their learning of previous weeks' new mathematical concepts and regarding their learning of the weeks' basic skills and methods.

In Table 3 we show how the students answered the question (41% answered): *To which degree did the teaching activities support your learning of concepts and their mutual connections in the previous weeks' topics?* And in Table 4 we show how the students answered the question (44% answered): *To which degree did the teaching activities support your learning of the basic skills in the previous weeks' topics?*

Table 3. Learning of concepts

Degree		Numbers
1	To high degree	171
2	To some degree	257
3	To lesser degree	58
4	Not at all	4

Table 4. Learning of basic skills

Degree		Numbers
1	To high degree	203
2	To some degree	263
3	To lesser degree	54
4	Not at all	5

In both tables we find that a big majority of students think that their learning should be placed in the two upper boxes. In order to interpret these numbers in full we should have had similar surveys from the previous year or control groups. Unfortunately, this was not possible due to the time pressure in the teaching experiment. However, we must provisionally welcome the fact that the students experience that both sides of the education have succeed in an apparently balanced way, maybe with a little favour to the basic skills.

4 SUMMARY

We have conducted a big scale teaching experiment in which we have reduced the amount of working hours spent by teachers at a big mathematics introductory course (Math 1 at DTU) with the purpose of maintaining the quality of teaching and learning. We found that this could only be done by a course redesign where we had to introduce a new digital learning tool. In order to do this in an informed way and thereby increase the chances for success, we started with an analysis of the overall competencies that we want the students to obtain and in which teaching elements the physical presence of the teachers are really needed.

The starting point was the concept of mathematical competence and the eight different mathematical competencies it contains as founded in the KOM report and applied on engineering education by the SEFI MWG. Given the high level of the use of digital tools in math teaching in Denmark in general and in the course in question especially we suggested that the eighth competence, aid and tools, is not an isolated competence next to the other seven, but that it in today's teaching and learning are integrated in them and even changes them. In the new field of competencies integrated with aids and tools we saw a new problem that we had to address: The evolving lack of elementary mathematical skills.

From this point the choice of a new digital tool and the redesign of the weekly course program as shown in Figure 1 were not that difficult. By introducing an advanced digital assessment tool (Maple T.A. was chosen) to be used in a weekly test, it seemed like we could resolve two problems at the same time, the reduction of hours spend by teachers in the classrooms and addressing the need to strengthen the basic skills. In the new weekly program teachers are still needed and "on the floor" when we introduce new subjects, in the feedback and evaluation of homework and in the supervision and evaluation of project work. But other tools can take care of the elementary skills in a probably more efficient way: Extended online help, learning by peers and digital assessment.

From the questionnaire survey we have further concluded that the new course setup:

1. Apparently provides a less monotonous teaching, emphasizing different competencies and working forms.
2. Ensures a very large attendance to both classes with and without teacher support.
3. Is experienced by the students as very motivating.
4. Apparently supports the conceptual part of the teaching as well as the elementary skills in a balanced way.

As a whole, we will assert that we have shown that by digitals tools it is possible to minimize problems caused by heavy budget cuts on teachers.

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Challenges for Engineering Education in Developing Innovation and Entrepreneurship

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Conference Key Areas: Fostering entrepreneurship, Innovation as the context for EE, Attractiveness of EE

Keywords: Entrepreneurial mind-set, innovation development, educational challenges

INTRODUCTION

Both automation and globalisation of manufacturing have caused significant changes for European companies involved in engineering related activities. These have included the diminishing number of large manufacturing companies and the decreased expectation of single organisation life time employment [1]. The nature of the professional competences required today and for tomorrow is rapidly changing. In addition to acquiring core 'hard' skills in subject specialisations, graduating engineers are expected to have developed self-learning abilities, skills to combine pieces of knowledge to innovative solutions and appreciate the need to embrace at least entrepreneurial mind-set. A recent science policy report issued by the EC [2] has stressed that entrepreneurial skills and attitudes can be learned. The report even defines what the competences are and in which level they should be learned. Is there a broad

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consensus as to what these are and how to include them in curricula? We would question such a broad statement, or indeed if such a consensus is required – for example - are the needs different in different countries in Europe? The challenge for engineering educators in an already dense curriculum is to identify effective ways by which the essential elements of an entrepreneurial culture can be developed in students.

1 THE CHALLENGE

1.1 Competence and Entrepreneurial skills

It is widely appreciated that to be effective an engineer requires a very diverse range of competences and skill levels. The required mix of these and the emphasis placed on them will of course vary from position to position and indeed the individual occupying the position. As part of a complete engineering education it is important that students are introduced to key aspects of management, finance, teams, leadership, etc., with various ways employed to develop this awareness. However, with the changing nature of professional engineering positions in Europe today, the requirement for engineers to have additional competences emerges. The question then arises how best to encourage the development of entrepreneurial mind-sets in today's engineering students. Is such a mind-set needed by all students and is that sufficient or do students need additionally skills and competences in entrepreneurship?

In this context one interesting item of research was undertaken by TEK – the Association of Academic Engineers and Architects in Finland - in 2016 building on earlier work in 2014 [a]. During the 2016 survey TEK contacted 2779 of its members to seek their evaluation of the importance of various skills and competences in their present position. This was sent to TEK members who had been born in the years 1963, 1973 and 1983, thus enabling comparisons to be made with changes in age, or perhaps seniority - within an organisation. Replies were received from 544 members (i.e. a 19.6% return – a healthy response rate by any standards) Of these 74% were men and 26% women. 85% held a Masters level degree in engineering, 9% in science and 3% in architecture. The results of this survey to the question: “what competences you need in your current job?” are presented graphically in Fig 1.

Some of the outcomes as seen in Fig. 1. offer few surprises, such as the importance of problem solving and analytical thinking – to be anticipated for an individual having a technical background – and also the emphasis on communication and time management. What is particularly noteworthy is the lower emphasis placed on entrepreneurial capacities. However, at the same time it should be stated that this survey was classifying the answerers to senior managers, middle managers and specialists and therefore, by default engineers who might have established small companies of just a few individuals will probably not have been identified and they might have been a small minority. With the increasing pace of technical development and the changing nature of many companies, there is a growing recognition today, that an ‘entrepreneurial-like’ approach may be necessary in even the largest organisations. But from this survey, perhaps not unsurprisingly, it would appear that in comparison with other skills it is not of the highest priority. Do they not see the need of an entrepreneurial mind-set if they are not self-employed - or are entrepreneurial competences so common that the relationship to entrepreneurship is not appreciated or understood?

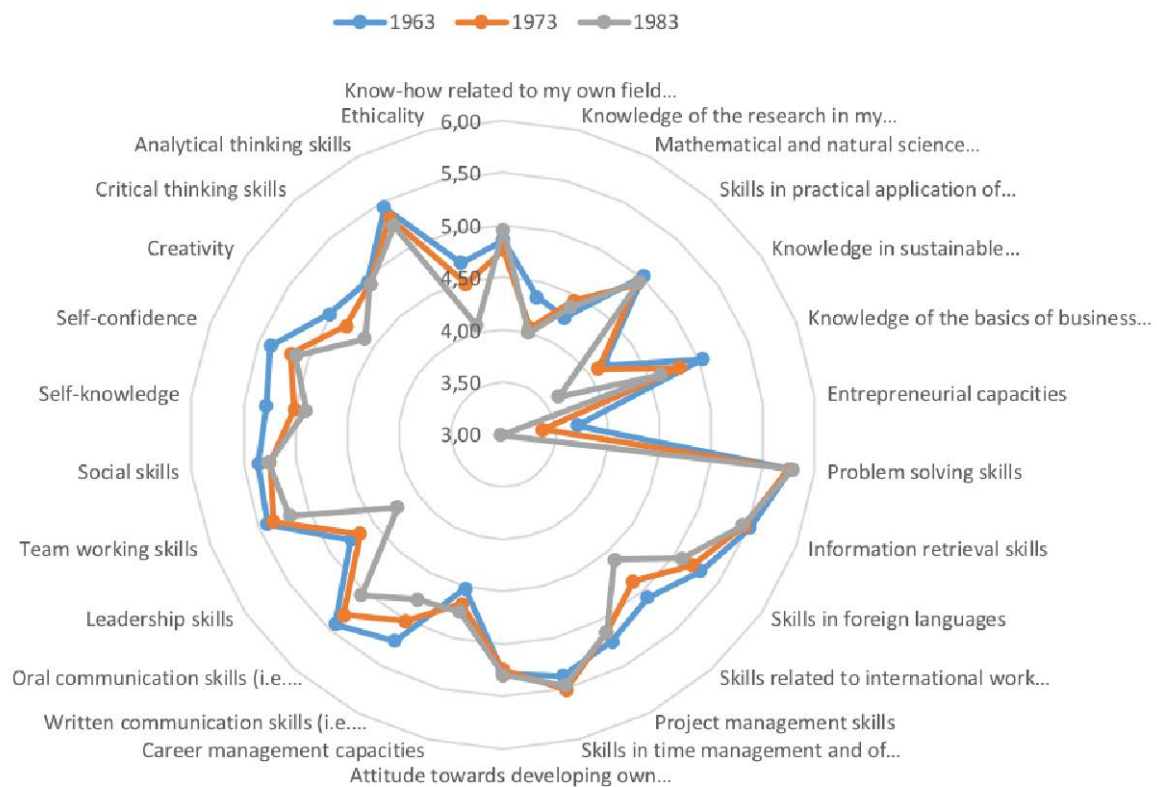


Fig. 1. Results of an estimation of the importance of the requirement of their competences, taken from the 'Survey on Continuing Professional Development' undertaken by TEK – the Academic Engineers and Architects in Finland in 2016

The highest appreciated skills were problem solving, information retrieval, time management, oral communication, team working and critical thinking – but aren't these parts of competences of entrepreneurship?

In addressing the topic of competence development previously, [3] it had been suggested that the best place and time to develop these skills is not necessarily the university. During a university education the initial foundations can and should be laid for all of these competences, but the emphasis must be on those to which the university is best suited. Examples of these are core mathematical, science and engineering understanding – without which an individual can hardly be expected to function as an engineer - and to have developed effective oral and written communication skills. Management, financial and leadership skills, while vitally important and their initial development should be started during and undergraduate education, can more effectively be developed in a work environment supported with continuing education.

Comparing these competences with the EntreComp competences [4] (Figure 2) one can notice there many similar competences required as parts of the entrepreneurship competence. It is evident that focusing in different positions and jobs different competences are highlighted but never the less it would be difficult to manage in engineering profession without the main subject based competences, value based competences, cross-disciplinary competences and interaction, internationalisation and organisational skills.

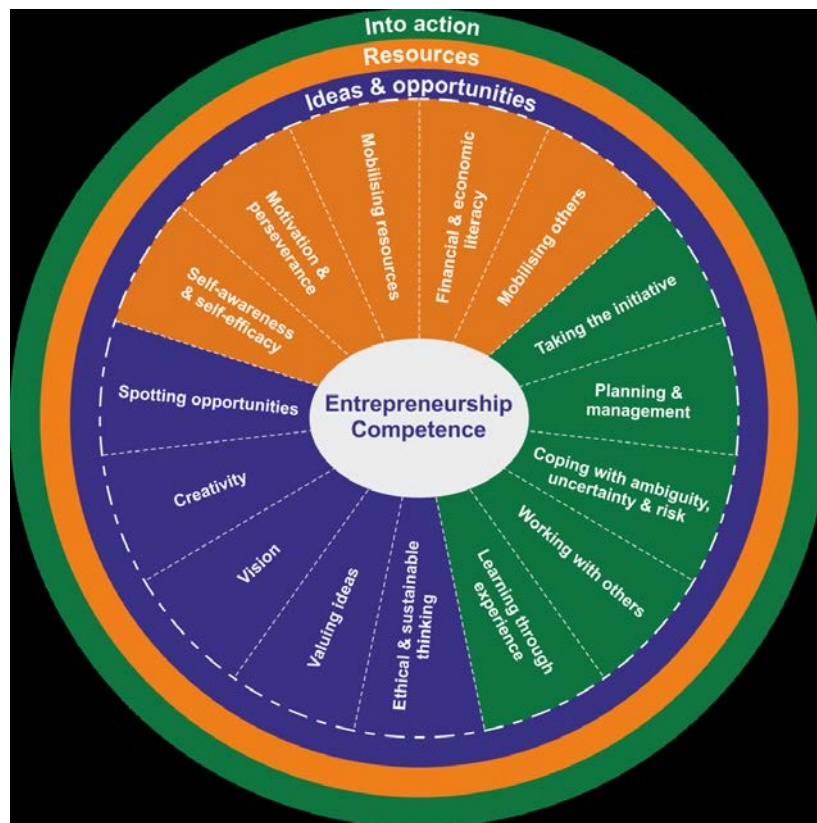


Fig. 2. A diagrammatic indication of the areas and competences of the EntreComp conceptual model

1.2 Needed competences - are they advancing entrepreneurial mind-set

An entrepreneurial mind-set is something that is appreciated in most of the positions in working life no matter if an engineer is self-employed, working in a small or large company or even in public sector. That mind-set means understanding the implications of results - in outcomes, economics, sustainability etc. Hardly any engineer can “just work”, but has to continuously enhance the results measured with different metrics.

1.3 How to teach the entrepreneurial mind-set?

Teaching in the traditional way might not be the solution to develop the necessary and appreciated competences. While lectures about financial calculations, theoretical analysis of risk management or quality standards might not encourage students to make the effort of starting their own business, that knowledge can save them from unhealthy solutions. Instead using different learning methods like problem or project based learning [5], CDIO (Conceive-Design-Implement-Operate) [6] or other ways to help students to develop the skills to solve problems, make plans, and discuss different cases from real working life can give new experiences and awake interest and creativity in producing different solutions. These learning approaches would help to create an entrepreneurial mind-set and relate this to required knowledge can lead to an overall entrepreneurial approach.

2 HOW THE UNIVERSITIES ARE REFLECTING TO THE DEMAND

The conundrum is that the curriculum is already crowded and no organisation would want to compromise sound engineering skills in its recruitment. Therefore, how are entrepreneurial skills to be developed? Furthermore how are students to be encouraged to build from the engineering skills new innovative combinations leading to products or services that can find paying customers? Are the competences needed in Bachelor level in applied sciences different from the skills needed in masters or doctorate level in sciences?

Real life projects with real customers are much talked as good way to build bridges between worlds of education and work. The challenge is to define the learning outcomes in concrete way and define metrics for them. What needs to be done during the projects to make sure the learning has happened?

According to a study where the current state of entrepreneurship education in three Universities of Technology in Finland was evaluated, the most important conclusion was that defining entrepreneurship in the context of starting a business limits students' possibilities to learn entrepreneurial skills. Few students have the will or possibility to practice entrepreneurial activities, if it is defined only in the context of starting a business. Thus for the purpose of entrepreneurship education, entrepreneurship should be defined as entrepreneurial activities that can be practiced in several contexts. Universities should support student opportunities to practice entrepreneurial activities. Offering such possibilities requires co-operation between entrepreneurship education stakeholders.[7]

In Universities entrepreneurship needs to be seen in its context - to be an entrepreneur in science is a different issue than starting a business of selling ice-cream. In science the time to develop the product, find its customers etc is much more time consuming and thus needs long term commitment and financing before it starts to pay back.

2.1 Imperial College London

At Imperial College London innovation and entrepreneurship are not explicitly included for every student in its already highly demanding curriculum, but according to a student's interest it is possible in the majority of engineering programmes to include business courses which specifically involve facets of entrepreneurship. In addition students are encouraged to participate in a diversity of non-curricular activities where their entrepreneurial skills will be developed. To support such activities spaces and facilities are made available where they can develop ideas. These spaces might include design tools and fabrication techniques such as 3D printers.

Undertaking projects during a university engineering course can be a beneficial way to help students develop an awareness of entrepreneurial skills. Within the Faculty of Engineering projects can take different forms. Some are staff-led and a well known example of these is the 'Constructionarium' project in the Civil Engineering Department. This is a major third- year project to give all students experience of a construction site. Students work in teams and live on site and are responsible for all facets of the work including safety. The projects are serious and real and enthuses students with a taste of being in charge of actual construction site. Some projects are entirely student led. These have included 'Racing Green Endurance' when in 2010 students transformed a petrol powered racing car, the Radical SR8, into a high performance electric vehicle, having two radical EVO Electric motors with no gear boxes and including regenerative braking, energy dense batteries, and a computer management system. To demonstrate the capabilities of the vehicle they drove the Pan-American Highway (26,000

km) from Prudhoe Bay in Alaska to Ushuaia in Tierra del Fuego Province, Argentina. Funds for this project were raised from industry. Another example is the E.Quinox project – a student-led engineering summer Project in Rwanda, associated with the development of a battery hire and solar power recharging stations for remote communities via the installation of energy kiosks. This involves engineering students from different disciplines working in teams with some Civil & Mech E students working in teams. The students have had to raise finance themselves but subsequently have received support from UNDP and the Rwandan government. This particular project has received the "Supreme Humanitarian" award of the IEEE. It should be clear from these examples taken from the many projects how they are contributing to the development of entrepreneurial skills.

2.2 Metropolia University of Applied Sciences

In Metropolia University of Applied Sciences special MINNO (Metropolia innovation projects) are part of every curricula. This 10 ECTS course additionally to other courses should give the basic understanding about entrepreneurship. But one can question is that enough? How to develop the entrepreneur mind-set?

In the programme of Electrical Engineering and Automation in Metropolia the learning starts in the first year with an introductory project. That is a “gaming project”, having the other students or lecturers as customers. In that project teams are in the beginning expected to produce a project plan including budget, schedule, risk analysis etc. Additionally shortly after the project has started the student need to make a marketing speech to potential customers - how to sell the product. Already in this phase students learn the basic elements of entrepreneurship.

Later on during the 3rd year in the MINNO project students are going deeper to project management - they even need to participate the national student competition of project management which might lead to the European finals.

Additionally to the courses developing entrepreneurial competences and mind-set, Metropolia offers several courses directly focusing on skills to create a company – such as ‘how to develop a business plan, how to choose the legal form of the business, what are the responsibilities and official requirements etc.

Last year Metropolia joined an EU funded ERASMUS+ project “Development of an entrepreneurial mindset in higher education” EmindS which aims to develop entrepreneurial mindset of HE & VET students based on the EntreComp competence model [4], through the application of a systematic methodology using student centered innovative approaches [8]. In the project the competences are analysed, a tool for evaluating them will be developed and finally active learning sets will be developed. This work will hopefully generate information about good practices to provide usable learning experiences for Metropolia students.

3 REFLECTION

In this paper experiences of two very different types of universities in different European countries having engineering programmes are clarified. Can we awake and add value to the discussion to find appropriate way of offering the students best opportunities to manage in the requirements of the industry of the future?

In a university of applied sciences the learning might be more practical and directed to products that have shorter way from invention to market while in a research university the

innovation or research result needs more development to find its practical, sellable form of a product.

In both of the cases project management seems to be one of the most important entrepreneurship competence. From the EntreComp competences that covers the sub-competences: Planning and management, coping with ambiguity, uncertainty and risk, working with others, learning through experience and valuing ideas.

But how to make sure that in addition students become aware of additional dimensions such as ethical and sustainable thinking, creativity, vision and spotting opportunities, which are essential for inventing the ideas and opportunities. And what about resources - as in student projects the resources can be easier to get than in real life. The study-projects are mostly rewarded with ECTS points - not with money - and the motivation is supported with the willingness to work towards graduation. Resourcing competences include self-awareness and self-efficiency, motivation and perseverance, mobilising resources, financial and economic literacy and mobilising others. Additionally there is still one competency left: Taking the initiative - which we consider to be a key element of entrepreneurship mind-set. If that is missing - nothing happens.

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Engineering Education Introductory Project - Can The Concept Be Copied And Transferred?

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Conference Key Areas: Education, Innovative Teaching and Learning, Attractiveness of EE

Keywords: Changing the teacher, copy a course, standardisation

INTRODUCTION

The teachers of programmes and courses need sometimes suddenly to be changed for different reasons. Such reasons could be as the original teacher is changing the job, getting ill or is just overloaded with work. In these cases it would be beneficial to have standardised forms of running the courses. Also ready material for the students and for the teachers would be helpful. In this paper we introduce an example how the transfer have been done and what kind of experiences we got from that.

1 PROJECTS IN B.ENG EDUCATION IN FINLAND

1.1 First year of the education

In Finland the B.Eng. curriculum in the Universities of Applied Sciences is planned to take 4-years. Programmes are based on secondary high school education or vocational technical

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education. During the first year in the University the students need to be able to strengthen the competences that are weak after their previous education. The students coming from senior high school typically master more theoretical things like mathematics and physics but have very little experience of engineering. On the other hand the students with vocational education have more experience and understanding about the practical technical issues. The diversity between the students becomes even greater as several of them have already some years of work experience. To give a solid foundation for the engineering studies for such diverse groups of students is a serious challenge. This challenge gives also a great opportunity to benefit from joint learning from each other's in small groups. During the following years students are deepening their knowledge on sciences and engineering parallel with other competences needed.

Engineering curricula in Metropolia University of Applied Sciences went through a major overhaul few years back, when practically all degree programmes designed the first year studies to employ integrated, problem- and project-based learning, combined with co-teaching methodology [1]. Additionally the CDIO model was already strongly empathized during 10 years [2; 3]. That immediately led to drastic decrease to first year drop-out rates. This indicated that the students' engagement to engineering studies improved [2]. The enhancement of the programmes has been based on continuous self-evaluation and cross-sparring with critical friends from different other universities and internally. The method is developed in joint projects with over ten universities around Europe. The system is completed in an ERASMUS+ project which finished 2016. This kind of systematic work has proved to be very beneficial and effective [4].

As an implementation of the new curriculum, the Electrical Engineering Degree Programme developed an introductory project integrating project management and entrepreneurship to programming, mathematics and physics. The project is scheduled at the second half of fall semester. The learning outcomes are set to emphasize soft skill such as team working, basic finance, time lining, marketing, project management and communications skills. Additionally, to those skills, the importance of engineering ethics and responsibility of the sustainable development are highlighted [5].

1.2 Teachers role in education

In Finland one characteristic factor of teaching in all levels is the freedom of the teacher. Learning outcomes are defined nationally for secondary level of education and by the University for Tertiary Education. The teachers, lecturers and professors are mostly allowed to decide their way of reaching learning outcomes in their own courses. That freedom leads to high commitment and responsibility to the teacher. Furthermore it motivates for continuous development of the execution of the courses.

As a teacher gets a new course to take care of it demands quite an effort to design. In that case it might be a smoother way to get ready instructions for the first turn and according to the experiences then renew the course gradually. Especially the need for instructions are required if a teacher gets with a short notice a course for instance in case when the standing teacher is temporary prevented. On the other hand the teachers might have difficulties on "following the orders" as they have learned to act according to their own way.

The first year project has been developed and fine-tuned by the same teachers over several years. However, the fall 2017 change of teacher for a part of groups was evident, and therefore an interesting question arose: how well the successor likes to follow the design and concept, or does the new teacher recreate the course again? In this paper we are presenting a case study on transferring a pedagogical concept when the teacher changes.

2 THE FIRST YEAR PROJECT

2.1 Who can run the project course

The introductory project was developed and run over several years by the same group of teachers. While a static situation enabled fine tuning of the concept, it was evident that the day would come when another teacher would take over the course implementation. Therefore, an interesting question arises: how well the successor follows the design and concept, or do the new group of teachers recreate the course again? In this paper we are presenting a case study on the challenges of transferring a pedagogical concept when the teacher changes. Students' learning results were compared and several teachers were interviewed and their observations were compared.

The first year curriculum is divided into four modules - each of which takes 8 weeks. The students are evaluated from the modules with only one grade. That means they need to pass all the elements to pass the course. The required elements are typically taught by a group of 5 teachers. The teachers are cooperating and trying to add value to each other's content, which also enhances their teaching competences.

An introductory project is a vital part of the second module in the degree programme of electrical engineering. The learning objectives of the project are set in project management (including scheduling, budgeting, communication, risk analysis, self-evaluation etc.), team building and group working, presentations, basics of marketing, finding information, basics of building, and coding additionally to self- and group evaluation and feedback.

2.2 The structure of the project course

In the beginning of the course students are forming groups of 4 people. In some classes the students are allowed to form the groups themselves and in some classes the teacher have made the decision. If the students can form the groups themselves they usually work with their friends and thus do not experience that much of "tolerating difficult colleague" or other challenging surprises. They might even benefit from the pleasant atmosphere and can concentrate on other learning outcomes. However, in earlier studies we have found no significant differences due to method of group forming [6].

The first task for the group is to collect a box of LEGO® Mindstorms and explore what is in the box [7]. There is an introduction how a 12-year-old can build and program a robot but that is sure not enough for the students. Instead they need to find out what additional features the content enables them to build to the robot. That requires the group to start to search for information - what can be done with the content. Another question to decide is which programming languages they want to use. Additionally they can define what extra parts or materials they will collect. There is available a big box of spare parts from robots

and from other LEGO® building series. Furthermore the group is allowed to bring in whatever they manage to get from elsewhere.

The project management exercise starts by writing a project plan that covers all the features of the learning outcomes. Additionally tasks the plan needs to include are:

- How to create a story of your robot to sell it to your customer. How to introduce the story in a 1 minute presentation to your potential customers (other students in the class). After the presentations the most attractive robot of the class is chosen in the first competition.
- How to technically manage the track of the second competition. The track is introduced after the 1st competition. It is about 4 meters long black line in a white background including a wall, where the robot needs find a detour. After passing the wall the robot needs to find the black line again and follow it until it hits a blue spot. In the second competition the time of running the track is measured and the quickest one is the winner.
- Finally the robots need to be undone, original parts returned to the box and other parts in their places.

At the end of the project the final report needs to be done. That report includes a self and group evaluation.

During the whole project the groups are following up their advancement with a weekly diary. The diary includes notes of participation of the members, challenges they have met, learning points, and major inventions.

The evaluation of the project gives maximum 30 points which is 20% of the whole module. The points are granted:

- 8 points from project plan
- 2 points from the 1st competition including marketing speech
- 2 points from the 2nd competition
- 8 points from final report
- 2 points self- and group evaluation
- 8 points from the diaries (1 per week)

This division of the points is giving the students a clear message how important the different parts are. Especially the emphasis is given to the joint support to other students and constructive attitude. That includes also the responsibility of reporting internally in the group about schedules and unexpected problems. Failures in programming or other things are accepted - only a good analysis of the reasons is needed.

3 STANDART PLAN OF THE COURSE

3.1 Materials and schedule

Standardisation of the first year project course means clear description of:

- different steps of the course including schedule
- slide sets for teachers' lectures (see picture 1, week 43)
- format for students' written assignments (project plan, weekly reports, final report)
- description of the evaluated non-written assignments (competitions)

In the figure 1 is an example of the course plan. That kind of format can easily be adapted to the new groups.

Week	Tuesday	Thursday	Obs
43	Lecture: what it means to be an engineer? Which competencies and skills are needed, what are the expectations of working life? How to learn, project based learning, CDIO, basics of project management. Starting the project	Conceiving the project Group Work	
44	Building, constructing, Conceiving the project, project plan	Building, constructing, Conceiving the project, project plan; Independently	
45	Building, constructing, Group Work Independently	Building, constructing, Group Work	Download the project plan latest on Wednesday
46	Feedback from project plan	Competition 1 Constructing, programming,	
47	Constructing, programming,	Constructing, programming, Independently	You can see the track on Nov 21
48	Constructing, programming	Constructing, programming	
49	Constructing, programming,	Competition 2 on the 8th December in room 504	
50	Undo the robot, count the parts, return the extra robot parts to "spare part box" and other extra legos to the big brown box. Return the cleaned robot box.	Finalize the reports	Download the final report latest 21.12.

Fig1. Plan for the 8 week project course

3.2 Instructions to the students

Additionally the special occasions are needing an exact guideline as otherwise the temporary teacher might have difficulties on keeping in schedule, getting the expected outcomes and finalising the operate stage - recycle the materials for the future use. In the

figure 2 there is an example of the guideline for the final competition. That guideline tries to guarantee that the students have a fair competition, all the groups get their results and the Lego-boxes will really remain usable in the future.

Final steps of the project course:

- Recycle the lego-box:
 - o Undo the robot, count the parts, add missing parts, return the extra parts to the “spare part boxes”;
 - robot parts to plastic box
 - extra motors and sensors to the separate plastic box
 - other parts to the cartoon box
 - broken parts to the shown box
 - o fill the report sheet - leave in the box the report and the list of names.
 - o after the teacher have accepted the box, replace it in the cupboard.
- Have a team discussion about the team work, roles and learning outcomes of the course. During the discussion give encouraging feedback to each other and fill in the group- and self-evaluation form. Return the form individually.
- Finalise the “final report”, please note that the report covers the whole project of 8 weeks. Pay attention to the learning outcomes, risk analysis, project management etc. Add photos and links to videos to the report. The technical attachment might include screenshots of the used code. One report from the team.
- Fill in the diary and submit - one final diary from the team.

Fig 2. An example of the guideline for the end of the project course

4 EXPERIENCE FROM CHANGING THE TEACHERS

4.1 Outcomes of the change

The introductory project course was developed over several years by teachers, who were senior adopters of the project- and problem based learning and CDIO principles in Metropolia. The new teachers in charge of the course were less familiar with the methods. Furthermore, the situation was quite challenging because the teaching resource management was done late and the new teachers did not get sufficient time to prepare their own adaptation and plans in advance. The current and previous teachers met briefly few times to transfer material, concept, timing, and other necessary information to carry out the implementation.

The standardisation helped a lot and made it possible to offer the students the course despite the absence of the previous teachers. The new teachers mentioned that the standardization of the course did not limit at all their pedagogy, but quite the opposite released them from planning the course over again, and instead they could concentrate their efforts on teaching practices. Detailed instructions on implementation were considered very valuable in use.

When comparing the student's learning outcomes we cannot see any significant differences. Student groups did robots which performed similarly the same tests as previous student groups. The robots were also quite equally innovative as earlier. The drop-out rate remained negligible, and students' grades based on achieving the learning objectives sustained very good values.

4.2 Students view

Student feedback remained almost as positive and constructive as it used to be. Some students felt they would have needed more guidance on planning the project and writing the project report, which was also observed by both new and old teacher. On the other hand, we also need to remember that this is an introductory project, and the students will get more practice throughout the rest of their studies.

Despite the encouraging feedback, it was noticed that the new teachers did not have such an inspiring attitude to the course as the teachers who had created it. One could see the course was "a beloved baby" of the original teachers - and a "stepson" to the new teachers.

5 CONCLUSIONS

An introductory project developed and fine-tuned by a teacher promoting project- and problem based learning and CDIO was standardised and transferred to another teacher with almost none experience on these principles. The course standard was documented in detail, which allowed the new teacher to focus on teaching practices instead of detailed preparation of the course. The learning results did not show any significant differences compared to previous year's results. Still the motivation and enthusiasm of the new teachers were not in the same level as they were with the original teachers. This change of attitudes might have an effect to the attractiveness of the education [8]. On the other hand the detailed material gave confidence to the temporary teachers and guaranteed the right message to the students. The students results documented were in the same range as they used to be although the feelings have no measurements that one can scientifically produce evidence.

The transferability of the courses could be a subject for engineering education research in the future, that might lead to the multiplications of the courses and thus to share good practices for adaptation elsewhere.

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Socializing Problem Solvers
Why the Technocratic Paradigm still dominates Sustainability Engineering Education.

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Keywords: Sustainability; Technocracy; Existentialism; Problem-based learning

INTRODUCTION

The technological advances since the industrial revolution have brought prosperity, longevity, abundance and warded off plagues and famines but they have also allowed the unabated extraction of natural resources with little consideration for their renewability or the fair distribution of the economic proceeds of this extraction. As such, humanity is threatened by climate change, plastic pollution, the mass extinction of species, the depletion of critical natural resources, whilst at the same time dealing with increasing wealth inequality and mass human migration that is destabilizing political systems. Such a problem we have labelled a *sustainability* problem. If left unaddressed, it threatens the liberal democratic order and its capitalist economic foundation. Yet the complex economic, social and environmental interlinkages of the sustainability problem are only slowly starting to be addressed by social sciences disciplines such as political sciences, development studies, and economics among others. In the engineering disciplines, the situation depends very much on which discipline one looks at. In disciplines that are further from “core” engineering, like planning, design, mediaology etc. new programmes are being developed which offer an interdisciplinary, pedagogically innovative approach to the subject. In the “core” disciplines of civil, mechanical, electric and chemical engineering, there is a general recognition that a paradigm shift away from a technical, disciplinary focus is needed. However, practice shows that sustainability has been integrated more at the disciplinary level, where it has been integrated at all.

So whilst “core” engineering education remains wedded to a disciplinary, technical view of the world, not all engineers are technocrats, and not all engineering education programmes socialise technocratic problem-solvers. We must apologize to engineers and engineering educators from hereon for using the term “engineers” to refer to the median engineer, who has undergone his education in a median engineering school with median didactics. That median engineer may be a bit of a caricature of himself: the drawback of a conceptual paper is that it tends to deal in simplified categories with somewhat less sensitivity to the subtle variations offered by reality. The simplified models developed by conceptual papers are meant to be tested and refined by empirical work. Please bear with the author, the empirical work is in progress. The purpose of this conceptual paper is to ask some fundamental questions about identity and sustainability that we believe to be interesting and timely in engineering education today, and to suggest some unusual answers that could be tested and refined against empirical evidence.

Let us consider our conceptual median engineer: he likes to solve problems - that is what he has been educated to do, and solving problems is part of what makes him an engineer, the two go hand in hand, almost like dictionary definitions of each other. But he was not always an engineer - he was once a child, and then a teenager whose friends have become lawyers, artists, bankers, shop owners etc. He may have had a proclivity for solving problems from an early age, but at some point, he went from being a young adult to being an engineer. He *professionalised*. You could argue that this happens progressively over an entire career; these things are ongoing processes. But they definitely have a starting point, which is the moment the high schooler decides that he wants to study engineering and goes to study at a university or a vocational school (the difference between the two is exactly one of those subtle variations of reality that needs to be refined empirically but which for the sake of a conceptual paper will be simplified as “engineering education”). What the high schooler goes through at university is a process of *socialisation* - he develops what the sociologist Anthony Giddens (1991) called a new *self-identity*, a new way of thinking about himself, a new lens through which to see himself within the world. Much research has been done from a social psychology perspective about the differences between personal, social and human identity. However, in this paper we are looking at self-identity from a phenomenological ontological perspective, the focus of which is on the person’s experience from the inside-out, even if that experience is located within a group, profession or surrounding. What we will

argue in this paper is that the lens through which engineering students construct their self-narrative makes the world appear full of specific problems that can be solved using man-made constructions that we shall call broadly by the Heideggerian term *modern technology*. This is another large throwing-together of constructions that vary from space rockets to mobile phone apps, but the reason we make it so large is that this is the aggregation made by Martin Heidegger (1977), whose analysis underpins the sociological approach of Giddens. This should not stop us from critiquing Heidegger's amalgamation when we discuss its implications.

The key question guiding our inquiry is situated within the field of engineering education, and beckons us towards a theoretical examination of the relationship between the development of engineering self-identity and sustainability as it unfolds around technology throughout the learning process of the engineering student. The task of this conceptual paper is as follows: first, we will try to open up the black box of engineering education to propose a theory of how engineering students are socialized as problem-solvers. Then, we will suggest that the issue of sustainability offers an existential challenge to engineering identity, and offer an interpretation of what might be causing the technocratic response to such a challenge. Finally, we will look at two educational approaches that could trigger a different response to sustainability issues in engineering students.

1 THE DOMINANCE OF THE TECHNOCRATIC PARADIGM

1.1 Late modernity and the special role of engineers

Giddens (1991) defined the age that we live in as *late modernity*, which is a continuation of *modernity* in the information age. The name "modernity" is shorthand for the set of institutions that shape society in the post-enlightenment era. The features of this epoch are the dominance of Capitalism as a mode of social and economic organisation, the importance of material power (wealth) in social relations, the possibility of total war given by destructive technologies, and the possibility of an Orwellian society given by surveillance technologies. These features make modernity both the most prosperous and the most dangerous time for mankind: we live in what Beck (1992) called the "risk society". To temper the risk of nuclear annihilation and Big Brother surveillance, we've put in place organisations and institutions whose job it is to reflect on society and to feed those reflections back into how we live our lives. This is why Giddens calls *late modernity* a *reflexive* period of time. In *late modernity*, globalization dominates, and the risks and the reflexivity are planetary.

In such a context, expert skills are pulled out of their local context and catapulted into global expert systems which provide the technical knowledge in a particular area for the whole world. Giddens calls this the "dialectic of the global and the local": nobody who chooses to live in society can opt out of these expert systems, everyone depends on them for the most basic functioning of their life. For instance, I don't question how my computer or the internet works every time I want to check my email: I am blindly reliant on the experts who designed them. Despite this, trust in experts, which was so high in the 20th Century, is wavering in the 21st Century: economists failed to predict the 2008 financial crisis; political experts failed to predict the return of populism; sociological experts failed to raise the alarm about mounting inequality... Remarkably, engineers seem almost immune to this critique. And whilst even bio-scientists, physicists and climate scientists are being dismissed by an increasing cohort of people, there are no widely circulating "alternative facts" about the tenets of the engineering profession. Why is this?

To understand why the engineer is special, we must go back to Heidegger. Heidegger argued that *modern technology* was different from anything that had preceded it in that it caused people to see the whole world around them not as nature, but instead as a stockpile

of energy and resources waiting to be extracted for the production of commodities ("standing-reserve" or *Bestand*). Heidegger unfortunately failed to link this explicitly to Capitalism as an extractive system, but this oversight was fixed by Giddens. The pivotal role of modern technology in every aspect of modernity has bestowed upon engineers a special role: they are the people tasked with what Heidegger called "enframing" (*Gestell*) the world. *Enframing* means performatively seeing the world as resources ready to be used for production. Enframing is one way to "reveal" the World, to open it up to human understanding. For example, the engineer looks at a river and reveals it to be a potential place to build a dam for the production of hydro-current. He finds a tree and reveals it as a source of wood pulp from which paper can be produced. There are other ways to reveal the world - through art, for instance - but modern technology only makes us see world as something that can be used in production. The engineer enframes the World because of his special position as the maker of the technology. Thanks to his intervention, the world becomes enframed for the rest of society. It may be that I walk through the forest and see nothing but trees, but that is not the point: everything I do is predicated on the world having been enframed as a standing-reserve. I would not be here at this conference by any other means since the aircraft that I took to get here and the fuel that it burned to bring me here required the enframing of the natural world as a resource.

Now we come to the advent of technocratic thinking and technocracies. With the engineers being endowed with such a special role in late modernity, how those engineers think and work is of paramount importance for the reflexive process of this "risk" society. Therefore, how engineering students are educated to become engineers is of the uttermost importance. So why does the technocratic paradigm dominate engineering education, and what consequence does this have for late modern society?

1.2 Existential Anxiety and Technocratic Thinking

Being human is a wondrous and frightening experience: we are the only animals capable of deeply reflecting on our own existence (that we know of). When any human stops to consider his own existence deeply, there are five big questions that remain unanswered: what is this strange thing that I experience as "being" (*existence*)? What is this World around me that I seem to be a part of but separate from (*the World*)? Why am I going to die, and what does that mean (*finitude*)? Who are all of these other people whose inner being I can never experience for myself (*others*)? Who am I (*self-identity*)? Giddens calls these "existential questions", a term he borrowed from a long-standing tradition of existentialist philosophy. The starting point existentialism is that we experience existence as a deeply troubling phenomenon. Just thinking about the questions we have listed, you have probably felt a sense of unease. These are not questions any human normally enjoys thinking about because to think about your own death or about the very fragile construction of identity that is "you" causes anxiety and feels like standing in front of an "abyss" according to Heidegger. This is a general human experience, and there are general human coping mechanisms for dealing with anxiety. Our best coping strategy is building reassuring everyday *routines* (this means little actions that we perform and repeat on a daily basis) and rituals, the essence of which we don't question on a regular basis and therefore provides us with *ontological security* (this means having a firm and safe sense of who we are). In traditional societies these routines and rituals are often grounded in religion and strict social structure. In late modernity, these routines and rituals are built around complex codes of social interaction and action that, if you think about it, wouldn't take much effort at all to disrupt. A recent sale on Nutella in French supermarkets caused all social codes to fly out of the window as people began brawling down the shopping aisles. As I said: it doesn't take much... But even to stop and think about how fragile our complex social system is causes anxiety.

Now try asking an engineer about existential questions - the most common answer I got when conducting some preliminary interview research for this paper was something like an uncomfortable shuffle, a puzzled look, "we don't think like that, we solve problems". When asked why, this was usually followed by "because that's how we're trained". So, engineering education builds into its socialisation process a set of routines and rituals which can be summarized as "problem-solving". These routines focus on training a pathway from a problem situation to a (usually technical) solution that bypasses existential questions. Thus, epistemological and ontological questions being deliberately ignored, the result is a problem-solving attitude grounded in a positivist view of science, in which problems and solutions are neither considered contentious nor subject to hermeneutic tensions. *Ipsa facto*, this generates a technocratic approach to problems. The technical solution-searching process is possibly the strongest antidote to existential anxiety known to man in late modernity, and it has spread beyond engineering, a point we will come back to in the next section. Note that this solution does not always clearly identify a problem to which it is the answer - that does not strictly matter in order to ward off existential anxiety. What matters is the act of daily solution-development grounded in a reassuringly materialist approach to the world that conveniently circumvents existential questions by assuming existence to be a pure physical fact. Why is the technical solution-searching process so good at this, and why are engineers so prone to it?

To answer this, we turn once again to Heidegger, who explained that it is the essence of technology itself to provide us with an escape from the emptiness of anxiety. Heidegger tells us is that the technician's gaze enthralls us into busying ourselves with the smaller question of "beings" (things, people, places) rather than the larger and frightening question of Being (ontology). Thus, in busying ourselves with beings, we are worked up into a trance of production and consumption that has no other purpose than the activity of production and consumption itself, and staves off "real" thinking about Being. Heidegger warned against people who try to push away from the "Abyss of Being" by hiding behind the routine and mundane existence of beings. Giddens is not so judgemental, but does recognize the enthralling, all-encompassing nature of such frenetic activity as is directed by late modernity, capitalism and its technological systems. Engineers being the experts tasked with the design and production of technology in late modernity, it stands to reason that they are the most deeply involved in the cycle of activity described by Heidegger, and therefore the most deeply embedded in the production of routines that come with it. Such routines, grounded in materialism, lead to a reductionist, technocratic approach to complex problems. Adding the analysis of Giddens to that of Heidegger, these routines become a part of engineering self-identity. To be a part of the expert system of engineers, one must embrace the routines and rituals of the profession, and the place where these are developed is in engineering education. Is this a problem? Why can't we be happy with our technocratic engineers as they are? The reason is primarily that the sustainability problem has torn open the black box of engineering routines, rushing existential questions back into a discipline from which they had been banished. The answers that engineers give to these questions now may well determine how we collectively fair with sustaining our lifestyles in the coming decades, and perhaps even centuries.

2 THE SUSTAINABILITY PROBLEM OF ENGINEERING EDUCATION

2.1 Sustainability and Existential Anxiety

Calls for fundamentally rethinking the unsustainable practices of consumer capitalism have been echoing through academia and environmentalist movements since the 1960s. In the 21st Century, it has become clear that sustainability issues are not a question for distant future generations, but that a paradigm shift in our approach to the society-nature relationship is necessary right now. Sterling (1999) has called this paradigm shift a move towards "strong" sustainability, which requires to rethink capitalism and its modes of operation. However, our increasing awareness of the problem has yet to crystallize into

action. According to Huckle (2009), this delay can be explained by the strictures that capitalism places around modern life - requiring “economic growth or capital accumulations (with) an inbuilt tendency to discount present and future environmental costs”. At the same time, Huckle says, the power of the State to actively steer society towards a sustainable mode of living has been systematically undercut by powerful business interests as well as by the electoral imperatives of political parties. Thus, despite repeated and increasingly urgent calls for a paradigm shift and the dire warnings about what could happen should we fail to shift, we keep our efforts within a technocratic, technocentric, materialistic and reductionist approach within the consumer capitalist paradigm (Sterling, 2009). This can be summarized as “technology will solve it” - fanciful thinking about clean coal, carbon extraction processes, bio-engineering flora and fauna to ward off their imminent destruction through habitat loss and climate change, the list goes on. At the same time, fantasies about eternal “green growth” abound, systematically failing to challenge the dominant GDP-growth obsession and ignoring the basic maths behind the exponential function. The standard tenet of the technocratic approach is, as Gough and Scott (2007) explain, to have “confidence in the ability of human beings to develop scientific and technological solutions to environmental problems as they emerge”. Enter engineers, stage left, thrust into the spotlight as the saviours of humanity by politicians, business leaders and the general public alike.

Looking at the sustainability crisis within the theoretical framework that we have previously established, the impending environmental collapse is forcing us to confront ourselves with the existential anxiety that the frenzy of production and consumption mandated by capitalism was meant to obscure. The question of self-identity in the context of the sustainability crisis is particularly thorny: to think meaningfully about the sustainability crisis is to recognize the role that each one of us plays in the system from which the crisis emerges, the limitations of human possibilities that will necessarily flow from the maintenance of the system as it is, and the return of death and finitude as a prominent features of a world in which there is not food, water, shelter, or resources enough for everyone. An authentic confrontation with the anxiety produced by such realizations would force us to examine the destructive character of our everyday routines, thus breaking the safety cocoon of our self-identity. Most of us are not willing to engage with this, and prefer to imagine an army of engineers ready to produce the technology that will fix the problem and allow our mode of living to continue untroubled. Perhaps this partially explains the frenetic race for developing STEM education, often at the expense of humanities and social sciences. The engineer's self-identity as a technical solution-searcher is reaffirmed by the expectations placed upon him by public discourse. It provides ontological security and alleviates the existential question of identity. He therefore has no incentive to deviate from this discourse.

2.2 The Dangers of Technocratic Thinking about Sustainability in Engineering Education

There is just one problem with this discourse: the technocratic approach doesn't work because it always plays catch-up, attempting to solve problems without investigating their structural source, often long after lasting or permanent damage has already been caused, and very often without any regard for the misdistribution of the ill effects it might cause, predominantly borne by the poorest people on the planet. Nothing but a complete, fundamental rethink of society's *modus operandi* will enable action in time to avoid a poor, nasty and brutish future (to paraphrase Hobbes) for the vast majority of humanity. And yet, by design, as part of the socialization process, engineering education reinforces the prominence of problem-solving routines in the self-identity formation of students. The closer one gets to “core” engineering, the stronger the technical approach. Yet even civil and mechanical engineers cannot ignore sustainability issues today - neither do they attempt to, but they tend to teach sustainability as a technical problem concerned only with the environment, without much input from the social sciences and humanities. It should be

emphasized that this is not the case in all engineering programmes, and the more one veers away from core engineering and towards planning, medialogy etc., the more sustainability issues are embedded within a broader, interdisciplinary, reflexive view. But we have reason to believe that the problem-solving approach to sustainability dominates in the vast majority of core engineering programmes around the world. *A priori*, the very learning methods by which students are socialized into the engineering identity cannot generate any other approach. For instance, a teacher in manufacturing processes, who has himself been socialized as an engineer at university and later in his professional life, will teach, guide and evaluate his students in such a way as to encourage them to develop identities that reflect his own self-identity back at him, thus comforting his own self-narrative and stave off existential questions. Thus the more teacher-driven the method of learning, the stronger the teacher's hold on the development of students' self-narratives and routines, the stronger the technocratic approach.

To disrupt the formation of a technocratic way of thinking in engineering students, they must be confronted with a broader set of existential possibilities, and made aware of the contingent nature of the routines and narratives which they build. Such an awareness would allow for a more authentic confrontation with the systemic nature of the sustainability crisis. Such authenticity requires of the individual that he be willing to experience existential anxiety, and be willing to radically change his self-identity and the actions that he takes if the situation calls for it. Such is the call issued by the current state of collapse of our socio-economic-environmental system. The traditional learning system of engineering students must therefore be disrupted. This is a point also made by Sterling (1999) who argues that in order to generate meaningful change, education needs to be transformative rather than transmissive - and this means, among other things, switching the learning experience of students from a problem-solving approach to a problem-reframing process.

3 USING PROBLEMS TO CONFRONT ENGINEERING STUDENTS

3.1 Problem-oriented project-work as existential confrontation

The good news is that there is no need to reinvent the pedagogical wheel. Disruptive pedagogies already exist - indeed most of them are historically grounded in one way or another in existentialism. These pedagogies have been called problem-posing education (Freire, 1968 / 2000), exemplary learning (Negt, 1971), problem-based learning (Schmidt, 1983) and participant-directed, problem-oriented learning (Pedersen, 2008), among others.

In engineering education, project work has been around for a long time. The term "project" refers to a means of organising the learning process, but it says very little about its underlying purpose. Most project-based teaching in engineering education makes use of *task-based* projects, which are strongly teacher-driven and focus on finding a solution to narrowly defined technical problems; and highly structured *disciplinary projects* that are equally teacher-driven and focus on closed problems within the confines of the disciplinary boundaries of the subject in question (De Graaff & Kolmos, 2007). These kinds of projects, while useful for spurring student interest and contextualizing theoretical knowledge, in fact reinforce the routine-building process by comforting engineering students into a narrow framework of knowledge application. Students are encouraged to transpose the problem-solving *methods* that they acquire in these projects to the different contexts that they encounter in their career. However, since advances in cognitive sciences have taught us that problem-solving is entirely contingent on the knowledge-base from which it draws, what these projects are unwittingly accomplishing is entrenching the future problem-solving possibilities of students within the set disciplinary paradigm that they learn at university. Future professional problems that confront engineers will then be read within the disciplinary framework that they have developed during their education. Thus, it is not sufficient for learning to be "active" in order for it to be disruptive. Learning must be a process of authentic confrontation with a problem that forces the issue of self-identity back onto the table.

There is however a setting in which project-work can become disruptive to the engineering's student socialised problem-solving self-identity: when the projects are genuinely *problem-based*. Pedersen (2008) differentiates problem-based project work from other types in that a genuinely problem-based project has no known solution and no defined disciplinary boundary, but instead engages students in a dialectic research process in which the cooperation / conflict nexus builds around the institution, the supervisors, the project group members and the outside world. There are two features of truly problem-based project work that can actively disrupt the students' self-identity formation process: the dialectic process and exemplarity.

The dialectic process in the context of problem-based education was best described by Freire (1968) as the dialogue between the self and the other that makes the existence of the self contingent on its encounter with the other, and the confers product of the encounter emergent properties with the power to (re)shape the social world. Thus the co-operation and confrontation process described by Pedersen acquires the power to challenge the nascent self-identity of the engineering student when it crystallises around external actors who pull the students away from discipline-bound solutions, break the routines-in-form and expose students to new viewpoints and power dynamics that scrape the coating of ontological security provided by the engineering classroom and expose them to existential questioning. However, exposing engineering students to the dialectic process without proper safeguards is likely to yield existential anxiety, spurring a retrenchment towards technocratic thinking. One means by which such anxiety can be managed is through the use of *exemplary* problem-formulations.

Exemplarity is a concept developed by Negt (1971) in the context of German working class education. Negt rejected the possibility of acquiring interdisciplinary thinking through disciplinary studies, and argued instead that students should consider problems with their own societal reality as a starting point and springboard to come to grips with broader societal questions. In Negt's view, this would foster the possibility for social (and political) action. In other words, exemplarity offers an outlet for an authentic confrontation with a problem, the outcome of which shifts the paradigm of action from the disciplinary and technological to the interdisciplinary and societal. Such action is no longer "meaningless" as Heidegger stated, but deeply meaningful.

Both the dialectic process and exemplarity require that the students go through a confrontational problem-identification and problem-formulation process, as described by Holgaard, Guerra, Kolmos and Petersen (2017). This process is time-consuming and takes students from an open theme, to a problem area, then to a problem-formulation which needs to be stated and restated as the dialectic unfolds. Specifically, we submit that the dialectic confrontation happens in the stage of problem analysis that occurs between the problem-identification and problem-formulation phase of the project-work. Exemplarity is only possible when the problem field is mapped to include both the students and societal actors as stakeholders and the starting point of the problem-formulation process, rather than a side-idea to be entertained in the beginning of the research process then promptly discarded once a technological "solution" appears.

3.2 Resistance to genuine problem-based learning in engineering education

There are multiple reasons why, despite the sixty years of existence of problem-based project work, there has been no substantial shift in the paradigm of engineering education, even when society looks to the engineering professions for solutions to the sustainability crisis. Dialectics and exemplarity are difficult concepts to grasp. Truly coming to grips with these ideas challenges ontological security. If this is something difficult to ask of students

whose self-identity is still in formation, it is quasi-impossible to ask of engineering teachers, whose self-identity has been coagulating around the technological solution-seeker narrative for substantially longer. It comes as little surprise that when problem-oriented project work was introduced at Aalborg University in 1974, the greatest resistance came from the engineering teachers who wrote letters to the Rector demanding the return of traditional pedagogy. However, as a full return to lectures was not possible, engineering teachers at Aalborg have instead delayed students' exposure to truly problem-oriented project work by introducing task-based projects in the early years of their engineering education (Servant & Spliid, 2017). Thus it can be surmised that by the time students are exposed to problem-based projects in the later years of their bachelor education, their self-identity has already been shaped to a large extent by disciplinary perspectives and the problem-solving narratives that develop around task-based projects. The extent to which problem-based projects have been able to challenge students' ontological security has been further diminished by the introduction of a host of disciplinary courses alongside the project work, whereas half of the courses used to relate directly to the project work (reference). Given that this has happened in one of the best-practice institutions for problem-based project work in engineering education, one can only surmise the possibilities for genuine problem-orientation is engineering curricula worldwide.

CONCLUSION

This conceptual paper has tried to explain why the technocratic paradigm dominates the engineering profession by locating its starting point within the socialisation process of engineering students as they go through their education. Using insights from the philosophy of Heidegger and the sociology of Giddens, we have tried to show that the dominance of the technocratic paradigm stems from the particular role of technology in late modernity, and the special role that engineers play with regards to technology in that system. We have described technocratic thinking as a coping mechanism that provides ontological security against existential anxiety. We have then explained how the sustainability crisis threatens that ontological security, to which the response is to extend technocratic thinking in engineering education to sustainability issues. We have then proposed a means by which engineering education can counter technocratic thinking, by using problem-based project work that is both dialectic and exemplary.

In conclusion, we would like to remark that the possibilities for opening engineering education up to a paradigm shift on sustainability already exist. The pedagogy which could be used has already been described, but is just not applied, particularly in "core" engineering subjects. We hope that we have succeeded in opening a dialogue with engineering educators on the role of existential questions and ontological security in defining how engineering education socialises students; and through these reflections, pave the way for a renewal of interest in dialectic and exemplary problem-based methods of educating engineers.

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Towards a skills development theory

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Conference Key Areas: Engineering Skills, Teaching and Learning, Education Research

Keywords: Skills development, teaching, professional practice, theory development

INTRODUCTION

HE Engineering Programmes are required to prepare students for practice and professional work skills are an important component. This paper reports on part of a PhD study [1] (to be published in September 2018) to investigate how work skills can be taught in HE with a focus on preparing students to solve real problems as opposed to academic problems [2].

The research concerns a Masters' level programme containing Short Industrial Placements (SIPs) where pairs of students work on a real and significant problem for a host company. SIPs have been part of the Engineering Education Practice at the University of Cambridge for over 50 years and both the students and host company's value their contribution.

In their Induction module, students are taught a number of key skills and given opportunities to practice and integrate them before undertaking their first SIP. These include: solving a range of industrial problems using a systematic evidence based approach, presenting analysis and recommendations to senior company audiences and working in a small group under significant time pressure. This skills teaching was judged to be effective as students on previous programmes had been able to solve real problems in their first SIP. This contrasts with the common perception that HE does not adequately prepare students for practice.

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An Engaged Scholarship approach [3] was adopted to study this anomaly to investigate any implications for theory [4]. There are four research activities in each Engaged Scholarship cycle: Problem Formulation, Theory Building, Research Design and Problem Solving. This paper focusses on the Theory Building research activity where a potential skills development theory was constructed. Whilst a summary of the other three research activities is provided, the constraint on paper length does not allow for sufficient detail regarding the literature review, research methods and results required of a research paper. This paper is positioned as a concept paper to promote discussion and debate.

1 PROBLEM FORMULATION

This research activity requires a systematic and detailed investigation of the area of study from both a practice and academic perspective to understand its multiple dimensions. From a practice perspective, there were two main findings; SIP skills were developed through five facilitated HE class-room based experiences that simulated solving real problems in a work context even though the description of SIP skills was limited. An analysis of literature identified a gap related to a general level teaching model related specifically to developing skills in HE. Three significant theories: Constructive Alignment (CA) [5], Experiential Learning (EL) [6] and Self-Efficacy (SE) [7] were found to align well with the skills teaching in the Induction module and applying CA to the teaching practice revealed perfect alignment between the learning activity and the formative assessment, providing one explanation of why the practice was effective.

It was concluded that a first-hand view of the five simulated experiences was necessary to deepen understanding of the practice and the research question identified was “What happens during the five experiences and supporting lecture session to support the development of SIP skills?”

2 THEORY BUILDING

The theory building Engaged Scholarship activity develops a plausible theoretical lens that can support the answering of the research question and is closely linked to the previous problem formulation activities requiring a deep familiarity with the problem domain [3]. Three activities are involved: creating, constructing and justifying a theory [3].

2.1 Creating the theory

Creating a theory uses an abductive reasoning process, triggered by an anomaly, to select a plausible solution that might resolve the anomaly [3].

In this case, the anomaly was the successful SIP skills development practice in the Induction Module because it produced results that contradicted the prevalent view that HEI's are not adequately preparing students for work. Drawing on the problem formulation work above, a plausible explanation of how SIP skills are developed, was *‘multiple work-relevant experiences, appropriately facilitated/taught and related to a specific set of work skills enables students to learn these skills and subsequently deploy them in practice’*. This has the potential to become a Skills Development Theory (SDT).

2.2 Constructing the theory

Constructing a theory uses a logical deductive reasoning process to identify concepts or events, the relationships between them, the associated the boundary conditions, and the reasons for the relationships (Bacharach 1989). Taking the ‘potential theory’ above, there are

three high level concepts: work-relevant experience, appropriate facilitation/teaching and a specific set of work skills.

From the problem formulation activities, the three main theories that contribute to skill development are Experiential Learning (EL), Constructive Alignment (CA) and Self-efficacy (SE). How these theories relate to each other is explored first.

The 3P Model of Teaching and Learning [8] shown in Figure 1 was the preferred model of CA because it identified a broader range of concepts and the relationships between them than other versions of the constructive alignment model [5, 8] which focussed on curriculum objectives, teaching/learning activities and assessment tasks.

The authors propose that both EL and SE can be nested within CA and the case for this is presented below. An EL review [6] found that EL involved the following components;

- an 'active' doing phase or **experience** that forms the material of learning that is not usually taught
- **reflection** – either deliberately or not deliberately
- a mechanism for **feedback**
- a formal **intention to learn**

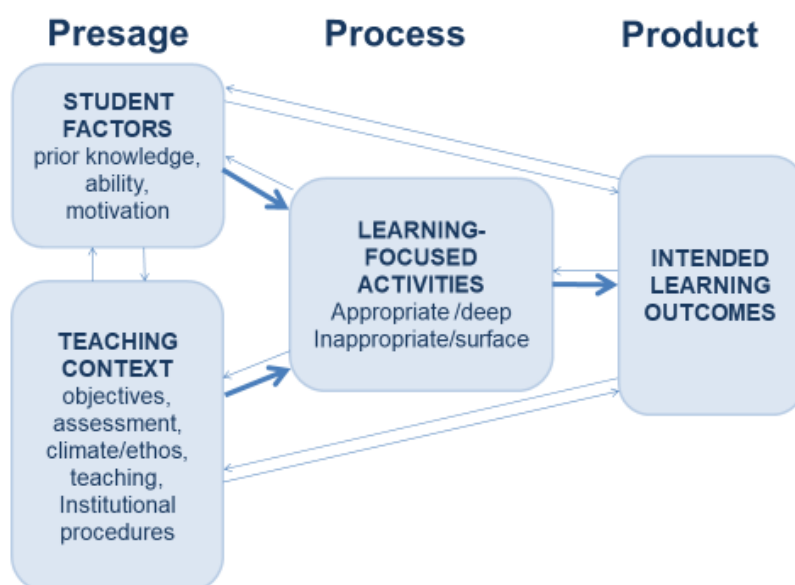


Figure 1: 3P Model of Teaching and Learning

An **experience** with **reflection** and **feedback** was seen to fall within the 'Learning-Focussed Activities' box of the 3P model and the formal **intention to learn** connected with student motivation in the 'Student Factors' box.

Bandura suggests four methods for supporting the development of self-efficacy [7]: mastery experiences, vicarious experiences, social persuasion and enhancing physical and emotional states. The mastery and vicarious experiences are considered to fall into the 'Learning Focused Activities' box, with social persuasion relating to student motivation and creating a positive mood related to the climate/ethos aspects in the 'Teaching Context' box.

Having established how EL, SE and CA relate, the connections between the proposed theory, see section 2.1, and CA are compared. The 'multiple' aspect of experiences is not explicitly

captured in the 3P Model. To include the components of EL, SE and build in the 'multiple' experiences the CA model needs adapting to work at a more detailed level and focus on skills.

Adjusting the CA Model an initial representation of this skill development theory is shown in Figure 2. 'Multiple' cycles was stressed by adding a specific note. Such cycles are considered to encompass all components of CA as the teaching objectives and associated Intended Learning Outcomes (ILOs) should progress through each cycle as the specific skill set develops. The components of EL and SE are not currently represented and can be added to the 'Learning-Focussed Activities' box. At this more detailed level, from a teaching perspective there are a number of 'givens' that a teacher cannot directly influence when teaching skills – these being student prior knowledge, ability and institutional procedures.

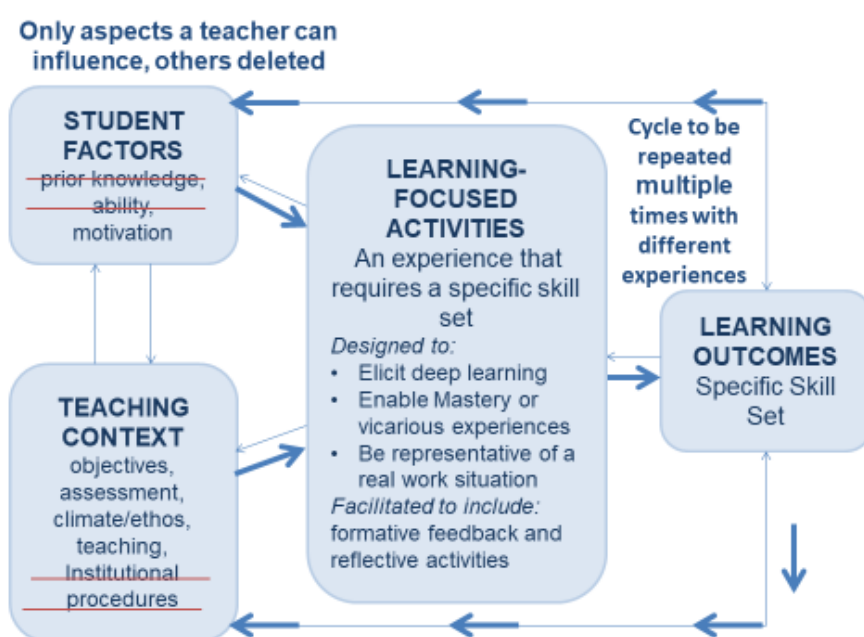


Figure 2: Conceptual Skill Development Model - Initial Representation

The Conceptual Skill Development Model above was refined, see Figure 3, based on the rationale below. In Figure 2, the 'Learning-Focussed Activities' box is now significantly expanded and would benefit from being split to emphasise the different types of components. Two categories emerge: providing experiences relevant to practice and supporting learning from experience. Both these categories encourage a deep learning approach as they incorporate a range of higher level cognitive activities [5].

The original 'Teaching Context' box was renamed 'Create a learning environment to encourage deep learning' to incorporate other aspects that influence a deep learning approach such as assessment [5]. Motivation was moved from the 'Student Factors' box and included as something the teacher can stimulate by making the case to the students that the skills to be learnt are both relevant and important. This eliminates the need for a Students Factors box in Figure 3 as the other two aspects were deleted, as not being something a teacher could influence – see Figure 2.

One aspect of the original 'Teaching Context' box was objectives. Given the problems identified during the problem formulation on defining skills, combined with the need to define

both objectives for the series of multiple experiences as well as each individual experience, it is proposed to treat this as a separate box: 'Describe skills'.

The logic links remain those in the CA model with the bold arrows indicating the main direction of flow and emphasising a repeated application. Returning to the proposed theory: *multiple work-relevant experiences, appropriately facilitated/taught and related to a specific set of work skills enables students to learn these skills and subsequently deploy these in practice*, and comparing this to Figure 3, it can be seen that;

- work relevant experiences are part of C,
- appropriately facilitated/taught has aspects in parts of A, B, C and D
- work skills are captured in A and also in E.

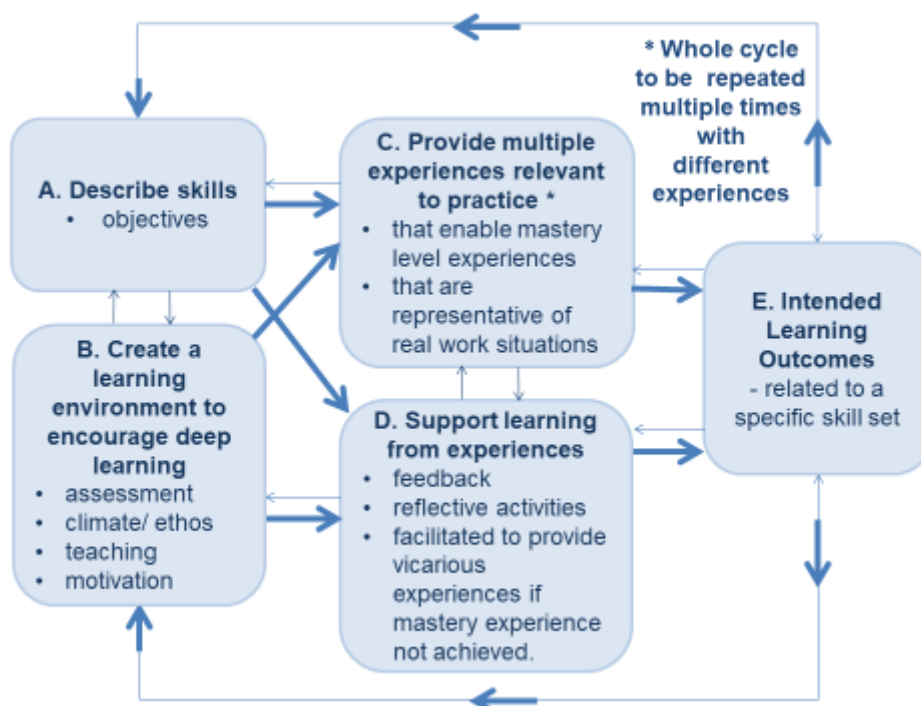


Figure 3. Refined Conceptual Skill Development Model

In conclusion, there would appear to be a reasonable fit between the proposed theory and conceptual skill development model constructed.

The final aspect of constructing a theory is stating the boundary conditions or limits at which the theory is expected to work. At this formative stage, the most limiting activity was likely to be providing experiences relevant to practice, as a HE environment may not be representative of a practice environment and a HE teacher may not have sufficient understanding of appropriate practice activities. Another boundary will be the minimum number of experiences required to create the intended learning outcomes. This is unlikely to be the same for all skill sets, as more complex skill sets will probably require more experiences. It is anticipated that the number of experiences would be determined through practice.

2.3 Justifying the theory

Justifying a nascent theory is the final part of the theory building process [3] and it is necessary on both an empirical and a conceptual basis. Inductive reasoning is used to test the fit with the world on an empirical basis and rhetorical arguments to persuade on a conceptual basis.

On an empirical basis, no evidence was found to contradict the theory. On a conceptual basis the credibility of the new theory was strong as it was based on the established Constructive Alignment theory in which two further well established theories were integrated. As none of the three contributing theories were logically compromised in this integration, it was deduced that the new theory was also logically valid. Validity is the main criteria for the ES theory building stage [3]. With this seemingly achieved the new skill development theory required conversion into a format suitable for testing.

The new theory is represented as a system model that highlights the complex nature of skill development. This model was translated into a simpler analysable format, a conceptual skill development framework, for testing the theory.

3 RESEARCH DESIGN & EXECUTION

This research activity selects a research design and then executes it to answer the identified research question i.e. "What happens during the five experiences and supporting lecture session to support the development of SIP skills?"

3.1 Research Design

A variance research design was selected as this would enable the practice to be compared with the derived theoretical framework. Engaged Scholarship employs a mixed methods research strategy and the methods employed were selected on merit [9]. A non-participant observation strategy was selected to compare the teaching practice with the theoretical framework because the observer was an experienced University teacher. Questionnaires were used to collect information from the students on what they thought helped them to learn skills as this was the only practical method in the time available.

There was a firm belief amongst the Induction Module staff that the five simulated experiences were responsible for the development of the students' SIP skills. However, as limited evidence was available to substantiate this claim, the assumption that students had low levels of SIP skills on starting the programme required testing because, if this was not the case the theory would not be valid. As a method of empirically testing their SIP skill levels was not available, an alternative strategy of finding a proxy as an indicator was adopted. Students prior experiences such as business plan projects and relevant work experience was captured via a questionnaire to provide an evidence-based indicator.

Full details of undertaking this research are available in the PhD thesis [1]

3.2 Research Results

The comparison of the practice to the theoretical framework enabled some preliminary testing of the SDT to be undertaken. The many connections observed between aspects of the conceptual skills development framework reinforced the view that skill development is an interlinked system and a systems model view is an appropriate way to represent this.

Of the four high level components (see Figure 3) that combine to enable the intended learning outcomes to be achieved, C - multiple experiences and D - supporting learning from them, were seen to be directly responsible for teaching skills. Components A – describing skills and B – learning environment were seen to be essential enablers.

All aspects of the theoretical framework were recognised as part of the teaching practice and two further aspects were identified.

Overall, the SDT was found to be promising. The skills development practice, despite a poor definition of SIP skills and weak reflection activities was still effective as the combination of multiple, constructively aligned, relevant experiences enabled the students to learn SIP skills.

The student view on what they thought helped them to learn skills provided sufficient evidence that their understanding of skills and skill development was lower than expected. This indicated that the student factors of ability and prior knowledge, eliminated from the SDT earlier require reinstating and reinforce the connectedness of teaching and learning, overlooked earlier in the pursuit of a teaching perspective.

Analysis of the data on students' previous experience revealed little exposure to opportunities that would enable them to solve real industrial problems. It was concluded that the majority of students at the start of the programme had low levels of SIP skills, thus indicating that the experiences in Induction were largely responsible for developing these skills.

4 PROBLEM SOLVING

This final Engaged Scholarship research activity involves communicating and interpreting the findings with the intended audience. The work summarised in this paper has been presented and defended as part of a PhD thesis. This paper is intended to share the findings with a wider Engineering Education audience and engage in debate on the implications.

The conclusions from the research summarised above are that the proposed Skills Development Theory is promising, the model requires further refinement and testing, and the student factors previously removed reinstating. This results in a preliminary skills development model shown below in Figure 4.

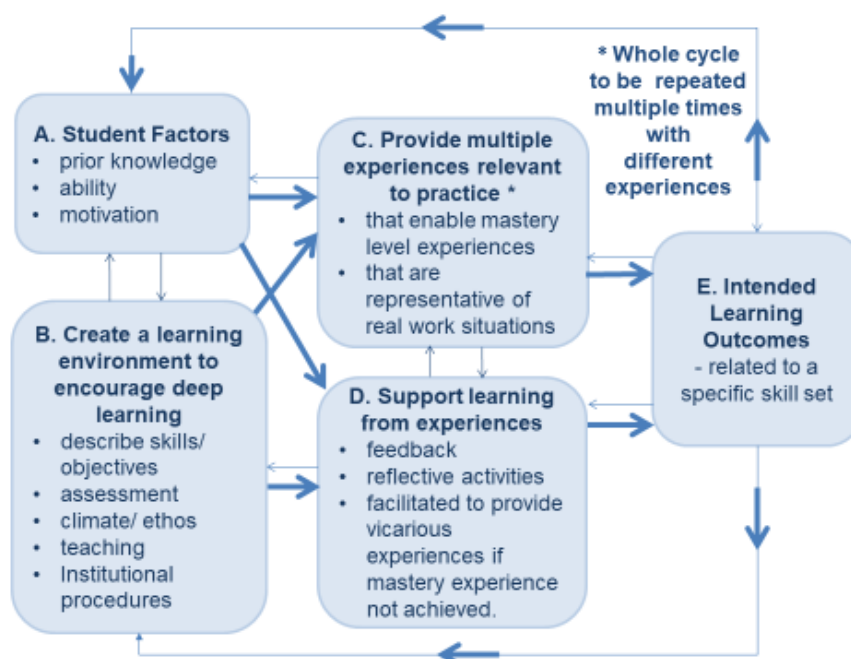


Figure 4. Preliminary Skill Development Model

Further work is required to refine the definition and description of each aspect of this model and determine if and how other aspects should be included. Other work from this PhD study has focussed on describing skills which requires integration. It would also be interesting to investigate the typical number of different exercises required to become sufficiently proficient for different skills. This will depend on many factors: the range of representative problems to

be experienced prior to real-world practice, the diversity of contexts in which they happen, the complexity of the work involved, the level of resource available and the abilities of the students.

This model remains at a high level and provides a holistic perspective. Alternative views, such as a process view would be helpful in describing the activities that Engineering Educators would have to undertake to be able to apply this in practice.

5 IMPLICATIONS FOR TEACHING AND LEARNING

The Preliminary Skills Development Model demonstrates that teaching skills is significantly different to teaching knowledge because of the different nature of the activities involved in the process. Designing simulated experiences that are relevant and authentic, facilitating mastery and vicarious experiences, as well as providing timely reflection tasks are all examples of activities not often associated with teaching knowledge using traditional lecturing approaches.

Engineering Educators need to be trained on how to do these activities and those aspects most likely to be new include:

- developing a good understanding of what the graduates are actually expected to do in practice in industry and across a range of different sectors
- designing and testing simulated experiences
- skill development facilitation skills

This is a big ask of already busy teaching staff and not easily undertaken without significant Institutional investment in such an approach. Developing a team approach, drawing on specialist expertise and experience from both industry and educational designers is just one way that this could practically be achieved.

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Introducing Engineering Essence in Liberal Arts Education in Japanese University

Engineering in Liberal Arts and Liberal Arts in Engineering

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Conference Key Areas: Please select three Conference Key Areas

Keywords: Liberal Arts, Innovation, Fundamentals, Non-expert

1. INTRODUCTION

In Japan the liberal arts education is expected to be an important element to promote innovation and bring the economy back to prosperity again. Technological invention is indispensable for the innovation, but that is not enough in nowadays. Identifying the subterranean market needs behind flood of information is also important for the successful innovation. The liberal arts education is believed as an essential mean to help the understanding the global market and to communicate with people who has different cultural back ground. Steve Jobs pointed out the importance of liberal arts, saying “It is in Apple’s DNA that technology alone is not enough—it’s technology married with liberal arts, married with the humanities, that yields us the results that make our heart sing.”

Moreover, it is necessary to resolve social conflict associated with introduction of new technologies. It requires both expert’s social literacy and non-expert’s science and technology literacy. In this paper, two approaches to investigate how to incorporate the engineering to general liberal arts education, as well as the necessity of liberal arts education in engineering education, are discussed.

2. LIBERAL ARTS EDUCATION IN JAPAN.

The origin of the liberal arts can be back to ancient Greek scholars' work, In European medieval period, seven subjects; grammar, rhetoric, logic, arithmetic, geometric, music and astronomy, consisted classical liberal arts education. It is believed they were to foster independent and judicious citizen and that technology was just skill transferred in apprentice system.

There are many published articles discussing the issues on liberal arts education in Japan[1]. Rie Mori has introduced briefly current situation and historical context[2]. The author is looking the situation as follows from engineering education perspective. The meaning of liberal arts has been changing in Japanese higher education system, since European modern knowledge was introduced in the mid-19th century. It may somewhat have a slight or significant difference from that in European countries. What Japanese had intended to introduce was practical application of science, without the core philosophical idea to understand the whole world. It is clearly shown in the Japanese translation of "science"; "KA-GAKU". That literally means studies of independent disciplines.

The liberal arts education in Japanese universities underwent atrophy in 1990th century, but is reviving recently. Let's review Japanese liberal arts history briefly. In Japanese education system before World War II, the liberal arts education was conducted in three years in senior high school. The senior high school education at that time was assigned as preparatory education for university, in which education system was designed to foster higher professionals. It was consisted with foreign languages, humanities, social and natural science, and they emphasized enlightening humanities. At that period, the number of university students was very limited. Only a few percent of the young generation had a chance to study such liberal arts.

After WWII, education system reform was conducted, after American system. The former senior high school was consolidated to new university and college system. Foreign languages, basic natural and social science, and humanities were placed as compulsory course in the first two year of the university. For example, a student in an engineering course had to study several subjects in humanities, social and natural science, and foreign languages respectively. It was said as general education, as well as liberal arts education. While university entrance rate was rising, importance of general (liberal arts) education was not well understood among students, regarding as useless knowledge or just repetition of high school education. In 1991, the ministry of education reformed the rule for university curriculum, and most university contracted the general (liberal) education to promote higher professional or interdisciplinary studies. However, recently, the liberal arts education is getting

arrestive and reviving as effective way to educate innovators and entrepreneurs, as described in the introduction.

3. ENGINEERING EDUCATION FOR INNOVATION

According to the innovation policy of Japanese government, it is expected to strengthen the tight between basic academic research and social implementation by the education. It is pointed out that the liberal arts education is keen to develop innovation leaders. The Japan Federation of Engineering Societies [3] insisted the importance of promoting connoisseur's eyes to identify social and economic value, as well as technological invention. They also emphasized the role of management in innovations. The training of this ability was not included in traditional Japanese engineering education. And it needs collaboration with people who have no engineering background. Thus, new approaches, such as Problem/Project Based Learning, or design oriented, are noticed. They are to build up communication skill of students, and to found wide range of liberal arts knowledge.

The conventional engineering education in Japan have taught how to make things but not what to make. In other words, the purpose of engineering has never been dealt with in Japanese engineering education. The decision making is based on their value standard, but natural science, including technology or engineering, is on neutral ground to the values in society. The Engineer should know how such value is formed. Thus, new type of education for engineers is required in Japan.

There is a book titled "KYOYOU NO KOUGAKU"[4]; "Engineering of Liberal arts", if translated into English directly. It is written for medical school students who are studying rehabilitation. Mechanics, materials, measurement, indoor environment, process management and human error are included. That is published for special student, but could be one of the ways to go.

Integration of engineering and liberal education was discussed in many universities in US, to foster innovative and entrepreneurial capacity in engineering undergraduate students by a liberal arts education.[5]

4. TRANS-SCIENCE AND LITERACIES

Social implementation of advanced technologies, such as genetic manipulation, often brings about people's anxiety. A.M.Weinberg defined "Trans-Science", as "questions which can be asked of science and yet which cannot be answered by science." [6] The scientist and engineers tend to take enlightening approach, but it does no work well for the technological risk issue. Collaboration between the experts and non-experts to reach an agreement is essential, because science cannot lead a solution. The experts tend to require people to have rigid and precise understanding.

The social acceptance is another issue. The experts, scientists and engineers, should know the non-experts' way of thinking. Various methodologies have been developed to make citizen's participation in technology assessment. Consensus conference is one of the well-known examples in Japan.

From the view point of Responsible Research and Innovation (RRI), although fairness in scientific research activity has been mainly discussed in Japan, little has been said about responsible innovation. It will be required to conduct innovation in responsible way to accord with UN's Sustainable Development Goals.

The engineers, as well as other experts, need to develop their accountability to not only their clients but also wide range of stake holders, concerning to the value and risk of their achievements. At the same time, literacy of experts on social and cultural aspects is needed to explain their accountability. Generally, development of the literacy of non-experts is requested for the decision making on such socio-technical issues.

5. ENGINEERING IN LIBERAL ARTS

As previously mentioned, the liberal arts are activities to understand what the real whole world is. When one looks at today's world, it never exists without technology. So, engineering or technology should be included in the liberal arts. Like students in science and engineering should study social literacy, engineering literacy for non-engineering students should be developed.

There are quite a few such subjects, as far as the author has looked into in the curriculums of Japanese major universities. One of them is "Introduction to modern technology" in the University of Tokyo. An appointed professor in an engineering department lecture on the outline of their research activity and the relationship with society.[7] It is certainly good and realistic practice, but still limited in a specific engineering field, and it is designed for engineering and science students.

Based on the discussion in the previous sections, two approaches should be included in liberal arts. One is fundamental engineering knowledge and the other is framework in engineer's activity.

5.1. Fundamentals in Engineering

Nowadays, the technological products is getting so integrated and complex that an engineer has to have wide range of technological and scientific knowledge. An engineering expert can be just a non-expert in other engineering field. Since it is quite hard to study all technological elements and the engineering knowledge is

expanding rapidly, comprehensive and compact fundamental and systematic knowledge in the engineering is desired.

There are substantial numbers of classes named basic engineering or engineering literacy, in which lessons in mathematics, errors, units, drafting, descriptive geometry, dynamics, electromagnetics, or materials science are given to engineering students. Those engineering literacy classes are designed only for engineers, although science literacy is often designed for every people. It should be noticed that some of such science literacy is containing technology as well.[8] In such case, it is necessary to emphasize the deference between science and engineering (technology) . They have own their origins and purposes. Mixing up those two would mislead what the non-experts expect on them.

If such knowledge system is well developed, it will be easy to identify what is possible by technology, and pseudo-scientific dream and non-realistic technology are eliminated. Unfortunately, it is still just in the starting point of discussion.

5.2. Framework of Engineer's Conducts

Engineers are struggling with various problems for better design or manufacturing. It is desirable that non-engineering people know the nature of the problems which engineers are facing with. They are different from those of scientists. They are determining the engineer's way of thinking and design.

(1) Compromising trade-offs between cost, quality and delivery

Engineers are requested to improve quality, to decrease cost and to shorten delivery. Those are conflicting with each other. The engineers should manage the balance satisficing their customer's demands. They have another trade-offs in improving the qualities, because there are plural inconsistent properties. Many technological failures are due to mismanagement of the balance.

(2) Heterogeneous objects

Natural raw materials, whatever they are organic or inorganic, are not homogeneous. Their composition, surface structure, strength, and etc. are changing with location and time. But engineers have to make almost same products using such heterogeneous materials, which do not show theoretical behaviour. It is inevitable to apply safety factor to ensure the quality or safety. To make things worse, every material is unavoidable from deterioration by corrosion or decomposition.

(3) Dealing with uncertainty

In general the boundary conditions for design are determined by the customer. It means that the engineers have a degree of freedom and responsibility as well. Sometime the boundary conditions are not well defined and vague. Furthermore,

sometimes the phenomena which are controlling the working mechanism of the product is not scientifically understood well, and the engineers have to design without necessary information. As the result, engineer's calculation tends to be in an overestimation to the theoretical value, applying empirical coefficients.

(4) Multiple solutions

Based on the uncertainty mentioned above, engineers do not always lead unique answer. There could be another solution, and the best answer is depending on the case and often not found.

(5) To make mistakes is human

Engineers are requested to prepare for misuse of the customer, as well as engineers' mistake. They have to imagine whatever possible. And engineers are also human to make mistake.

The concept of engineering in liberal arts is schematically shown in figure1.

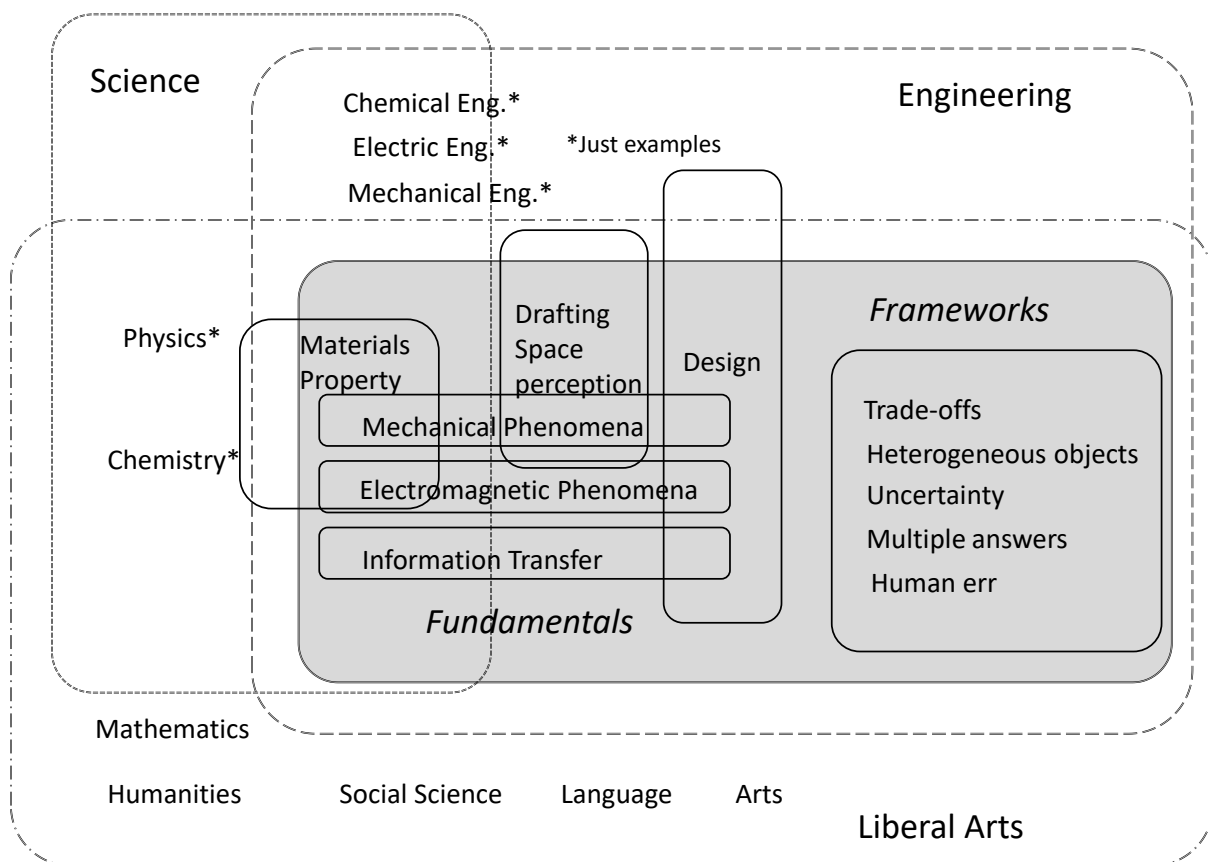


Fig. 1. Schematic Illustration of the Concept of Engineering as Liberal Arts

6. CONCLUDING REMARKS

In this paper two approaches are proposed to incorporate engineering into liberal arts education. One is to develop compact but comprehensive engineering fundamental theory. And the other is to clarify the frameworks which determine engineer's conduct. The establishment of the specific contents is still future work. It is expected to develop public understanding of engineering, and to form social ability to select appropriate technology systems. A working group in Japanese Society for Engineering Education has been established and started discussion. There are several examples such as history of technology, including accidents and failures, or PBL type activity to solve local issues. The contents, introduced in section 5.1 and 5.2 in this paper are under intensive discussion, and expected to put into a practice plan in a few years.

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Engineering translated to primary schools

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Keywords: Engineering, Primary schools, Denmark

1: INTRODUCTION

Denmark will lack 13.500 engineers & science-candidates (Engineer the Future, 2015) and 30.000 technicians in 2025 (Danish Industry Association, 2015), if the nation does not consider extraordinary educational efforts to fill in these gaps. To meet these challenges the Danish government has launched a STEM-strategy for the entire

educational system, where engineering is recommended as a teaching strategy in schools to strengthen pupils' scientific and technological literacy (Danish Government, 2018). STEM is an abbreviation for Science, Technology, Engineering and Mathematics. However, the recruitment challenge is not the only valid argument for focusing on engineering in schools. Another argument is to prevent, that pupils enter society as technological illiterates. Teaching concerning both the E and T in STEM can lead to technological literacy and interest in science and technology. It is part of modern literacy to have an understanding about, where the technology that surrounds us and defines our lives originates. al

For this reason we propose the following research question:

How can technological literacy be strengthened through initiatives in primary schools in Denmark?

To find the answer a case study has been conducted on the project "Engineering in School" (EiS). EiS is a large scale (4 municipalities, 65 schools, 520 teachers), longitudinal (2017-2020) project that integrates the development of curriculum materials, didactical models for teaching, collaborative teacher professional development (TPD) and science events, for primary schools in Denmark (The Danish education system is presented in appendix 1).

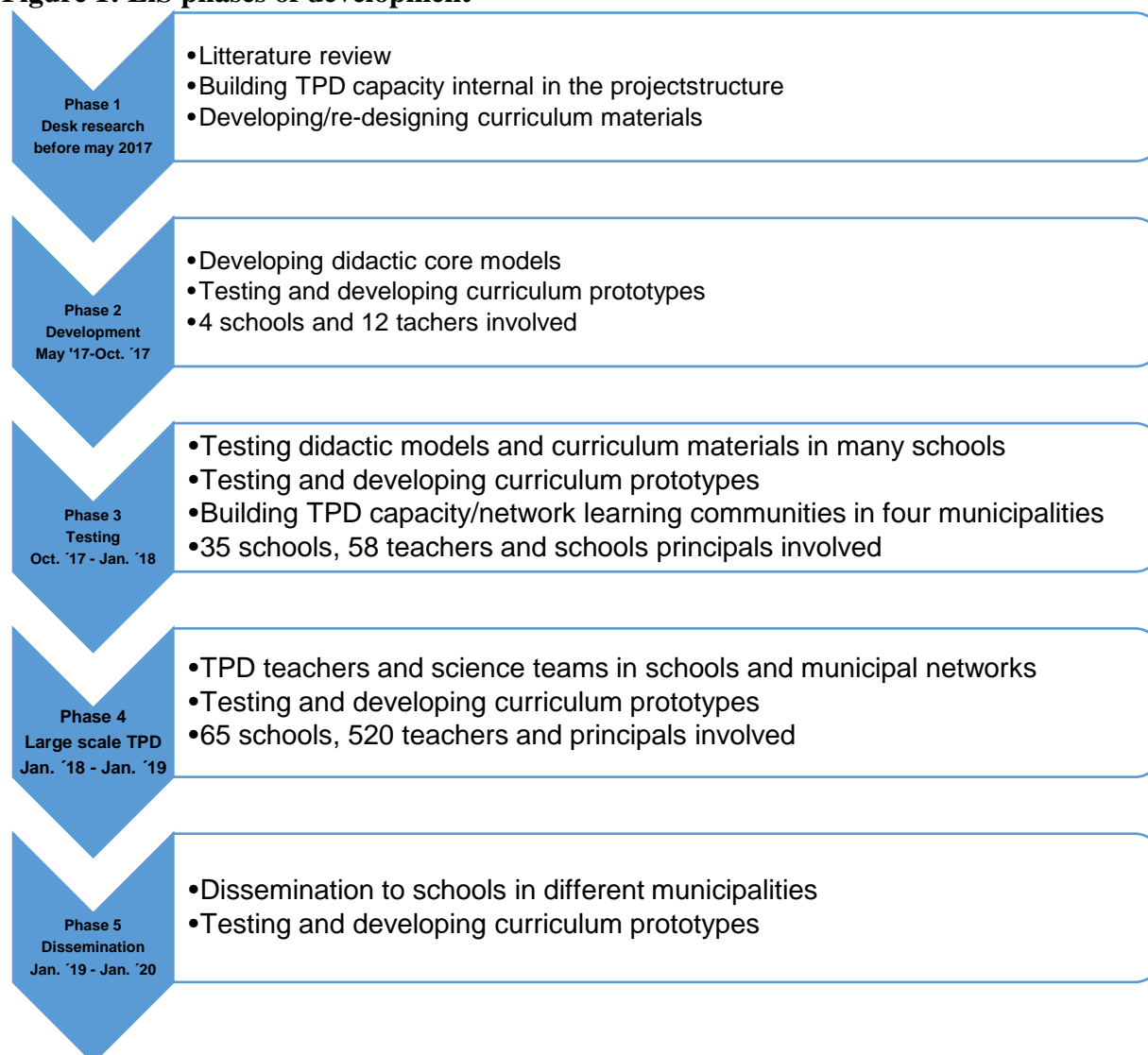
The development of curriculum materials and didactical models are predominantly inspired by design criterias from the American engineering programme Engineering is Elementary (Engineering is Elementary, 2018). The TPD-programme is inspired by the Danish QUEST-project and designed with reference to Guskeys criterias for effective TPD (Nielsen & Sillasen, 2014). According to Guskey (2003) effective TPD is based on 1) developing teacher pedagogical content knowledge, 2) ample time and resources for actionlearning, 3) introduction to assessment strategies, 4) collegial collaborations and knowledgesharing in schoolbased contexts.

2: METHODS

Since engineering is a new concept in the Danish school context there was from the outset a need to learn about engineering as a teaching strategy and the most optimum way to structure engineering curriculum materials. To meet these challenges the EiS-project is divided into five phases (see figure 1): Desk research, developing, testing, engagement and dissemination. The desk research (phase 1) started with a literature review with the aim to identify principles of good engineering teaching practices, existing resources for building teacher professional development (TPD) and as a byproduct the research was published in a Danish math and science didactical journal (Sillasen, Daugbjerg, Nielsen, 2017). In phase 2-3 we used this knowledge base to further develop and test didactical theory, curriculum materials and a TPD-programme. During these phases empirical data was collected from multiple sources giving feedback to didactical and curriculum developers. Through action learning we collected teachers selfreports about their experiments with engineering activities in their own teaching practices and conducted observational studies of the teachers in action. Pre- and postsurveys distributed in phase 3 mapped pupil and teachers learning outcome and attitudes towards engineering activities. Furthermore, a focus group was formed with representatives from university engineering departments. The purpose of the focus group was to give feedback on and further develop the engineering didactical models. Results from these investigations will be presented and

discussed below. In phase 4 (2018) we upscale the TPD intervention in the four municipalities to include 65 schools and 520 teachers. Phase 5 (2019) is dissemination in two directions: To other schools in the four initial municipalities and to other municipalities. When the project ends in 2020 the aim is that 900 teachers have participated in engineering TPD and that we have tested 12 engineering curriculum activities available for teachers through open access.

Figure 1: EiS phases of development



The EiS-project is designed based on characteristics of Design Based Research (The Design-based Research Collective, 2003). It depicts the complexity of a DBR-project in the sense that we simultaneously experiment with learning environments, develop theories of learning engineering, enactment, design and redesign of prototypes of didactical models and curriculum materials.

3: RESULTS

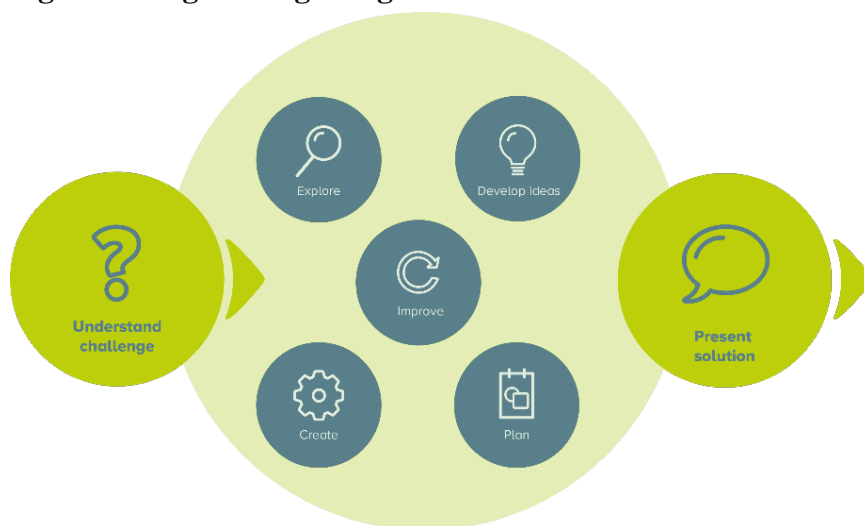
In this section we present examples of the didactical models, curriculum materials, TPD-model and assessment results which is the outcome of phase 3 and phase 4.

3.1: The Engineering Design Process model

The purpose of doing engineering in schools is to raise pupils' interest and strengthen their technological literacy and STEM competences. Through the engineering didactical model, EiS clarify for pupils what challenges engineers work with and methods they use for problem solving. The teaching must reflect the engineering process - problem analysis, generating ideas, using existing knowledge and iterative improvement of prototypes - that engineers use when they solve problems or develop novel technological innovations. However, it is important to recognize that working with engineering problems in a school context is different from the situation when engineers solve real-world-problems. Pupils are not engineers working in a big company. In a school setting it is only partially possible to situate pupils in the same situation as engineers when they are solving a real-world-problem. When developing effective didactic models for engineering in schools we have to carefully select characteristic engineering features that are relevant to produce meaningful teaching. For this reason it is not the aim for schools to educate new engineers or create innovative products that can be sold. No. The aim of doing engineering in schools is for pupils to gain experiences with engineering as a strategy to solve problems and strengthen their self-awareness about own capabilities to solve problems, while learning and utilizing science and technology at their level. From teachers' experiments with engineering in phase 2 and 3 we learned, that two of the most important engineering features that pupils learn is: 1) Working with the Engineering Design Process (See figure 2) and 2) knowledge about material properties necessary for solving a given challenge. These findings are supported by the Engineering is Elementary programme (Cunningham, 2017).

In Project EiS we developed an Engineering Design Process-model (figure 2) which consisted of seven workprocesses: Understand challenge, explore, develop ideas, plan, create, improve and present solution.

Figure 2: Engineering Design Process-model



Engineering-activities in a school context is organized as projects, where pupils work with a technological challenge that starts with *understanding the challenge* and ends with *presenting the solution* (See figure 2). Naturally, evaluation of the product and

process is done either continuously or at the end of the process, to solidify the learning outcome. The teacher can infuse authenticity into the engineering activity by framing the challenge through a narrative, that can contextualize the problem, motivate and legitimize the pupils to work with it. When pupils are presenting their solution, the teacher must have focus on two questions: What scientific knowledge have the pupils learned and how was the learning process? When answering these questions pupils automatically reconsider the initial challenge retrospectively and assess to what degree they have solved the challenge.

In between the beginning and the end pupils work with five work processes. We have not indicated that these work processes follow a particular succession. From teacher feedback we learned, that pupil's problem solving strategy takes different paths. However there was a distinction between whether the engineering activities was done in lower grades (grade 1-4) or upper grades (grade 5-7). In grade 1-4 the pupils primarily iterated between *creating* and *improving* their prototypes. While in the upper grades pupils have developed more reflective skills to put emphasis on *developing*, *planning* and *exploring* their prototyping in a systematic manner.

The other important feature is that pupils learn *about* material properties to construct a prototype. A central part of creating or improving the prototype to meet the constraints of the initial challenge is for pupils to consider which materials can be used to solve the challenge most optimal. For this reason the exploration process becomes important, because this is where pupils gather knowledge about what types of materials might be most suitable to build the prototype.

While the EDP model support the scaffolding, it is important that teachers initially identifies learning goals and consider the degree of freedom the pupils are allowed during the different phases of the process. To further support teachers educational design curriculum materials is developed and the basic principles for the materials is presented in the following section.

3.2: Curriculum materials

A unique feature in the EiS-project is that curriculum materials are developed in close conjunction with the didactical models. This provided space for a rich discussion between the didactical developers and the curriculum developers to ensure quality in both components. From the outset a cohorte of teachers was interviewed to determine design characteristics for good engineering teaching materials. These design characteristic were used to produce the first version of teaching materials that subsequently was tested in phase 3 and 4. As part of this testing the design criterias was also assessed and discussed with the participating teachers. Based on this evaluation a refined set of design criterias emerged (Se table 1).

Table 1: Design criterias for curriculum materials. Quality engineering teaching material integrates a majority of these criterias.

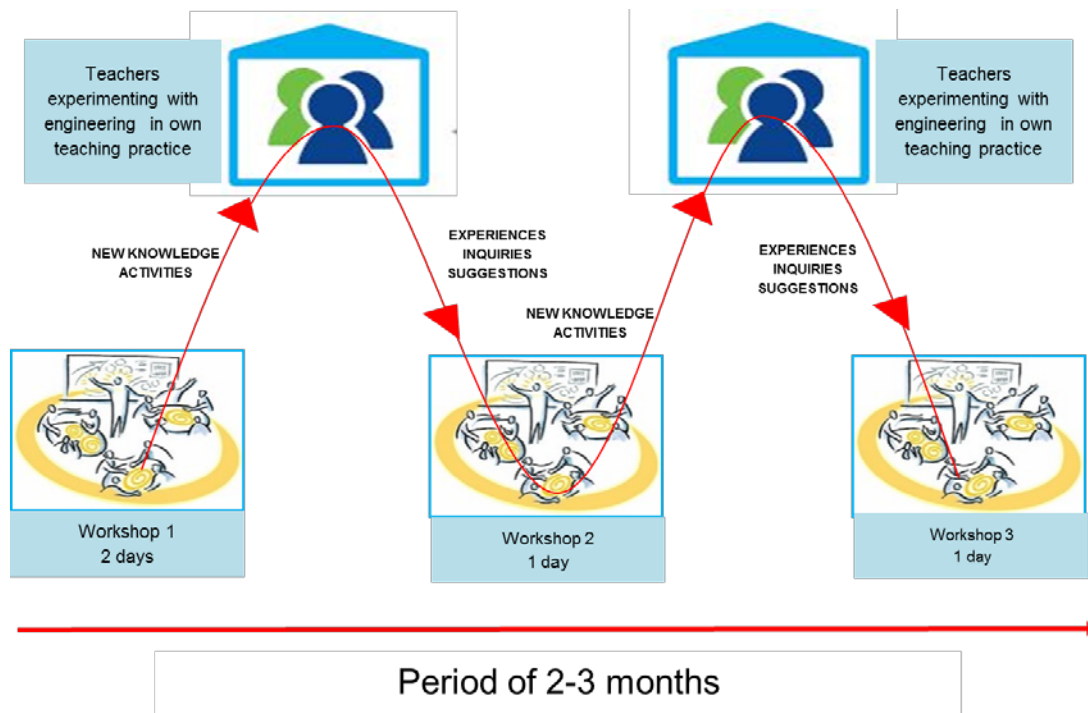
Design criteria	Comment
EDP-model	Pupils work proces is guided by the EDP-model (figure 2)
STEM curriculum	The engineering activities relates to STEM subjects
Narrative context	A narrative situates the engineering challenge in a real-world-context.
Multiple solutions	The challenge, materials and constraints opens for multiple ways to solve the problem.
Materials	Pupils should be able to gain experiences with different materials and tools to manipulate materials.
Degrees-of-freedom	An engineering activity should enable pupils to solve the challenge with various degrees-of-freedom.
Practical-constructive-optimizing process	Pupils construct a prototype that can be improved through iterative testing and re-design.
Ethics	The challenge should include an ethical aspect. E.g. the solution might solve a challenge that is a real-world-problem that improve life quality for humanity.

The purpose of the curriculum materials is to support pupils' autonomous work with engineering activities. For this reason the curriculum materials is organized differently than traditional science textbooks and experiments. Since engineering is basically a systematically problembased work proces, the materials is designed to support pupil work in the different work processes in the EDP-model (figure 2). Thus a curriculum materials consists of a narrative, worksheets for each EDP-workproces and additional resources for exploring material properties and scientific knowledge that can support pupil learning. Curriculum materials are available at www.astra.dk/engineering.

3.3: Teacher training model

The EiS TPD-programme is designed using principles of professional learning communities (Stoll et al, 2006) and combines three activities: Fading support, scaffolding and increasing teacher responsibility during workshop activities and experimenting with engineering in their own practice (Van der Pol et al, 2010). During phase 3 and 4 of the EiS-project the TPD-program was tested and upscaled to full capacity. The TPD-programme was organized as two iterative action learning cycles where teachers in the initial two day workshop was introduced to engineering didactical models and curriculum materials (Se figure 3) followed by a period of experimenting with engineering activities in their own teaching practice. In the second iteration teachers were encouraged to invite other teachers to engage in experimenting with engineering activities through a collaborative collegial process thereby enhancing dissemination of engineering activities within the local learning community within a school.

Figure 3: TPD-model



3.4: Evaluation

The EiS project has been continuously evaluated on multiple levels. The engineering didactical models has been revised based on feedback from the focus group and the teachers who has worked with it in practice. The teachers also evaluated the TDP-program, through surveys and oral feedback. Pupils and teacher learning outcome was assessed using pre- and postsurveys in phase 3. Teachers were asked about their attitudes towards engineering as a teaching practice in schools and their pupils learning outcome. The results showed significant increase in teachers attitude regarding engineering as increasing pupils motivation, creativity and innovation. They also learn better to investigate problems more systematically. These results resonates with pupils results. Pupils reported that engineering is a good variation to “normal” science activities, engineering helped them to better understand science concepts and that teachers are better to scaffold pupils work. Pupils would like to have more engineering activities in the curriculum. Our presentation on the SEFI-conference will elaborate these results.

4: CONCLUSION

Based on our preliminary research it appears effective to develop a tailored engineering didactics for primary schools in conjunction with curriculum materials and spread through a TPD program. In this case, it is yet too early to conclude anything in relation to the long term effects on technological literacy and choice of career paths. Research conducted in relation to the Engineering is Elementary program, suggests that working with engineering in primary school have a positive effect on building science and math skills, it promote classroom equity by accommodating different learning styles (Cassidy, 2004) and pupils become more aware of diverse opportunities for careers including engineering, science and technical careers (Engineering is Elementary, 2018).

5: DISCUSSION

The first four phases of the EiS-project revealed some challenges that we will address in this section.

5.1: Challenges

The biggest success in EiS is that engineering has improved the teaching in primary science for the teachers participating in the project. Curriculum activities in Danish primary science have not developed significantly during the last 15-20 years. From the teachers' self-reports we learned that engineering has improved the pupil learning and also introduces new ideas into the teaching practice. Despite that teachers report, that time, materials and planning engineering activities takes its toll the reward is better science teaching and learning opportunities for the pupils.

Another challenge is to develop quality curriculum materials that enables pupils to learn science and technology. Experiences for the EiS project and the American EiE-programme have shown, that developing and testing engineering teaching materials is a lengthy and cumbersome process. It seems that collaboration between engineering faculties and teacher training institutes can be productive regarding innovating new materials, and research connected to EiE shows it has a positive effect on the pupils' science knowledge and technical skills. It is not possible yet to measure if the EiS project has the positive effect of enabling and inspiring pupils to further education with in science, technology and engineering, but preliminary research shows it has a positive effect on attitude and innovative skills. The challenge is that engineering is competing with other novel initiatives on the educational arena. The large foundations in Danish commerce have realized, that to ensure future generations of a skilled laborforce they must invest in the educational system. Several foundations have launched large funding programmes for educational innovation. The challenge for schools is to balance their interest in getting involved in innovative projects with the teaching activities in schools. Pupils still need to be taught basic science and math even if their teachers are involved in developmental activities.

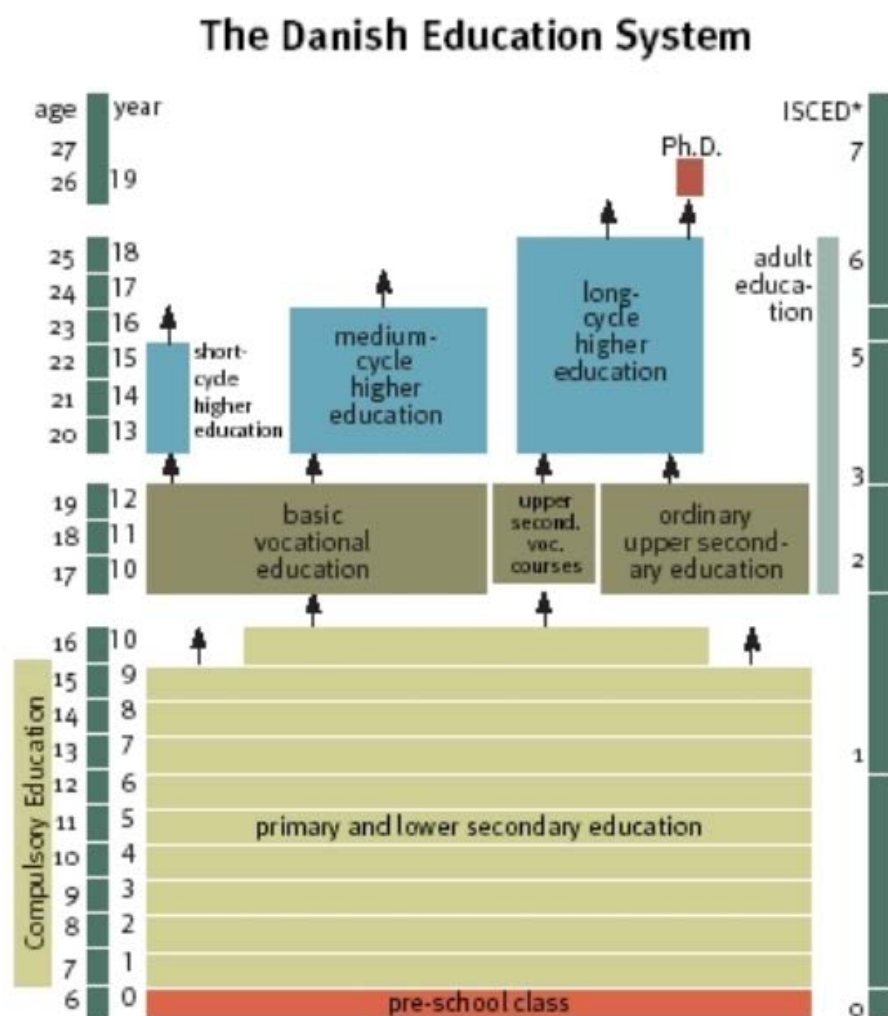
5.2: Future aspirations

The EiS-project revealed many possibilities. The next step in the EiS-project is to spread and solidify EiS in the participating municipalities. Focus will also be on disseminating engineering in schools in new municipalities in Denmark. During 2018 the EiS-project have experienced increased publicity and other municipalities and schools have shown an increased interest. Further development of curriculum materials is also an opportunity, materials focusing on utilizing specific technologies could strengthen the current collection. To ensure progression in STEM education in Denmark an extension of EiS could be to develop the engineering didactics and curriculum materials for upper secondary education.

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Appendix 1: The Danish Education System



* International Standard Classification of Education

Source: Ministry of Foreign Affairs of Denmark

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Development of an anonymous online course feedback system for improving students' learning experience in engineering higher education

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Conference Key Areas: Engineering Skills, Discipline-specific Teaching & Learning, Educational and Organizational Development

Keywords: learning experience, course feedback, online course feedback system

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INTRODUCTION

The extremely rapid technical development together with global operational environment in engineering disciplines require that students of engineering in higher education learn effectively very complex issues in quite a short time. To enable students' effective learning, studies and teaching must be developed constantly. A systematic online course feedback system (OCFS) is one instrument for this. In this study, feedback refers to student feedback, which is provided by students to teachers, not e.g. teacher's response to students' assignments.

Feedback can be considered as a fundamentally important component of education [1] and many universities and other institutes of education use at least some kind of student feedback questionnaire to evaluate teaching [2,3]. The use of OCFSs is increasing, taking room from traditional pen and paper feedback [4]. Multiple different platforms and questionnaire types are used throughout the world, all of them having their own benefits and disadvantages. In Tampere University of Technology (TUT), Finland, there is an OCFS already in use, but it is about time to renew it. Hence, the time for both technical and content renewal is now in hand.

In this study, we present the results of a survey that was carried out in TUT to develop the anonymous OCFS to boost students' studies and learning experience in every possible way. Feedback of the current OCFS together with further development ideas were collected in TUT with teacher interviews and with an anonymous Webropol survey.

Course feedback gives, or can give, deeper insight into students' study experience. However, the course feedback is mainly used, at this point, to develop practical issues, like course scheduling and course materials. In this study, based on the survey, we present ideas for improving the collection and utilization of feedback from an OCFS in order to enhance students' learning experience in engineering higher education.

1 LEARNING AND COURSE FEEDBACK

Student feedback is important, because otherwise students' voice would not be heard by the teachers and other groups of interest, e. g. faculty, university, national and international education development forums. Traditionally the aim of student feedback has been to improve teaching [2]. However, this approach can take the focus away from where it should be: student learning. Teaching and learning are not always in positive relation to each other because the improved teaching does not necessary lead to improved learning. Often this causality takes place, but not always. Student learning is the ultimate goal for all universities and this is why student feedback should be more concentrated to student's learning instead of just evaluating teaching.

When thinking about learning, we must remember, that the learner, or in this case the university student, is responsible for his/her own learning and actions that enhance learning. Nobody else can do the learning for the student. However, when thinking about studying in a university, the student's learning experience can be supported by the teacher, and in this way student's learning can be enhanced.

It is also good to remember, that the learning experience does not have to be positive, e. g. fun or easy, to promote student's learning. Many times hard, difficult and time-consuming learning experiences are superior when it comes to student learning. However, in OCFS answers students very seldom want more of these time consuming and difficult tasks. Consequently, the teacher has a major responsibility to develop the courses, and in this way also students' learning experiences, in the direction which is beneficial to learning, even though the student feedback would indicate otherwise.

Therefore, teachers must choose case-by-case, whether they will attempt to make corrective adjustments based on the feedback received, or should they do something else, which will promote student's learning through student's improved learning experience.

1.1 The most suitable timing for course feedback

Student feedback can give the teacher great ideas to develop the learning experiences of students so that student's learning is also supported. However, this requires that the results of an OCFS are read and analysed carefully, and after this teacher can utilize the results to enhance the learning of students. Generally, student feedback considers learning events that have occurred in the past. The events have generated individual learning experiences, feelings and opinions among students, which influence on the nature of their course feedback. Sometimes some students base their feedback entirely on personal feelings and experiences, while others have more objective focus on their feedback without emotional components involved. However, feelings and emotions are of course an integral part of students learning experience, this should be kept in mind.

Nonetheless, often feedback attempts to influence on prospective actions so that some desired outcomes will be achieved in future. In this sense, student feedback collected at the end of the course implementation is problematic, because the respondents will not generally be participating in the forthcoming implementations. Therefore, usually nowadays actions taken by the teacher will only affect to future implementation, which will have new students with new needs and expectations that will likely differ from the needs and expectations of the students that previously attended the course. Therefore, it would make more sense, if course feedback would be collected earlier during the course so that attempts to make corrective actions would be effective for those who need them, the current students on the course.

Perhaps the best possibility would be real-time feedback, so that students could give feedback at any time, and as many times as they want during the course. Put to general terms, course feedback mechanism scheduled at the end of the course creates an undesirable situation: previously experienced unwanted features by current students will be attempted to remove proactively, in future, by teachers who must base their actions on reactive information from the past, and these actions will be targeted to students who did not observe these unwanted features.

2 CURRENT COURSE FEEDBACK SYSTEM IN TUT

A teacher can collect course feedback in many ways. The most widely used methods are probably pen-and-paper feedback and online feedback [5]. In general, one big question in OCFSs has been how to ensure adequate response rates [5]. The pen-and-paper feedback collection is traditionally done in classroom and urged by the teacher, but in the case of OCFS students answer to it usually outside classroom [5]. Traditionally the pen-and-paper feedback collecting method has gathered the highest response rates [5, 6]. However, the response rates of an OCFS can be extremely high if answering is compulsory for students.

TUT uses currently an OCFS. However, the technical platform behind it is coming to the end of its lifecycle, and it needs either massive improvement or total replacement. Hence, now is a perfect time to renew also the content of the OCFS in TUT. The aim of this renewal is to make the OCFS much better for students than the old OCFS was, especially so that students could have an insight into their learning when using it, in addition to giving traditional course feedback. This study does not concentrate on the technical platform of the OCFS.

Three numerical questions are the same and compulsory for each course in TUT in the current OCFS in TUT. A teacher cannot remove these compulsory questions even if he/she would try to do so. Feedback from all the courses in TUT can be studied and compared together with the compulsory questions, and TUT's teaching as a whole can be developed based on these answers.

In addition to compulsory questions, a course responsible teacher can add questions to his/her courses' questionnaires. The questions can be either numerical or open-ended. There is a question bank available in the OCFS, where the teacher can choose ready-made questions, or he/she can create new questions of his/her own.

The results of numerical questions are displayed as mode, median and average. The answers of open-ended questions are displayed as they have been written in the OCFS. One big disadvantage of the current system is that it does not provide any kind of figures or charts from the numerical results.

Answering the current OCFS is compulsory for all the students; otherwise the student does not have the course grade in his/her study record. The current OCFS does the checking, teacher has not to take care of this. The teacher gives the grades normally, but if a student has not given course feedback, the course grade does not appear in his/her study record. Because the course feedback is compulsory, there is a possibility for false answers from students. If a student just wants to get his/her grade to the record, the possibility for random answers, which are not anyhow related to the student's thoughts, is obvious. This is avoided by adding an "I do not want to give feedback" button to the questionnaire. A student can choose it, and then he/she can get the grade to the study record without distorting the feedback results. However, surprisingly few students choose this possibility. A vast majority of students really give course feedback using the OCFS.

3 METHODS OF DATA COLLECTION AND ANALYSIS

In this study, the primary research data was collected using two sources of evidence: face-to-face interviews and an anonymous online questionnaire. The participants in this study are teachers from TUT and their participation was voluntary. Three teachers took part both in the interview and the questionnaire and this was taken into account when the data was analysed.

The teachers of TUT were informed about this study and the possibility to take part in the interviews through their email list. As a result, we received ten interviewees to participate in this study. The interviews took place in October 2017 and the research assistant of this study acted as the interviewer. After the interviews, the amount of ten interviewees proved to be a suitable sample size for this study because the saturation level was reached in the interview data.

The interview method was semi-structured, because we wanted that the respondents could have the possibility to steer the topic of the discussion to subjects that they considered important. The teachers were interviewed individually, and the interviews were carried out face-to-face. In order to analyse the interview data, the interviews were recorded with the consent of the participants and based on the recordings the research assistant wrote detailed notes.

The questionnaire was created after the interviews with an online survey tool called Webropol and it consisted of 11 questions, 6 of which were open-ended. The rest of the questions were in the form of statements and the response options were formed with a five stage Likert scale. The link to the questionnaire was sent to the teachers of

TUT through their email list and the questionnaire was open to replies for two weeks in November 2017. We received a total of 22 responses.

Both the interview and the questionnaire data were analysed with the help of qualitative content analysis. This means that the analysis involved the identification of common patterns within the responses. The questionnaire data was coded with different colours and the findings were compared with the findings of the interview data. We wanted to use two different sources of evidence because using multiple sources simultaneously is often considered to increase the reliability of qualitative research [7].

4 RESULTS AND DISCUSSION

The results from the teacher interviews and the Webropol-questionnaire can basically be divided into two categories: Technical issues and content issues. Both of these are strongly related to students' learning experience, but in different ways.

4.1 Technical issues

The results of this study indicate that the user experience of an OCFS is extremely important. The usability of the system has to be smooth, and the user interface (UI) has to be easy to use. In addition, the OCFS has to be technically compatible with mobile devices.

The use of an OCFS is part of the students' learning experience. If the UI and usability of OCFS are not in order, the students get frustrated and this possibly affects the collected feedback, leading to distorted course feedback. In addition, in the case of distorted feedback, the student cannot or may not use the OCFS as a tool for their own self-reflection in learning. If this happens, one of the big purposes of the OCFS is lost.

The results also show the importance of practical course arrangements. As an example, scheduling, classrooms and course materials must be well planned and carefully chosen to ensure the best possible learning experience for students. These practicalities can be easily asked in the OCFS, and these issues can be quite easily affected even during a course.

This leads to one result of this study, the OCFS should be real-time, meaning that the students can give feedback whenever they want and wherever they are. The real-time possibility to give feedback aids the students to use the OCFS as a system for their self-reflection as learners. In addition, the teacher can react to many issues immediately during the course, not just after it. These issues undoubtedly include practical issues like course material updating, but also issues related to e. g. the depth of handling the subject matter, and classroom time used to the course topics. However, the utilization of real-time feedback can be quite time-consuming for a teacher, but we think it is definitely worth it.

4.2 Content issues

The questions in the OCFS should be both numerical and open-ended. The numerical answers are easy to analyse with statistical methods, different kinds of characteristics and charts can be established based on them. However, the teachers in this study very strongly think that the open-ended questions give the most valuable course feedback. The students can show their ideas connected to teaching and learning processes [8]. Here are a couple of comments from the teacher interviews (translated from Finnish):

"The feedback gives insight to a student's daily grind."

"Qualitative feedback is more useful. This means open ended questions."

"Feedback makes the student think about his/her own learning process."

“Feedback is much used to develop course practicalities. However, it would be more rational to see, what is learned and what is not.”

With open-ended questions a teacher can follow student's thoughts, and this way the teacher can get a glimpse of the students' learning process. The teacher gets a sight to the students' different learning styles and strategies. The learning of students increases when the teacher knows students' different attitudes and responses to teaching and learning [9].

Based on these results the questions in an OCFS should be developed towards aiding students' learning. The idea of using an OCFS as a system for student's own self-reflection tool for learning is rising all the time. These kind of questions also help teachers to develop the courses so that the students learn better and they have learning experiences that improve their learning.

4.3 Other issues

In addition to the answers relates to students' learning and learning experience, a couple of points arose continuously in the data: answering to the OCFS should be compulsory for the students, and the students as well as the teachers need training how to give and receive constructive feedback. Now, with the current OCFS in use, a big problem with the university level questions is that they are close-ended in a way that the teacher cannot get the idea behind the student's feedback. The numerical results for e. g. a question like “Overall rating of the course and its implementation” do not tell what was good and what should be improved in a course. Furthermore, if a student writes e. g. “The course was bad”, the teacher does not know what needs most improving. Hence, the skill to give feedback so that it tells in more detail about the course, and learning on it, is essential.

5 SUMMARY

The main finding in this study is that course feedback system, no matter in which form it is realized, should be more focused in the students' learning instead of, or in addition, to practicalities. Teachers are requiring an insight to students' learning and learning process. This way the studies, and especially learning, as a whole can be improved with the help of course feedback system.

Especially open-ended questions in OCFSs offer the teachers insight into students learning and learning experience. Student's thoughts and learning processes become visible in open-ended questions. Based on the answers in the open-ended questions the teacher can develop courses so that the learning of the student is supported in the best possible way. On the other hand, teachers would like to have different kinds of charts and statistics straight from the OCFS. This is in contradiction with the requirement of open-ended questions. It is very hard for a software to conclude any kind of charts from freely written answers to open-ended questions. However, with careful and continuous development work we think that also this can be possible in future.

The results also indicated that the OCFS should be real-time, so that students could answer to it continuously during their courses. Furthermore, in more general level, continuously during their studies. The possibility to give feedback in real-time would aid the use of OCFS as a tool to make the student's learning visible and this way enhancing teacher's possibilities to guide student's learning experience towards extensive learning. However, at least in TUT, the current OCFS does not technically suit to this kind of continuous real-time giving of feedback. Hence, when the OCFSs are developed, the results of this study must be kept in mind already in the very first

steps of system planning. This feature in OCFSs can be established, if it is recognized already in the beginning of the software development.

One important finding is that the technical platform of an OCFS has to be technically suitable for its purpose, easy to use and compatible with different kinds of mobile devices. Otherwise, the problems of the technical system affect negatively to the student's learning experience.

The answers in this study also highlighted that the students should have training how to give constructive course feedback. This issue is not connected to the feedback system what is used, but to feedback in general. The feedback should be written so that the message is clear for the teachers, e. g. what is working in courses and studies in general, and what is not. Very general feedback does not aid the teachers in developing courses and studies. Furthermore, it does not help the teacher to boost students' learning and learning experience together with the students.

The results of this study show that an OCFS should definitely be something else than it is now in TUT. The definition and planning work of the next OCFS in TUT has already started, and the results of this study are known and recognized in that process. Hopefully the system-to-be will be suitable to support students in their learning, and hopefully the teachers get a more thorough view to students learning experiences with the next OCFS in TUT.

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Upgrade of the MINT^{gruen} - Fluid Mechanics Project Laboratory (SEFI 2017)

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ABSTRACT

Conference Key Areas: Sustainability, Skills and Engineering Education

Keywords: STEM^{green}, Fluid Mechanics Project Laboratory, TU Berlin, MINT^{gruen}

INTRODUCTION

Since 2012, the Technische Universität Berlin offers a special orientation program in the subjects of mathematics, informatics, science and technologies (MINT^{gruen}; English: STEM^{green2}). It is a one year program, which is designed to help high school graduates to find the right study course and prepare them for their later studies. Students can choose between regular MINT subjects and specially developed MINT^{gruen} laboratories. After two semesters the students can decide, which study course they want to continue with and the credit points of the completed subjects, which fit into the chosen study course, are taken into account.

The department of Fluid System Dynamics at the TU Berlin contributes to the orientation of young students by offering a laboratory dealing with fluid mechanics in applied mechanical engineering. The Fluid Mechanics Project Laboratory (FMPL) provides

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² STEM: Science, Technology, Engineering, Mathematics

fundamental engineering skills by teaching the students all the basics of using engineering software (such as Excel, SolidWorks, VBA) and guides them through advanced usage. It also imparts structured working methods while teaching the importance of sustainable engineering. Students achieve basic and advanced engineering skills (software and working methods) as well as exploring the multifaceted nature and the importance of sustainable engineering at the example of fluid flow machines. The whole laboratory is wrapped in the teaching concept of problem based and project based learning. Since launching the project, it has been continuously evaluated by the students. The results show a very good rating for the teaching approach and a first analysis reveals that more than half of the students participating in the orientation program choose a MINT topic for their later studies.

1 OVERVIEW OF MINT^{GRUEN} (ENGLISH: STEM^{GREEN})

1.1 Structure, numbers and trends

After graduating from high school, young people have to decide what they want to do professionally. Some choose to take an apprenticeship for about 3 years, whereas others choose an academic career. The German universities offer a wide range of possible study courses. Most pupils feel overwhelmed by the countless possibilities and are unsure which course to take. They are expected to decide on “the right” study course which they will be practicing for the rest of their lives. This causes a lot of pressure and makes the decision even harder. Young people feel the need to be guided and orientated. Therefore, the Technische Universität Berlin launched the orientation program in 2012 MINT^{gruen} to show graduated pupils the variety in the fields of science, technology, engineering and mathematics. Since initiating the orientation program, the numbers of participants are steadily rising (Fig. 1).

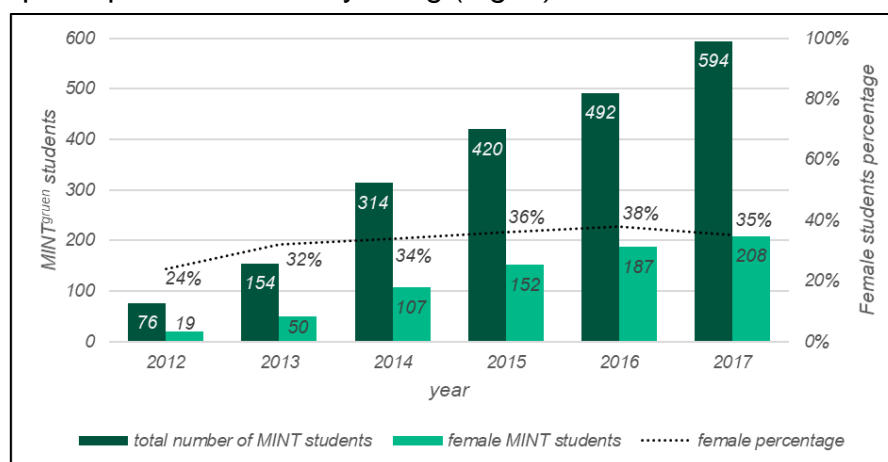


Fig. 1: Numbers and trends of the MINT^{gruen} orientation program

Fig. 2 displays the contents and structure of the orientation program, which lasts two semesters. The “Scientific Window” and the “Study Program Decision” are obligate courses, where students gain all necessary information on how to orientate themselves. In the “Scientific Window” the students have to deal with current research topics in the MINT sector and discuss these in terms of sustainability and sustainable development. They share and reflect their experiences in a separated orientation course. This helps the students to get a good impression of the different fields and makes the decision easier. The other modules are facultative and consist of basic lectures (i.e. engineering mathematics) and so-called Project Laboratories, which are explained in the next section. After taking the two-semester program, most of the courses can be transferred to the student’s chosen course of study.

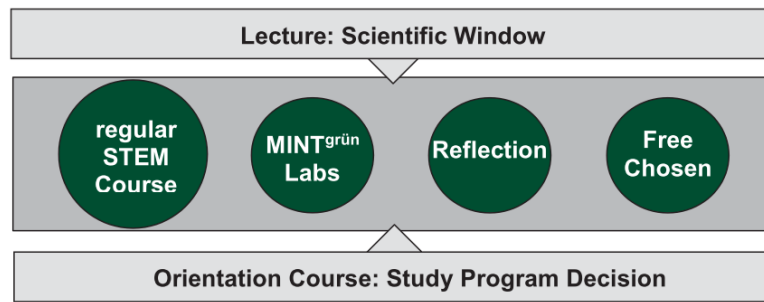


Fig. 2: Structure of the orientation program MINT^{gruen}

1.2 Project Laboratories

One characteristic feature of the orientation program MINT^{gruen} are the above-mentioned Project Laboratories that are specifically designed for MINT^{gruen} students. Especially in the earlier stages of study courses subjects are more theoretical. For a successful orientation, it is mandatory that students discover their practical and project related potentials. Furthermore, the students have to work on projects in their future jobs too and this is a first good practice, which usually appears not until the fourth bachelor semester. Therefore, the orientation program offers a wide variety of laboratories, which cover the following fields (for further information see the following source mentioned in brackets):

- Fluid Mechanics Project Laboratory ([1] and this paper)
- Industry-linked Fluid Mechanics Project Laboratory
- Mathematical Lab – Mathesis ([5])
- Creativity and Construction ([6])
- Chemistry Project Laboratory ([7], [8])
- Gender in MINT fields ([9])
- Robotic Laboratory
- Vibration Technology Laboratory
- Artefacts in technology and science history
- Environmental Laboratory

The department of Fluid System Dynamic at the TU Berlin contributes to the orientation of young students by offering a laboratory dealing with fluid mechanics in applied mechanical engineering, the Fluid Mechanics Project Laboratory.

2 STRUCTURE OF THE FLUID MECHANICS PROJECT LABORATORY

Since the FMPL is described in the SEFI 2017 proceedings [1] in detail, only a short recapitulation is given now.

For the students the main goal of the project laboratory is to design a rotor blade for a wind turbine model in small groups of 3 to 5. They design the blade from sketch, over calculations in MS Excel and a CAD³ software, to an actual 3D printed part, and measure it in a wind tunnel. A final report on the students' project is required as well as a final presentation. The report aims at improving the scientific writing skills the presentation is supposed to train the appearance and the speaking in front of an audience. The laboratory's structure is similar to an actual industrial project. Fig. 3 displays the 3D model of the wind turbine in CAD (a) and in reality (b). Fig. 4 illustrates the wind tunnel where the measurements of the rotor blades take place.

³ CAD - computer aided design; possibility to design 3D models of component, part or assembly

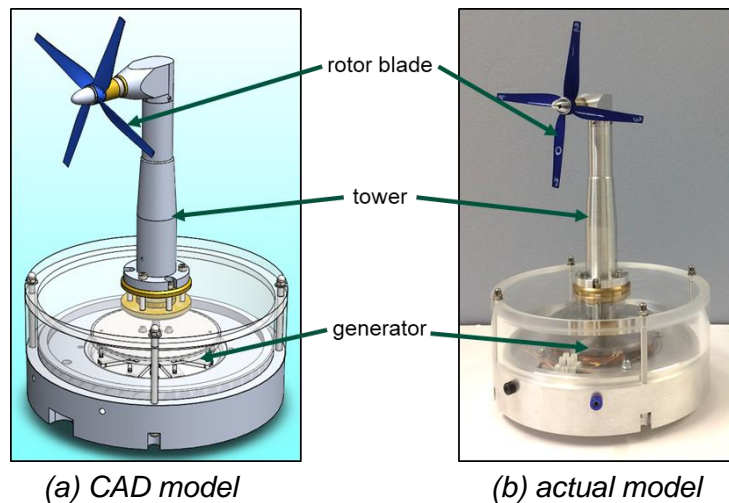


Fig. 3: Example of a rotor for a wind turbine model designed by the students

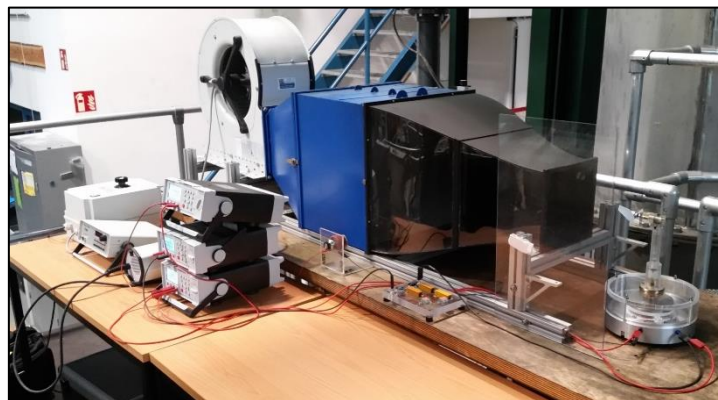


Fig. 4: Wind tunnel used for the rotor measurements

2.1 What's new?

It is an educational and societal task to sharpen the awareness of power producing and power consuming machines. It is pointless if the producers are “clean and green”, while the consumers stay “bad and red”. There is a need of a sustainable and environmentally friendly design for these power consuming fluid flow machines and their hydraulic systems. Consequently, the interest of young students for this topic needs to be awoken.

Power producers (e.g. wind energy, solar power, hydro power) are getting a lot of attention from the media while power consumers (e.g. industrial pumps, washing machines, dryers and many more) are left behind. Since it is easier to attract young students with power producing turbines, a new water turbine concept is added to the pre-existing wind turbine concept to upgrade the fluid mechanics project laboratory. Fig. 5 pictures the new test stand as a 3D model. Once students are attracted to a topic they were interested in beforehand, it is easier to cover uncommon topics like wastewater pumps parenthetically to build awareness and arouse interest. Furthermore, it is easier to implement a second turbine into the pre-existing concept because their design guidelines provide similarities.

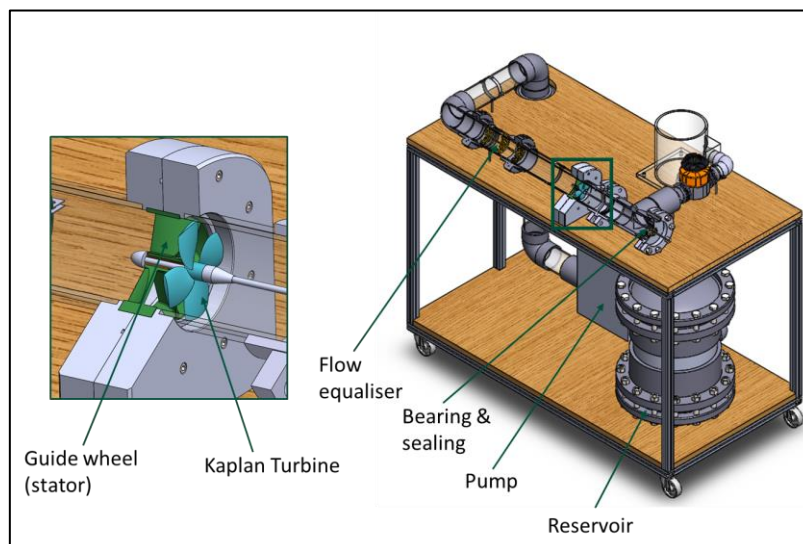


Fig. 5: Water turbine test stand and 3D printed rotor model

Since the water turbine concept had to be integrated in the pre-existing wind turbine concept, the structure of the project laboratory remains nearly the same. Students can now choose between *wind* and *water* and are put into two separate groups, which meet on different days of the week. Fig. 6 summarises the FMPL's structure and which topics are discussed at a certain point.

Phase Duration Contents			Achieved skills
1	2 weeks	Organisation and project management	Organisation of group projects Time management Creating project schedules with MS Excel Basic calculations in MS Excel
2	3 weeks	Fluid mechanics, wind energy and hydro power	Handcrafting and testing air- and hydrofoils Advanced usage of MS Excel (links, functions, variables) Complete rotor calculation
3	2 weeks	Computer aided design (CAD)	Introduction into 3D modeling Basic usage of CAD software Advanced usage of CAD tools (scripts & macros) Manufacturing of the student's rotor
4	3 weeks	Measurement techniques and test stands	Purpose of test stands Usage of sensors Measurement of each group's rotor Advanced usage of MS Excel (graphs, functions)
5	3 weeks	Writing and presenting skills	Creating templates for MS Word Basic usage of MS PowerPoint Scientific writing recommendations

Fig. 6: Structure of the Fluid Mechanics Project Laboratory

There is one main advantage in adding a second turbine into the pre-existing concept. To expand on these advantages, the next chapter introduces the teaching technique of problem based and project based learning. Furthermore it will be explained how the expansion supports the students in their development.

2.2 Project based and problem based learning

Project based and problem based learning is well summarized in the following two citations:

*Besides many facts, problem based learning teaches the ability to develop strategies to solve a problem.*⁴

*Learning as a problem based process is executed in a specific, scope related context. Trainees learn from an example and are able to transfer their knowledge to a new similar problem or situation.*⁵

By nature, a project laboratory includes problem based and project based learning methods, since the students face a pre-designed problem that has to be solved on their own. To use the problem based and project based teaching method to its full potential, it is expanded to satisfy student's needs:

A German survey from 2015 analyses current study states and student's orientation success. This survey [3, pp. 21-30] shows that students wish for a better support regarding the achievement of engineering skills (which were not taught in school) and handling of common engineering software such as MS Excel. A majority of the students mentioned a knowledge gap between the schools' content of teaching and required engineering skills at the university. Finally yet importantly, students criticise the lack of support for achieving scientific writing skills regarding their homework and their bachelor theses. The goal of the laboratory is to satisfy those needs and show the multifaceted world of fluid flow machines.

In order to satisfy those needs while reaching the main goal of the project laboratory (the design of a rotor blade), the problem based and project based teaching method is used as shown in *Fig. 7*. Like a real industrial project, the laboratory is split in four main phases (project scheduling, calculation and design, measurements, documentation), which are each divided into at least two sub-phases and corresponding problems to solve (not pictured in *Fig. 7*). These sub-problems are similar in the way they can be solved. The solution of the first problem is approached from a certain angle, while the solution of the second (or further) problem(s) is (are) developed from a different angle. But the main structure for solving the task remains the same: a short theoretical input, followed by a practical phase, leading to a final result (cycle in *Fig. 7*). While doing so, different engineering skills, as mentioned in the survey [3], are taught.

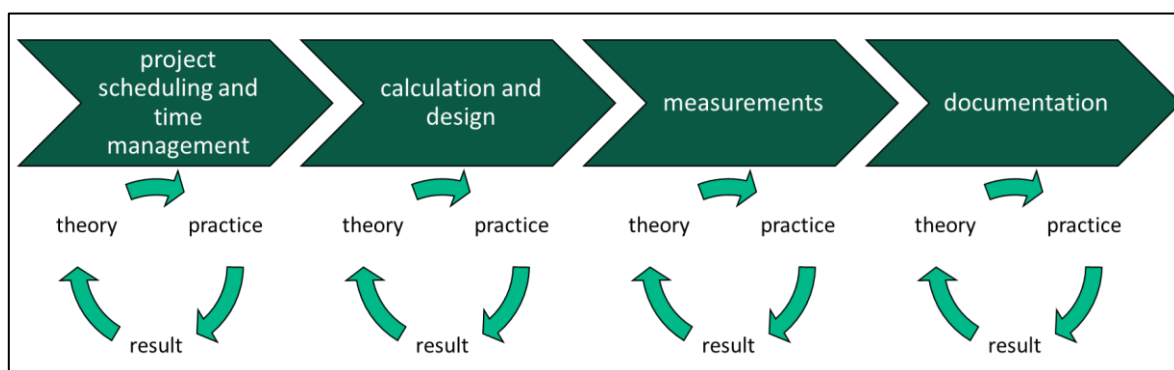


Fig. 7: Concept of problem based and project based learning at the FMPL

⁴Analogously translated from [9] p. 3; Similar definitions in English can be found in [11]

⁵Analogously translated from [10] p.18; Similar definitions in English can be found in [11]

After introducing the concept of problem based learning and how it is utilized in the fluid mechanics project laboratory, the main advantage of integrating another turbine into the existing concept gets sharper: As mentioned, the students are split into a *water* and a *wind* group. Before the students solve the main task for their own turbine, an example of the respectively other turbine is used to impart knowledge by the teacher. Subsequently, it gets easier for the students to adapt to their own problem and find a solution on their own. Furthermore, the discussed topics, wind and water turbine, are put into relation with each other. After applying their knowledge two times in a power producer related case, a power consumer case is investigated. This strategy leads to the above-mentioned interest in power producers and consumers, which is also one goal of the fluid mechanics project laboratory.

Another aim is to encourage the students to work independently by providing as many free choices as possible, fitting to the student's current level. That is one reason why the project was expanded with a second selectable turbine. The students now have the option to choose either work on the wind turbine model or on a water turbine model. Furthermore, the expansion of the project shows the great variety in the field of engineering in terms of renewable energy. The students also get to see the difficulties that are posed by conducting measurements in water.

Summary:

- The students gain knowledge about power producers and consumers at the same time, while understanding the importance of a sustainable und environmentally friendly design of both categories.
- The students are, due to the teaching concept, able to describe a problem and find a solution similar to a problem solved before.
- The student's wishes, as shown in the above-mentioned survey [3], are fulfilled.
- The students are getting encouraged to work independently, since they can decide on their own as much as possible.

3 RESULTS AND TEACHING APPROACH

Analysis reveal that more than half of the students participating in the orientation program in 2017 choose a MINT topic for their later studies (*Fig. 8*).

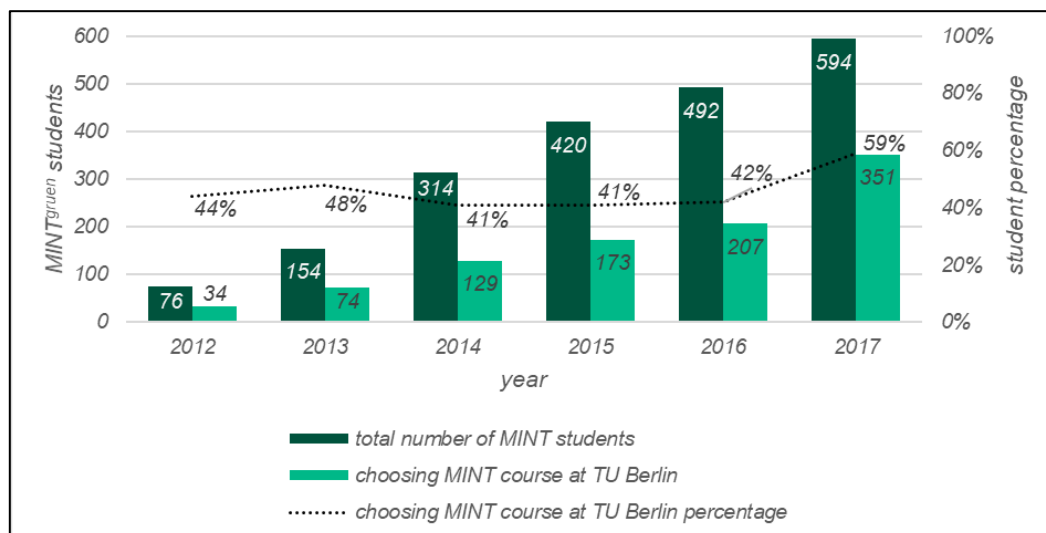


Fig. 8: Number of students considering a MINT related study course at TU Berlin

Even people, who leave the university and start an apprenticeship, consider the contents of the FMPL as useful for their later jobs. The Fluid Mechanics Project Laboratory as a whole was rated in 2017 with “very good” (Fig. 9) and with “good” in 2018 (Fig. 10).

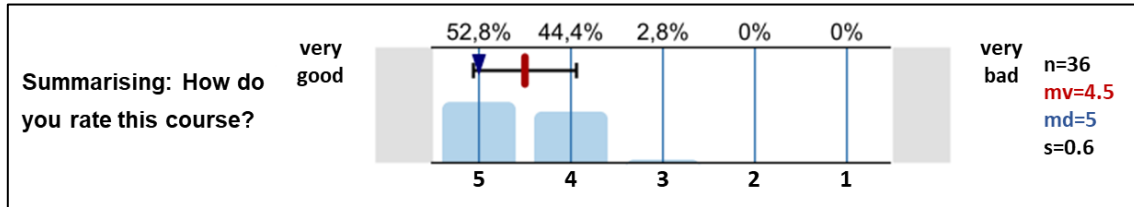


Fig. 9: Student's summarised rating of the Fluid Mechanics Project Laboratory 2017

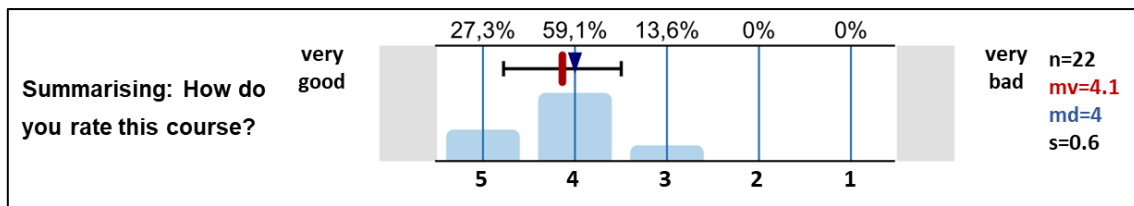


Fig. 10: Student's summarised rating of the Fluid Mechanics Project Laboratory 2018

When comparing Fig. 9 and Fig. 10, a drop in the overall rating of 0.4 points is noticeable. It is assumed that this drop is caused due to a personnel change mid semester and is not related to the implementation of the second turbine. Future data will tell if this assumption is correct.

4 SUMMARY AND ACKNOWLEDGEMENTS

Whilst lectures mostly use frontal teaching methods, the Project Laboratories focus on practical tasks and give the students the possibility to create a MINT-related object on their own. The teaching concept of this Fluid Dynamics Project Laboratory contributes highly to the orientation of our students. A huge field of fluid mechanical engineering is covered. Students gain a diversified insight on fluid mechanic related topics and their field of appliance. Due to the practical concept of the laboratory, students achieve various engineering skills and working methods, which can be used in many study courses, apprenticeships or even in their later jobs. Due to the teaching of basic and advanced skills regarding engineering software (MS Excel, MS Word, MS PowerPoint, SolidWorks), students are well prepared for their course of study. In this program, the students get supported in general studying related aspects as well as fluid mechanic related topics.

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An open source, information and learning resource for engineering education in the built environment disciplines

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Conference Key Areas: Open and Online EE, Discipline-specific Teaching & Learning

Keywords: open source, data and information portal, self-directed and project based learning

1 INTRODUCTION

Many research studies have highlighted the benefits of virtual learning environments or laboratories for enhancing the student experience in engineering education (EE) [1]–[3]. Previous research has also found virtual laboratories to be an equally effective method for student learning in comparison to on-campus lectures, with students possessing no prior knowledge of the lab topic still benefiting substantially [4]. The “emerging leaders” in EE are now using open and online e-learning platforms to put the student first, by focusing on “socially-relevant” and personalised projects to contribute to the increasing need for multidisciplinary learning and a global impact [5]. One of the most socially relevant topics in engineering today is the challenge of improving the energy efficiency in our building stock. In Europe, the targets for buildings are very ambitious, with an 80-90% reduction in carbon emissions anticipated by the year 2050 [6]. It is evitable that this target will mean a mass upgrade of the existing building stock through energy efficient retrofitting, in order to bring buildings to nearly zero energy status. For engineering students in this area, there are few well-documented examples of low energy buildings and fewer retrofit examples which could be used for project-based learning (PBL) and self-directed learning (SDL). Students in this area could benefit from a real world application that is supported by data and resourced through an intuitive user interface with demonstrative graphics [7].

This paper outlines the development of an open source, web-based learning resource comprising of an information portal, data portal and interactive app, all based on real data from a live building testbed. The learning and information resource acts as a virtual laboratory and presents interactive high resolution data and information from Ireland's National Building Energy Retrofit Testbed (NBERT). The online suite of tools can be used by educators, anywhere in the world, as a basis for the development of energy models and undertaking analysis of performance in a real world application. The learning resource attempts to streamline the pedagogical style in the classroom, enabling students to engage in the development of energy models and analysis based assessments in an exploratory and more fluid manner, to improve the student learning experience.

2 MOTIVATION AND BACKGROUND

In academic environments there are often many stakeholders, with overlapping roles, at the intersections between stakeholder groups. Figure 1 shows this clearly where some members of individual groups may have two or even three roles within an institution (e.g. a lecturer who is a researcher, or a student who may lecture and also be a researcher simultaneously). The NBERT learning resource (www.nbert.xyz) was created as a result of the need to satisfy the needs of multiple stakeholders. Those who created it had hybrid roles within an institution and therefore had an understanding of the needs of multiple groups simultaneously.

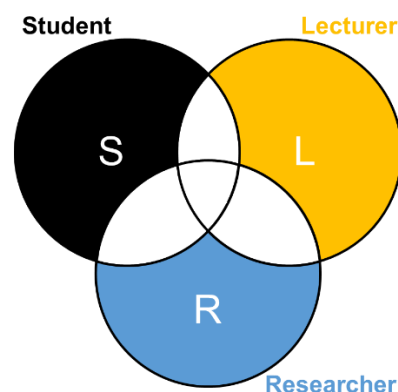


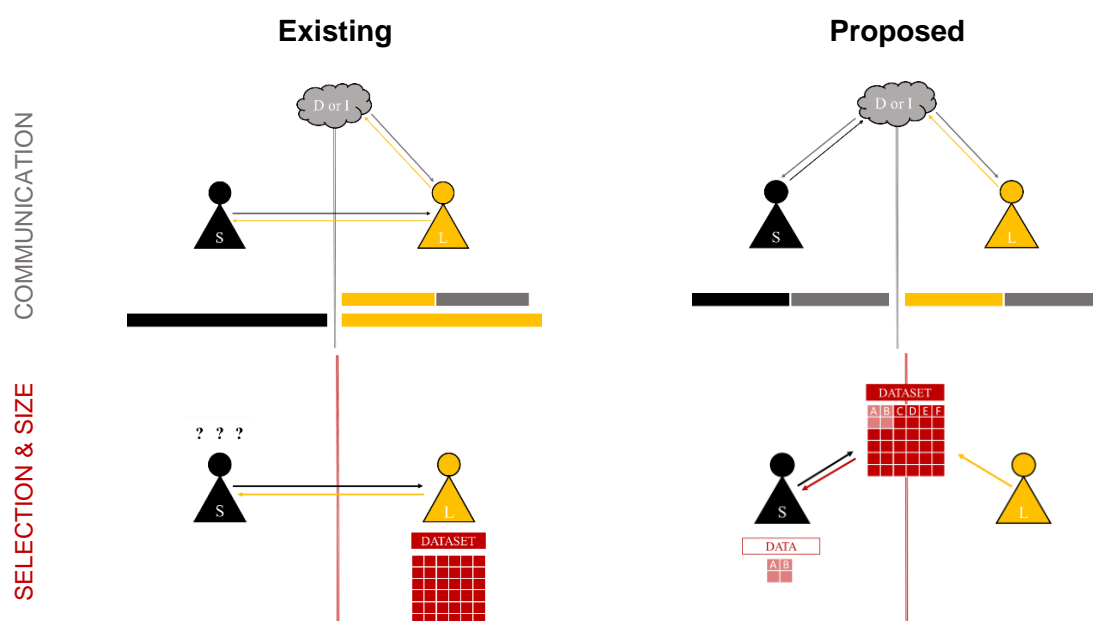
Figure 1: Simple stakeholder relationship in universities and institutions

The initial motivation for the learning resource came about as a result of the need to provide data and information to undergraduate students studying energy modelling modules. This information and data is related to the internal and external data logging systems and building information in the zero2020 building [8]. The modules which were considered to benefit from the learning resource, were all continuously assessed modules with PBL. In these modules, data and information were often needed to create or validate energy models, or to inform the choices made when modelling certain phenomena. Students made multiple requests for data or information from lecturers and often ad-hoc solutions were found each year. This unsystematic process was frustrating for both parties, with data and information being sent time and time again, from different lecturers to different students. From a student perspective this often led to a time-lag in a communication between data and information requests, where

lecturers did not have the time to deliver on these requests quickly. Students often got overwhelmed by the size of the datasets they received, as they often only required a subset of a large dataset. Lecturers wanted to make a system that all students could access, a system which would remove the need for multiple emails and multiple downloads on an annual basis. There was also desire from lecturers to allow students to control an element of their learning when modelling energy systems. The final motivation that led to the creation of the learning resource were the needs of multiple researchers in the department to gain access to data and information for model validation or calibration. Researchers in the built environment or energy modelling area were continually in search of well documented buildings with monitoring systems for both internal and external parameters. In a similar manner to students, researchers often found themselves having to analyse large datasets as no selection functionality was built into the source of the datasets they used. For the purposes of this paper only the student and lecturer perspectives will be discussed from this point onwards, as work on the researcher benefits has been discussed previously [9].

3 CONCEPT AND OBJECTIVES

The initial concept was to develop a cross-module platform for students that all module lecturers can access and use for students. This platform would replace the old delivery system mentioned previously. Designed around four main themes (indicated in Figure 2), the concept was to: reduce the response time between student (S) and lecturer (L), to reduce the size and repetition of data downloads, to add an additional level of self-directed learning (SDL), and to create the change from a cellular to a more centralised approach to data and information management at a departmental level. From a student perspective the concept was developed to: open up communications and enable students to explore data and information, allowing them to select the data they needed and choose some of their learning path.



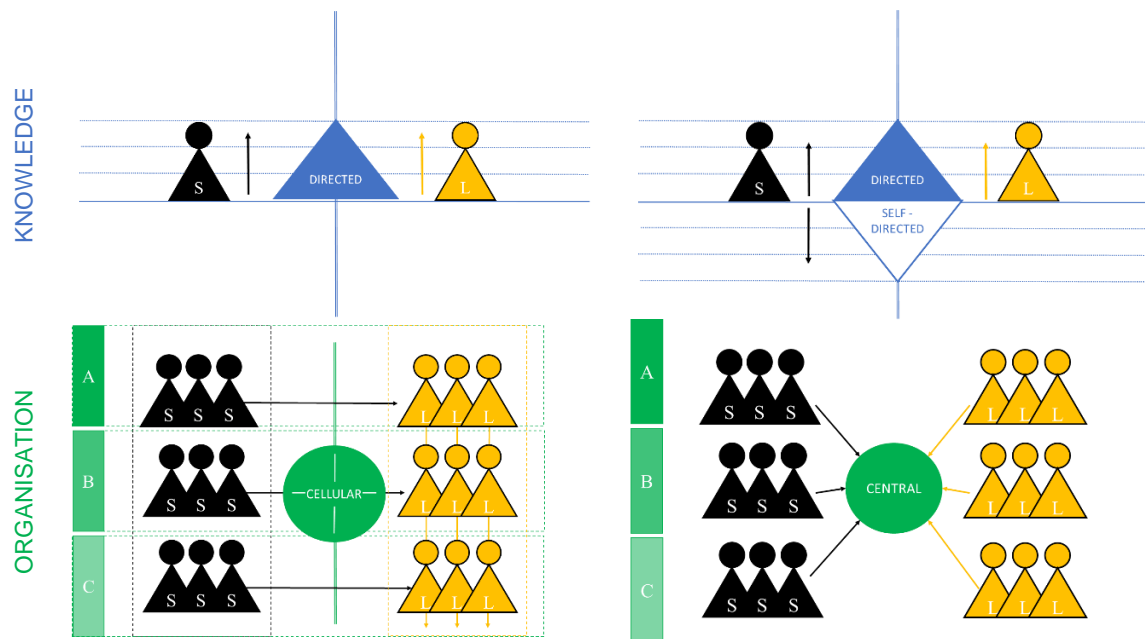


Figure 2: NBERT learning resource concept, from the existing to the proposed system

The communicative expectation with the platform was that there would be no need for extensive email conversations between students and lecturers. It was also expected that lecturers could manage the datasets more effectively and would be able to work collectively to provide data and information in a coherent, structured way. This was expected to allow lecturers to create additional learning resources and add them to this platform to expand on the learning in class across different modules. Finally, the hope was that this platform could be used outside of the college it was designed for and that it could be provided to any institution in the world. Using these themes, concepts and expectations to guide the delivery of the platform, the following objectives were defined:

1. Provide a publicly accessible source of empirical data from a well-documented low energy building for use in the education of operational building performance and to support the development of students' energy models.
2. Provide a rich source of information for undergraduate and postgraduate research projects in energy and the built environment for Ireland and further afield.
3. As part of a future suite of online building energy education applications, develop an online tool for the assessment of Irish climatic cooling potential of various ventilation strategies and building configurations that rely on untreated outdoor air for their source of cooling.

4 DESIGN AND DESCRIPTION OF THE NBERT LEARNING RESOURCE

3.1 Web platform selection

Based on the above objectives, it was decided to create a website which consisted of: An interactive information portal, an open source data portal, and a set of interactive education apps: (i.e. the climate cooling potential analysis tool). It was seen as

important from the start of the project to balance cost, time, quality and the functionality of the platform. It was also seen as important to select a reproducible template that other educators could use for future applications. For this, a variety of easy to use website templates were reviewed. Squarespace (<https://www.squarespace.com/>) was deemed the best option in balancing all the above qualities for developing the website as it required no prior knowledge of typical web development languages and had an easy to use and flexible template options. Outside of just creating a centralised web-platform, creating a modelling or data analysis page with download and upload functionality would require expertise in typical web development languages (HTML, Javascript, Java etc). To overcome this, web-based applications for both the data portal and climate analysis tool were created using Shiny (<https://shiny.rstudio.com/>). Shiny is a package used with the open source program RStudio (<https://www.rstudio.com/>) which requires no prior knowledge of web development language as long as you have knowledge of R-Language.

3.2 Learning resource tool website layout

Having selected the tools for the project the next phase involved the creation of the website that linked all RShiny applications into a single platform. Figure 3 below shows the main structure of the NBERT website where students can access all interactive apps and information and data portals in a single location. One of the main objectives with the website was to create varying levels of learning with increasing amounts of clicks. There was also an attempt made to create “click space” between basic information and detailed information and downloadable data or information.

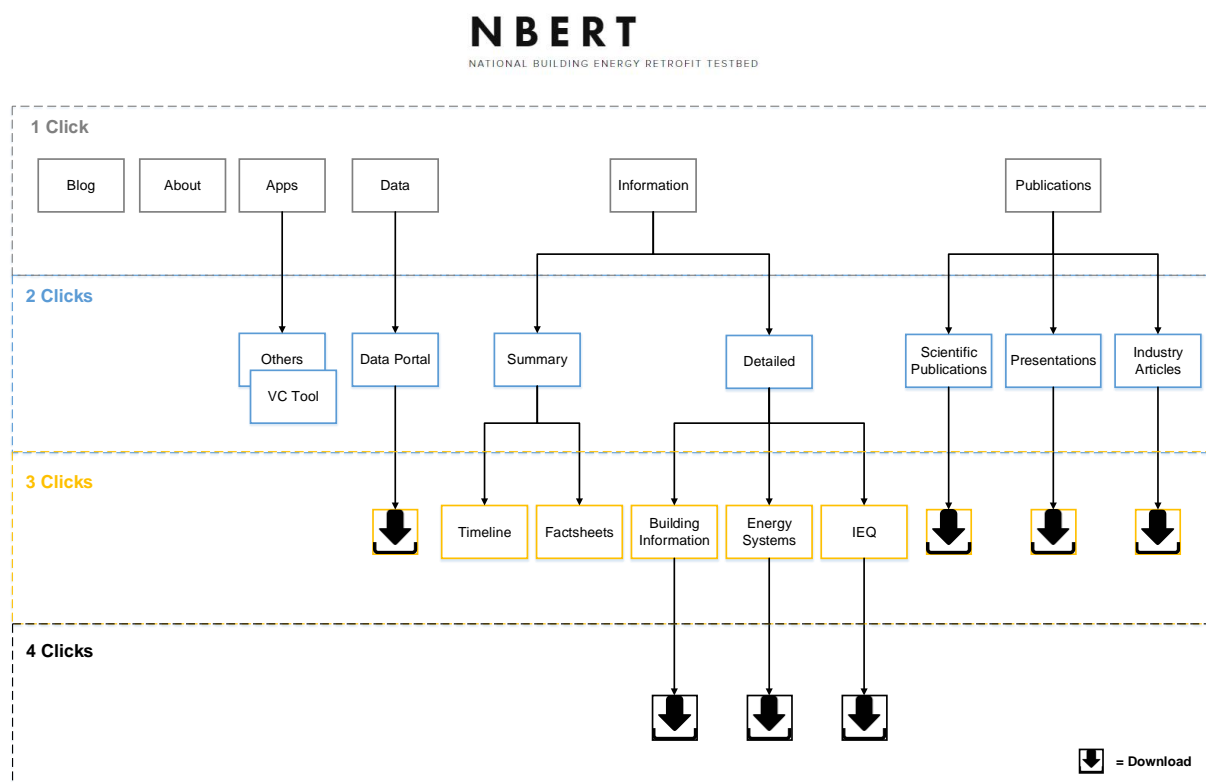


Figure 3: Structure of NBERT website

The three main components of the platform; information, data and apps are summarised below in sections 3.3 to 3.5.

3.3 Information portal

The NBERT information portal consists of documents, drawings and building specifications that have been gathered during the design, construction and commissioning of the zero2020 building [8], [10]. The portal has been designed to welcome and direct students, researchers and policy makers, to the information they may need. Table 1 gives an indication as the types of information that are available in the information portal.

Table 1: Detail on the information provided in the NBERT information portal

Type	Details
Building geometry and details	<ul style="list-style-type: none"> • Online images with summary text and downloadable pdf drawings
Material Specs	<ul style="list-style-type: none"> • Online overview with downloadable data sheet .pdf documents
Airtightness data	<ul style="list-style-type: none"> • Online details
Natural ventilation system	<ul style="list-style-type: none"> • Configuration drawings
Thermal bridging	<ul style="list-style-type: none"> • Online summary
PHPP / NEAP model results	<ul style="list-style-type: none"> • Online summary of model outputs
Energy and environment systems	<ul style="list-style-type: none"> • Online summary with downloadable schematic drawings, sizing details
Publications	<ul style="list-style-type: none"> • All publications relating to the testbed research made available • Dedicated section summarising the outcomes from long and short term monitoring campaigns with links to relevant data in the data portal
Performance data	<ul style="list-style-type: none"> • Details relating to the design and construction is presented
Timeline of construction	

The information portal contains two different sections; a summary information section and a detailed download section. Within the detailed section students can decide on whether they want to look at; building information, energy systems information, or internal environmental information. In summary, the NBERT information portal allows users to:

- Obtain high resolution data covering all aspects of a low energy building necessary to undertake a number of energy analysis modules and assessments as well as the development of bespoke energy models.
- Learn about the measured performance of a low energy building, its energy systems and the indoor environmental quality. Utilisation of the data in laboratory environments will also support interactive learning regarding the factors affecting energy and environmental performance of the building.

3.4 Data Portal

NBERT has capabilities in monitoring and gathering internal and external parameters from three physical systems; a Building Management System (BMS) a more detailed Internal Environmental Monitoring System and an on-site Weather Station. The data portal contains four years of data from 2013-2016 and there are three main data types: Weather data, internal environmental data and energy data. The NBERT data portal allows users to:

- Select user defined NBERT measurement data in graphical and tabular forms
- Download measurement data in various formats and resolutions
- Upload and compare energy model data to NBERT measurement data online

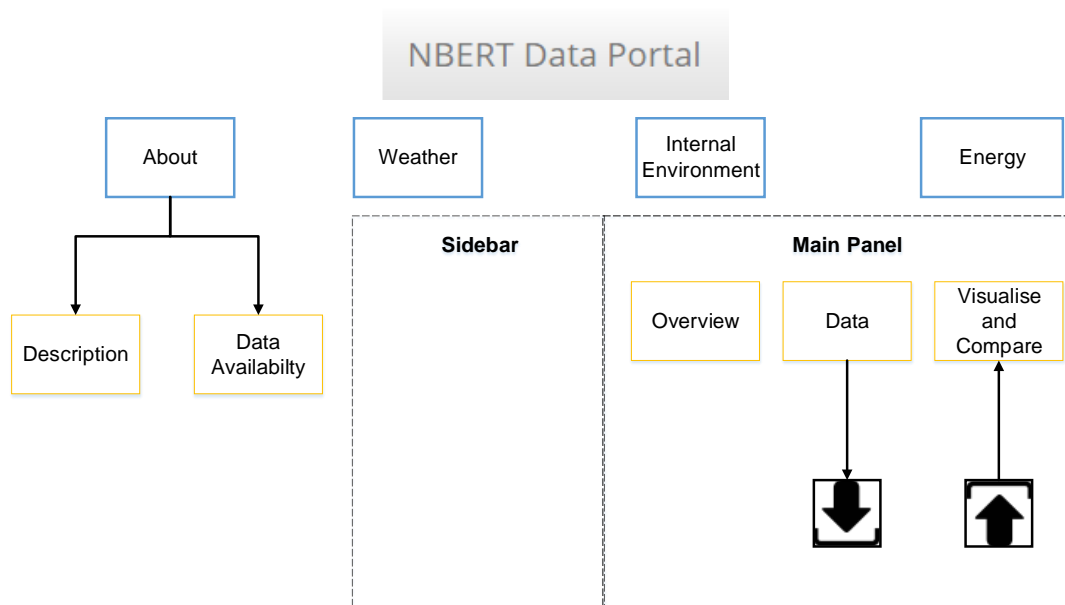


Figure 4: Structure of NBERT data portal

Before entering the data portal a set of “Terms and Conditions” must be accepted. Once this step is completed users have four main options as is shown in Figure 4. The “About” gives users some background about the data, and it is here that students can check to see if a dataset is complete for a year in a particular time interval, by using the data availability table. The three remaining tabs as part of the “navbar” layout are designed to have a sidebar and a main panel. The sidebar allows users to select the sensors they want to look at and select the time they want to analyse. All changes made in the sidebar are reflected dynamically in any of the main panel options. The “Overview” tab panel gives users an idea of the location, and specification of selected instruments or sensors. The “Data” tab panel allows users to see data in tabulated form and download that data in various formats. The “Visualise and Compare” tab panel uses plotly graphics (<https://plot.ly/>) to visualise all selected sensors in time series format. Another part of this tab allows users to upload the results from their models to compare with the NBERT datasets. A statistical summary of each dataset (user defined and NBERT dataset is also indicated). It is expected that students will use this

functionality to report their results from energy models developed within energy analysis modules.

3.5 VC potential tool

Interactive engineering design and analysis applications also form part of the new online platform. While these are intended to perform a more standalone function than the information and data portal they still form part of the overall portal and will be integrated learning delivery tools for energy modelling and energy analysis modules. The first of these applications that is now available is the Ventilative Cooling Potential Analysis (VCPA) Tool. The VCPA tool was also developed in RShiny. It will be used as a core learning tool for an energy analysis module titled Building Thermal Dynamic Analysis (BTDA) as well as a non-core component of the built environment module titled Building Energy Compliance (BEC). The VCPA tool will be used in class to explore the potential that exists in a local climate to provide low energy passive cooling of a buildings' interior. There exists a potential for direct ventilation from the ambient to cool a building when needed. The extent of this potential is a function of the buildings ability to remove excess heat build-up, the relationship between the ambient temperature and the indoor temperature, the airflow capacity of the ventilation solution and, finally, the required internal conditions for satisfactory thermal environment. The theoretical underpinning of this analysis is not covered here but is openly available [11].

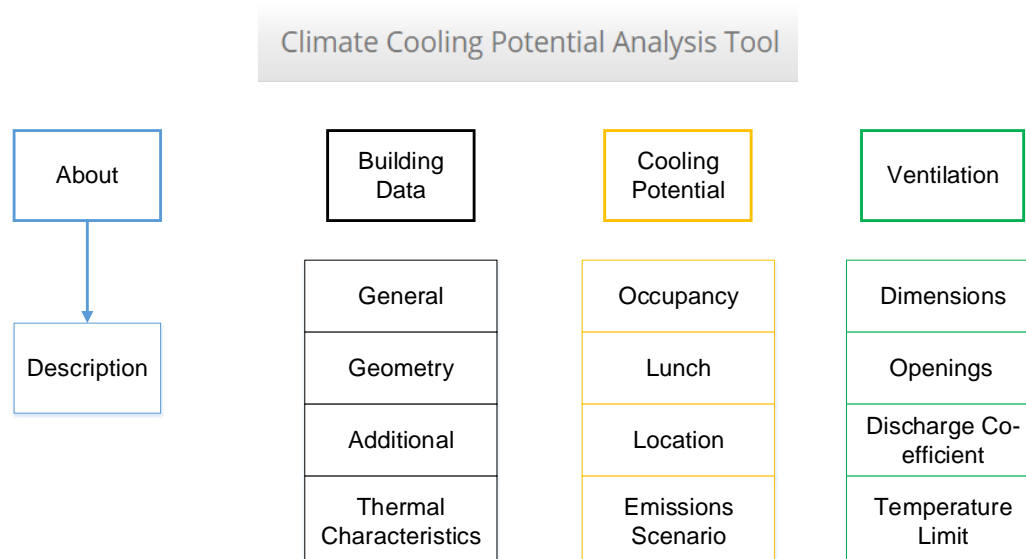


Figure 5: Structure of interactive VCPA tool

The VCPA tool is made up of a number of separate sections that the engineering student can work through and use in their analysis (see Figure 5). The first section in the VCPA tool is the “Building Data” section. Here, the student/user inputs all the required information necessary to estimate the number of useful cooling hours from direct ventilation designs that a particular climate and building configuration will have. This is where a lot of the learning process happens for the student. Knowledge must be developed around each input parameter and why it has an influence on the potential for the climate to provide cooling to the building. This parameter set is used as a training palette through the BTDA module. The student uses the information portal

discussed in section 3.3 to obtain all information necessary to complete a climate cooling potential analysis for the NBERT building as an example in class. The second section is the “Cooling Potential” section. Here, students can select different occupancy rates, climate locations and emissions scenarios. Once the building and climate details have been uploaded and the cooling potential analysis has been completed the student can investigate how different types of ventilation strategies and ventilation openings perform when compared with the required ventilation rates for a building in the “Ventilation” section of the VCPA Tool. Often when energy analysis and design assessments are carried out it is difficult and time consuming for a student to undertake a sensitivity analysis of various model inputs and design characteristics that might influence overall performance. The strengths of the VCPA Tool are that it allows students/users to investigate the effects of a plethora of building parameters, climates, and opening types, both dynamically and quickly. This gives the student the opportunity to consider a ventilation design problem and design a solution, while not getting consumed by first principles.

5 CURRENT INSIGHTS AND FUTURE WORK

While the introduction of the new cross module online data platform is still in its infancy there are already a number of key insights that are worthy of mention. These are summarised below along with key developments that are already identified for future revisions of the learning platform.

4.1 Initial Insights

- RStudio and RShiny are very well adapted to the development of online engineering education apps. Simple design and analysis tools could be developed quite easily directly by undergraduate students or more in-depth version by postgraduates and lecturers. The RStudio suite is also fully open source making it license free and fully accessible.
- It is possible to develop a full online information rich suite without specific expertise in computing science. No HTML or JavaScript was required to develop all aspects of the NBERT portal.
- It is possible to provide a fully open source information set for use by any university in the world. The NBERT portal will be available to any lecturer or educator interested in built environment topics and the development of energy, thermal comfort or internal environment models as well as specific applications like the VCPA tool.

4.2 Future Work

The platform is now in its beta testing phase and it will be formally launched in September 2018. Following initial testing a number of future work items have been identified. These include:

- Development of an online sensitivity analysis function within the VCPA tool
- Development of an online cooling performance challenge for students with student comparisons of proposals. (September 2018)
- Part L building regulations benchmarking of NBERT and uploaded data within the data portal
- Heating degree days tool within data portal

- New interactive apps for building energy modelling, HVAC systems analysis and cleanroom ventilation systems design.

6 CONCLUSIONS

This paper presents the concept, design and development of an open source web-based learning and information resource. The work presented highlights the need to create more streamlined cross module data and information management solutions, to improve module delivery in modules related to the built environment disciplines. The education resource created attempts to allow students to select manageable subsets of large datasets and emulates real world scenarios where engineers have to navigate online systems to extract only necessary information. The portal is available to any university course in the world that delivers programs in the built environment and wants to undertake an energy analysis of building energy performance. Publishing data online as open source increases opportunities for collaboration in research and increases the connectivity of the research community.

7 ACKNOWLEDGEMENTS

The project which led to the creation of the learning resource tool was funded by Ireland's national energy authority the Sustainable Energy Authority of Ireland under Research, Development & Demonstration Fund grant RDD00116.

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Evaluation Method of Student Achievement Levels

Project-Based ICT Education through Citizen Support System Development

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Conference Key Areas: University-business cooperation, Engineering skills, Fostering entrepreneurship

Keywords: University-business cooperation, Software engineering, Evaluation method

INTRODUCTION

One of the difficulties in ICT education through regular lessons is that educators must teach all system development techniques within a limited timeframe, despite the fact that students cannot learn without actually experiencing these techniques. To solve this problem, we conducted an industry-university collaboration project to develop a citizen support system as an extracurricular activity. The project was supported as a Ministry of Internal Affairs and Communications IoT Service Creation Support Project [1]. The purposes of the IoT Service Creation Support Project is to identify specific problems to overcome when creating and deploying IoT services through demonstration projects, build a reference model to solve these issues, and promote data utilisation. Students developed a citizen support system through University-Business cooperation [2]. Through this activity, students learned about entrepreneurship.

To confirm students' growth, we investigated a method to evaluate student achievement in software development education through collaboration between industry and the community. This paper describes the evaluation method. The proposed evaluation method ensures that students understand the contents of the curriculum by expressing these contents and evaluating the skills they acquired at certain activity milestones. In addition, the teacher evaluated students using the same indicator and encouraged them to acquire missing abilities. We think this method confirms students' growth by determining whether individual evaluation results for each grade are effective.

1 FEATURES OF THE BUS STOP PROJECT

1.1 What is the bus stop project

At Kanazawa Institute of Technology (KIT), students are educated through curricular and extracurricular education. The Project Design Program (PD) is the backbone of curricular education, and carried out as a regular class for all students. It has made great progress [3-4]. Project-Based Learning (PBL) is employed in PD courses.

Extracurricular activities also play an important role at KIT. They include the YUMEKOBO Projects (YUMEKOBO is a Japanese term that refers to the Factory for Dreams and Ideas), department/lab-related programs, collaboration programs with industry and the community, and internship programs. In these activities, students set their own objectives and learn from their successes and failures. For example, the YUMEKOBO Projects are self-directed to develop students' technical competence [5]. There were 16 YUMEKOBO Projects in 2016 [6]. The education project described in this paper was implemented as an extracurricular activity.

The purpose of the bus stop project is to increase software development abilities and cultivate students' problem-solving skills by developing an ICT system for citizen support. The system developed is designed to contribute to the revitalisation of the city and improve civic life. With the cooperation of Nonoichi-City, this project included many activities. Furthermore, local companies cooperated in developing the system. We targeted Nonoichi City, where the university is located, and tackled the issue of improving civic life, because students who are citizens consider it meaningful to solve their own civic problems and enrich the lives of others.

Our project was adopted by the Ministry of Internal Affairs' 'IoT Service Creation Support Project', and a demonstration experiment of a smart bus stop was performed in Nonoichi City. To ensure the success of the project, we developed a system in collaboration with parties who were able to meet a few times. Students must have the ability to develop programs without bugs according to a schedule set in collaboration with a company. Students were required to acquire new skills. *Fig. 1* provides an overview of the developed system.

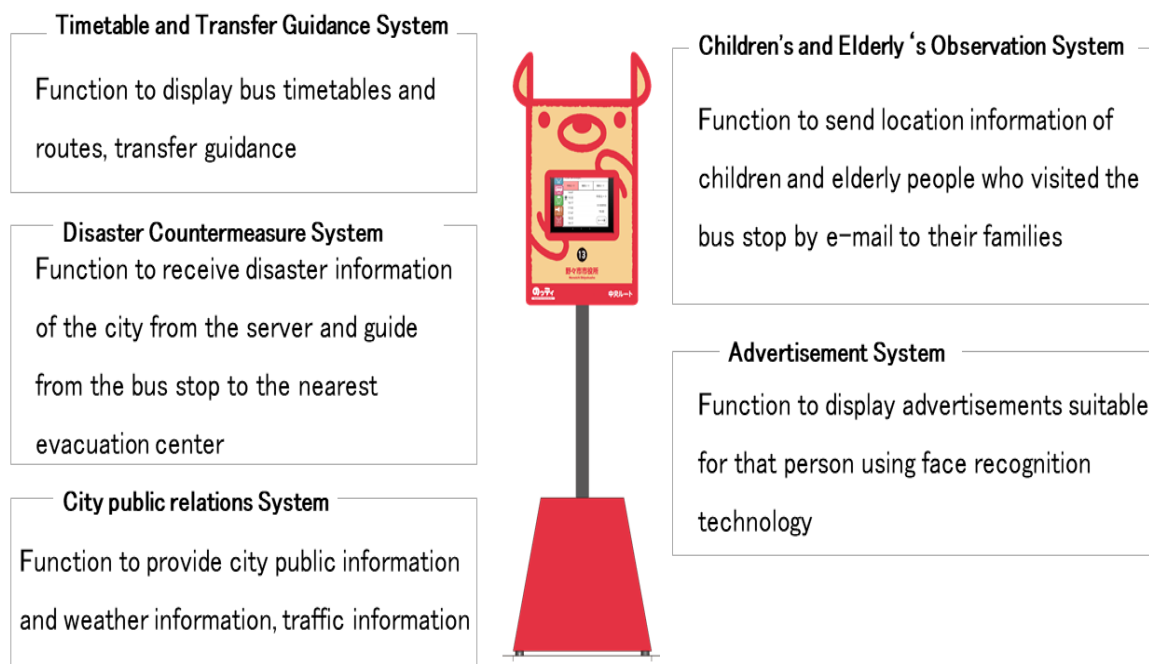


Fig. 1. Citizen support system for Nonoichi City

1.2 Flow of the project activity

We believed that by designing and implementing the project with an entrepreneurial spirit, rather than as set out previously, we would acquire more useful skills for society. Therefore, our curriculum combines entrepreneurship education such as the construction of a business model and CDIO education, based on the abilities to 'conceive, design, implement, and operate' (*Fig. 2*) [7, 8, 9]. The flow of system development education for the bus stop project is as follows. We constructed the flow based on the system development flow of this enterprise [10].

- 1) Planning: 'Assembling the concept'
- 2) Planning: 'Building a business model'
- 3) Proposal: 'Create a business plan'
- 4) System design and construction
- 5) Introduction/deployment
- 6) Operation and maintenance

This provided a mechanism by which to learn the abovementioned process over the course of a few years. Students cannot learn the entire flow in four years, and depending on the year of admission, cannot learn it in order starting from Phase 1. The size of the project group is about five people in a general enterprise, and the project is carried out over a period of six months to a year. As the students change each year, it is structured to take place over six years, and learning occurs through the activities carried out for three or four hours once a week. We are currently in Phases 3 and 4, and considering the process of commercialisation.

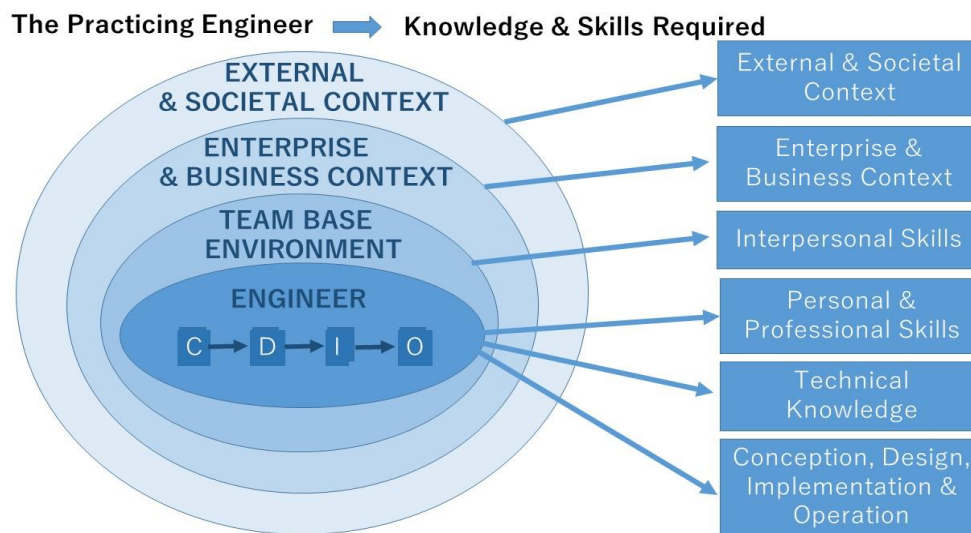


Fig. 2. Requirements of CDIO [9]

For software development, various indirect management tasks are required to create the work directly related to developing software such as request analysis, design, implementation, and testing, as well as other planned work. As the scale increases, so does the importance and weight of such management work. In software engineering, a project is defined as periodic work carried out to create unique products, services, and products [11]. The goal is to reach the deadline within the cost and resource constraints set for the project. We believe that developing the ability to develop software with limited time, costs, and resources is an important factor in education in the field; thus, we carried out activities involved in the project in this phase.

The major difference from regular lesson classes is that we develop the practice of keeping pace with the citizens and city officials who are customers and with cooperating companies. We must manage the requirements, cost, and time constraints of customers at the company level. To ensure the success of the project, we must plan and implement it appropriately. For example, one must plan what to do day by day to achieve the final goal. To do so within the prescribed time and cost, one must plan and implement according to how much time and cost each factor requires. We must avoid time and cost overruns and ensure the project achieves its goal. In addition, as students execute the project, teachers must consider student human factors and develop members' abilities accordingly.

2 EVALUATING THE ACHIEVEMENT OF PARTICIPATING STUDENTS

2.1 Achievement evaluation items

Society is constantly changing, noticeably so in the information processing field. We believe that the ability to respond flexibly to this change, the creation of new value, and ability to lead society in a better direction are important. We believe we should actively tackle social issues and focus on developing human resources able to improve society. Based on this philosophy, we are developing regional innovation systems through community collaboration as extracurricular activities.

We posited the following three requirements for becoming a global leader, and the aim is that students acquire these abilities.

A) Recognition/comprehension to cope with social change

B) Power to change one's own interests and abilities into actual behaviour

C) Spirit and power to fully utilise one's own resources and solve social problems

Another project purpose was to develop software development capability through developing an ICT system for citizen support. By providing education on the system design method while creating the system, we aimed to improve students' skills as information processing engineers.

The skills necessary for ICT and IoT engineers have been defined [12, 13]. In this project, because it focuses on educating undergraduate students, we assessed the degree of accomplishment by evaluating the basic knowledge and management abilities needed for system design. To nurture global leaders, a sub-work leader was assigned to fourth year undergraduate students, who had to compete a paper in English. Evaluation was based on whether the sub-work was successfully completed and the paper submitted and successfully presented.

2.2 Achievement evaluation method

Evaluation by students is subjective. Evaluation by a teacher should be according to an absolute index, but this is difficult, because different work is performed every year. Therefore, we evaluated whether each work activity was completed or not. For example, for programming language skills, we evaluated whether the section allocated was completed. The difficulty of the program differs depending on the section allocated; however, the program difficulty was not evaluated. In addition, in some cases, it was completed with the help of other members, and even if not completed through one person's abilities, we evaluated the success thereof. We thought it was important to understand the flow as the first step. Likewise, to evaluate management ability, the teacher instructed students to engage in management activities. However, in many cases, management was not well done. In these cases, the teacher provided detailed instructions or took over the managing activities. In this case, we also evaluated that student managed. In this way, we made an evaluation on the undergraduate students, focusing on understanding and experiencing the flow.

Evaluation by the teacher is told to the student verbally. At the same time, the list of work to be done next and the reason are reported. The teacher chooses and recommends the work that is best for the growth of the students from the next work to do. At the same time, we need to allocate personnel who do not inconvenience to companies that are cooperating. Because the project is not a class, students do not have to accept teachers' recommendations. Students will consider the advice of the teacher and decide what to do next for themselves. We believe that deciding by themselves increases their abilities. For that reason, we prioritize student selection and decide personnel assignment. Thus, there are many situations where teachers themselves have to work on their own. We believe that we must accept it.

3 EVALUATION RESULTS OF THE DEGREE OF ACHIEVEMENT

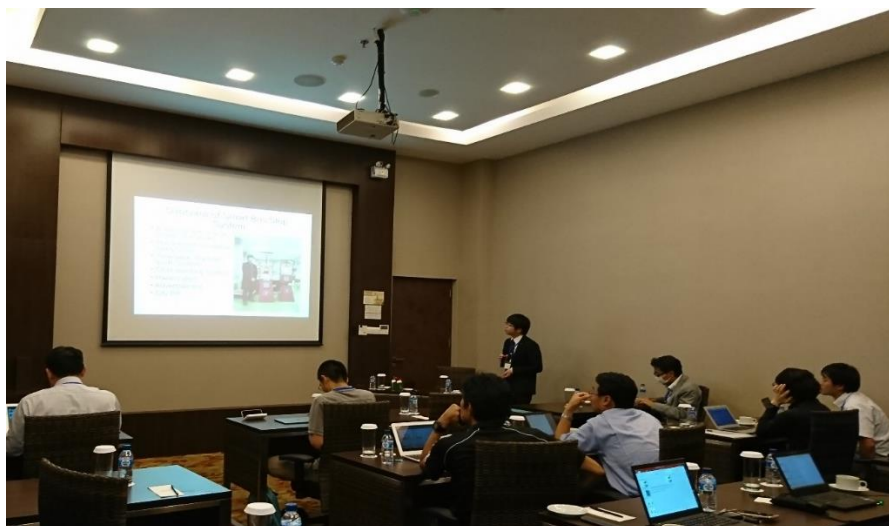
Some evaluation results are shown in *Table 1* and *Table 2*. We conducted a questionnaire survey on participating students as a self-assessment. The questionnaire determined the extent to which students' ability for system design developed through participating in the project. Questionnaires were received for 4 first-grade students, 13 second-grade students, 8 third-grade students, and 3 fourth-grade students. *Table 1* and *Table 2* show some of the items evaluated. *Table 1* provides the evaluation items for the basic knowledge necessary for system design, and *Table 2* those for the required management abilities. Both teachers and students conducted the evaluation.

Table 1. Basic knowledge necessary for system design

	First Grade	Second Grade	Third Grade	Fourth Grade	Teacher
Programming language skills	4	10	8	3	5
Hardware, software basic knowledge	4	8	5	2	20
Testing, debugging skills	0	3	3	3	3
Database technology skills	0	2	0	1	5
Security skills	0	3	1	1	2
System design skills	0	6	1	2	10
System requirements definition skill	0	1	2	1	10
Network, communication technology skills	0	4	3	1	15
Technical analysis, analysis skills	0	1	2	2	10
System maintenance operation skills	0	0	2	1	3

Table 2. Management ability necessary for system design

	Student	Teacher
Progress management ability for the entire project	11	11
Accurate instructions to program personnel	9	11
Distribution of work, personnel adjustment	11	11
Collateral of system quality	3	5
Ability to write documents such as design documents	10	11

*Fig. 3.* Presentation at an international conference [14]

We discuss the results of the evaluation in 2017 of the bus stop project. We conducted a questionnaire survey on participants' ability to acquire the required skills for system design through participating in the project. In response to the question on whether programming ability improved, 89% of students responded that it had. Furthermore, 38% said that their management abilities for the project improved. Regarding client's requests, 50% of the students heard these requests, and indicated that the ability to build a better trust relationship improved. In addition, 68% responded that their ability to work smoothly with project members improved. We received positive feedback from

students that they were able to learn practical contents and were good at participating in the project. Based on the results of the questionnaire survey, we confirmed the effectiveness of our education system. In addition, students were able to summarise and present the results as papers [14, 15]. We believe these skills are important in becoming a global leader. A presentation is shown in *Fig. 3*.

4 CONCLUSION

It is difficult to evaluate the outcomes of extracurricular activities, because there is no fixed curriculum. However, to encourage students' growth, we must see students' growth and encourage the next step in this development process. To confirm students' growth, we investigated a method to evaluate student achievement in software development education through collaboration between industry and the community. We also evaluated this. This paper described the evaluation method and results thereof. The evaluation method of the proposal ensures that students understand the contents of the curriculum by expressing these contents, and self-evaluating the skills they acquired at certain activity milestones. In addition, the teacher evaluates students with the same indicator and encourages them to acquire missing abilities. The proposed method is an effective method for student growth in that students understand the goals of the curriculum, make goals, implement and evaluate themselves. Also, we think that evaluation from the teacher and advice of goal setting is effective and helps the growth of the student. Therefore, the proposed evaluation method is considered to be effective.

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Development of Engineering Education Through Better Understanding of the Students' Values

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Conference Key Areas: Engineering Skills, Curriculum Development, Recruitment & Retention of students

Keywords: values, motivation, committing, differences between disciplines

INTRODUCTION

Values guide our actions. Therefore it is critical to understand the values of engineering students if we wish to understand their behavior, choices and actions. Understanding the values of students has a huge potential in developing higher education in many aspects: developing the content of the engineering studies, guiding

the selection of field of science matching personal needs, motivating and committing to studies, and many more possible applications.

Academic Engineers and Architects in Finland (TEK) has conducted research on the values of Finnish academic engineering students in 2017. The research is based on Shalom Schwartz's Theory of Basic Human Values which is a highly validated theory for intercultural research. The research was conducted as a part of TEK's annual Student Survey with approximately 2300 respondents.

The results of the research are categorized by field of study which provides interesting insights on the differences in values between different engineering studies. The results of the overall academic engineering students are also compared to the general Finnish values researched on a national scale. Compared to average Finnish values the engineering students value work morale related values very highly and value traditions much less than the average Finnish person. Notable differences can also be found when comparing different fields of science in academic engineering studies. For example all fields of science value either Benevolence, Universalism or Work highest except for architects whom value Self-Direction highest. The results provide a foundation to which conclusions and development suggestions for developing engineering education can be based on.

1 SCHWARTZ'S THEORY OF BASIC HUMAN VALUES

Values are important to understand because they strongly guide our actions. The methodology of the research is based on Shalom Schwartz's theory of basic human values. The theory is a well-validated tool for measuring values and comparing the values of different cultures internationally. The theory is used for example in the European Social Survey to compare the values of European citizens in different countries. [1] [2]

The 11 value types in this research are the following. The first 10 values are a part of the Schwartz value theorem and the last one, work, is a value defined by Finnish professor emeritus Klaus Helkama. The Schwartz value theorem only accounts for value types that are accountable in every major culture whereas the Work value has not been validated in intercultural research. However work as a value has been studied in Finnish context so it is justified to include it in this country-specific comparison of values. [1] [2] [3]

- **Benevolence.** Defining goal: preserving and enhancing the welfare of those with whom one is in frequent personal contact (the 'in-group').
- **Universalism.** Defining goal: understanding, appreciation, tolerance, and protection for the welfare of *all* people and for nature.
- **Achievement.** Defining goal: personal success through demonstrating competence according to social standards.
- **Self-Direction.** Defining goal: independent thought and action--choosing, creating, exploring.
- **Stimulation.** Defining goal: excitement, novelty, and challenge in life.

- **Hedonism.** Defining goal: pleasure or sensuous gratification for oneself.
- **Power.** Defining goal: social status and prestige, control or dominance over people and resources.
- **Security.** Defining goal: safety, harmony, and stability of society, of relationships, and of self.
- **Conformity.** Defining goal: restraint of actions, inclinations, and impulses likely to upset or harm others and violate social expectations or norms.
- **Tradition.** Defining goal: respect, commitment, and acceptance of the customs and ideas that one's culture or religion provides.
- **Work** (*not used in the Schwartz value theorem*). Defining goal: diligence, rigour, systematic, perseverance and thrift.

The above-mentioned 11 values project a two-dimensional coordinate system (Fig. 1) in which one axis represents the Conservation – Openness to Change dimension and the other axis represents the Self-Transcendence – Self-Enhancement dimension. [5]

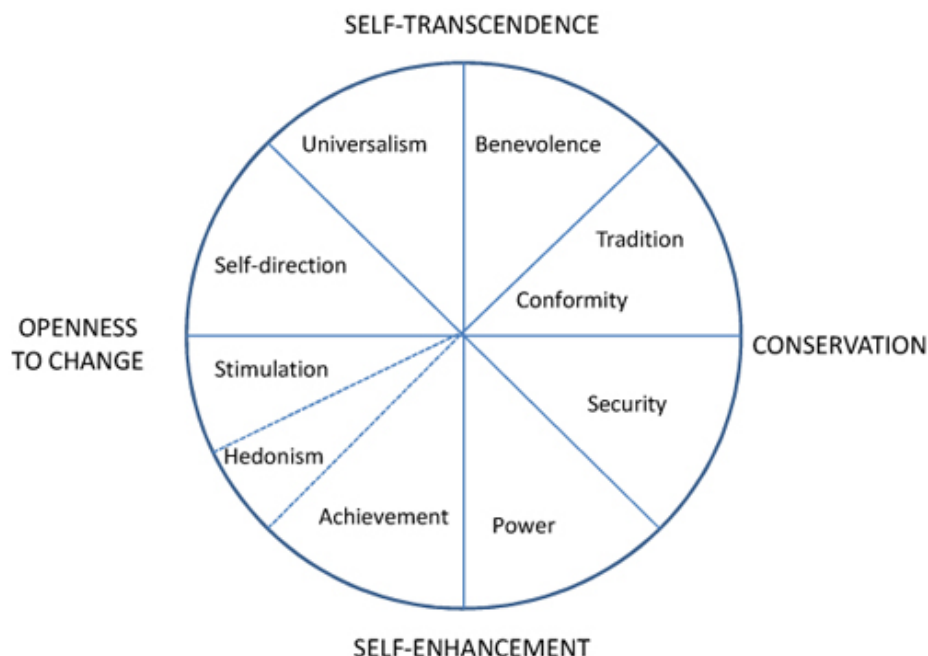


Fig. 1. The structure of the different value types not including the Finnish context value of Work. [5]

The values located close to each other in Fig. 1 are highly compatible with each other and vice versa. The Work value is missing from the value circle as it only includes the interculturably comparable values. [1] [2]

The values are measured by one or more questions on how the respondent relates to the value in question. For example the European Social Survey (ESS) uses a 21-question survey for the 10 interculturably comparable values whereas the Schwartz Value Survey (SVS) developed by Schwartz has a total of 57 questions. The respondents in the ESS weight how much the described person in each claim is or is not like the respondent. The evaluation is done in different scales in different surveys,

for example the SVS uses a scale of -1 to 7 and the ESS uses a scale of 1 to 7. The values are usually presented as a prioritized list. [1] [2] [3]

2 RESEARCH

The research was conducted by Academic Engineers and Architects in Finland TEK as a part of an annual Student Survey. The Annual survey studies the employment situation of students and in 2017 it had an altering other theme which focused on values. The survey was sent to 15 000 of TEK's about 20 000 student members. The response rate of the survey was 17 % with a total of 2526 respondents. [6]

For the values research TEK used a 21-question survey also used in the European Social Survey to monitor the 10 value types in the Schwartz value theory. In addition the survey also included two more questions relating to work as a value for which the questions have been developed by professor emeritus Klaus Helkama from the University of Helsinki. [4] [7]

The values of Finnish population has also been widely studied and the value profile of average Finnish respondents will be used as a comparison to point out how the students of engineering and technology differ from an average Finn. [4]

3 RESULTS

There are many ways in which we could present and examine the data, for example by age, by gender etc. We concluded to present the differences between different fields of sciences to highlight how similar most students of engineering and technology are based on their values. There are however also major differences which are also very interesting. The student population in the fields of engineering and technology will also be compared to an average Finnish value profile to point out the main differences that the students in technology have in the context of Finnish population.

The value research is usually presented as a prioritized list as it is also done in this paper. The comparison between Finnish population and academic engineering student population value profiles is presented in Table 1. The table also includes comparison of value priorities between different fields of science.

Table 1. The priority of values comparison between average Finnish people and Finnish M.Sc.(Tech) students.

	Benevolence	Universalism	Work	Self- Direction	Hedonism	Security	Achievement	Conformity	Stimulation	Tradition	Power
FINNISH M.SC(TECH) STUDENTS AVERAGE N=2076	1	2	3	4	5	6	7	8	9	10	11
FINNISH POPULATION AVERAGE N=1652	2	1	7	4	7	3	10	5	9	6	11
MECHANICAL & ENERGY ENGINEERING N=358	2	3	1	4	5	6	8	7	9	10	11
ELECTRICAL & AUTOMATION ENGINEERING N=485	1	3	2	4	5	6	8	7	9	10	11
INFORMATION & TELECOMMUNICATIONS TECHNOLOGY N=270	1	2	3	4	5	6	8	7	10	9	11
PROCESS & MATERIALS ENGINEERING N=363	1	2	3	5	4	6	7	8	9	10	11
BUILDING CONSTRUCTION & SURVEYING TECHNOLOGY N=119	1	3	2	6	4	5	7	8	9	10	11
INDUSTRIAL MANAGEMENT N=222	1	2	3	5	4	8	6	9	7	11	10
ARCHITECTURE N=59	3	2	4	1	5	6	7	9	8	11	10

A couple of things should be noted when comparing the values of an average Finn to an average academic engineering student. First of all, the Self-Transcendence and Conservation type of values generally tend to be emphasized more as people get older. As the student population is very young of age compared to the average Finnish person, it is very natural for the Openness to Change types of values to stand out. The highest priority of the Self-Transcendence values Benevolence, Universalism and Work is however not what is expected of such young respondents. These values translate to the students being very hard-working, unselfish people who want good things for all people, nature and environment more than for themselves. [8]

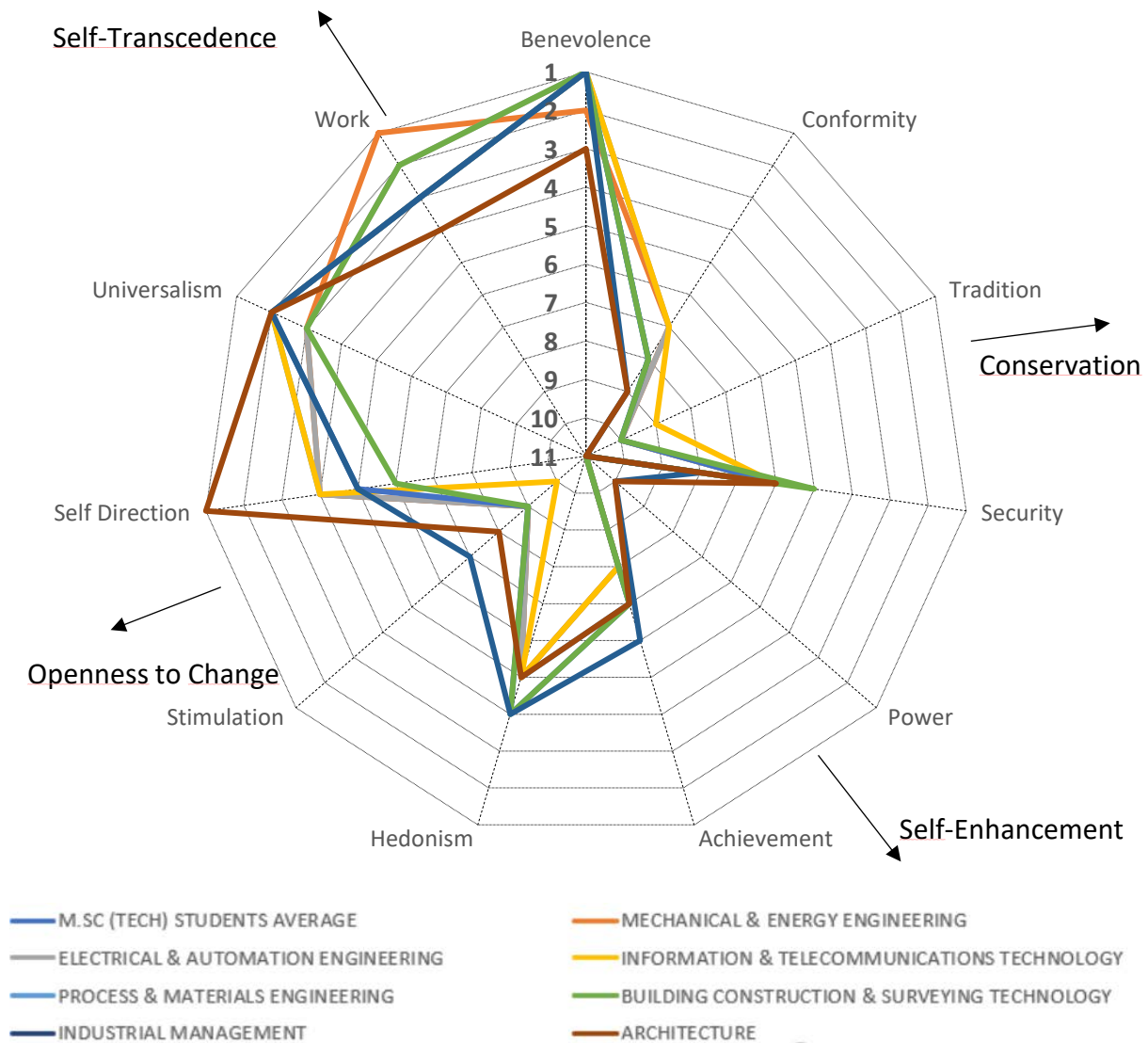


Fig. 2. The priority of values comparison between different fields of science in academic engineering studies

The values of the Finnish M.Sc.(Tech) students is quite similar between different fields of science. The biggest difference is seen on Architecture students whom value Self-Direction over all else whereas most of the students valued Benevolence the highest.

4 CONCLUSIONS

Since values dictate our actions, the research has huge potential in many aspects, including developing engineering education. We will point out a few applications but the list is in no way complete.

4.1 Student marketing

Understanding what kind of value profiles the potential applicants have has a huge potential in proper marketing for the target group. Since the benevolence and universalism are the top two values of engineering students, engineering education should be especially promoted on how it can help both humankind and save nature which are aspects included in the two values.

4.2 Developing engineering education

The value profiles of the engineering students give great insight on how the contents of the engineering studies could be further developed to match the interests and sources of motivation of the students. Students are often demanding more concrete examples on how the heavily theoretical studies are actually related to solutions in our everyday life. As the students value benevolence and universalism over other values, the study contents should be made concrete by how the studies relate to creating a better world.

The universalism aspect also includes a value "respect for nature" which implies that also the environmental aspects should be highlighted for students to be more motivated to the subject. After all, all of the engineering studies are strongly related to solutions that can contribute to the well-being of people, nature and general happiness of mankind. To name a few examples on how technology plays a key role in preserving nature and improves the well-being of humans: a stable and secure power supply enables hospitals to save more lives, the use of renewable energy sources reduce pollution and climate change, and autonomous vehicles can reduce the energy consumption in logistics sector. None of these solutions are possible without engineering expertise, but these kind of viewpoints in the importance of technology for general well-being is often neglected in engineering education.

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Innovation and Practice in Constructing World Class Engineering

Education: A Case Study of Tsinghua University

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China is promoting the Double World-Class Construction Project, which aims to constructing world-class universities and world-class disciplines. As the largest discipline area in China's higher education, engineering education is key to the development of higher education and plays a vital role in the process of Double World-Class Construction. Tsinghua University is one of the top universities in China and having great advantages in engineering disciplines. It has been ranked the best university for Engineering by U.S. News & World Report. The strategy innovation and practice for engineering education plays a leading and exemplary role for the universities and colleges in China. The paper will analyze the strategical background for engineering education in China and introduce Tsinghua's strategic thinking and innovative practice in constructing world-class engineering disciplines.

Key word: Double World-Class Construction, Tsinghua University, Engineering Education

In recent years, the Double World-Class Construction Project has become a hot topic in China's higher education community. The project aims to construct a number of world class universities and disciplines with Chinese characteristics. This has become the common consensus and action orientation of the key universities, including Tsinghua University. The research and strategic planning on the core issues of teaching, research, international cooperation and resource allocation, are the internal need to enhance the core competitiveness and achieve sustainable development of universities and disciplines, and also the inevitable choice to achieve the goals of "double world-class" construction and promote the comprehensive strength and international competitiveness of higher education in China.

Engineering is the largest discipline area in China's higher education. According to the statistics of the Ministry of Education, the number of engineering undergraduate and graduate students in 2015 accounted for 33% and 36% of the total number of higher education students respectively. ^[1] Engineering education plays a key role in enhancing the strength of higher education. In most influential global rankings, the highest ranking subjects in China's universities are engineering ones. For example, in 2015 and 2016, the engineering discipline of Tsinghua University was ranked first in the world. ^[2] It

can be said that engineering education in some universities has already become the world's leading disciplines. It is the leader of "double world class" construction.

As the leader of the key universities in China, Tsinghua University made the strategic goal of becoming a world class university in the 1980s. Under the sustained support of China's key national strategical projects such as "211 Project" and "985 Project", Tsinghua has gradually established and continuously promoted its global reputation and influence. As the dominant disciplines of Tsinghua, engineering education has won a high academic reputation and will continue to support the development of the university. The paper will analyze the strategical background for engineering education in China and introduce Tsinghua's strategic thinking and innovative practice in constructing world-class engineering disciplines.

I、 The Strategic Significance of Building the World-class Engineering Education

1. Building World-class Engineering Education is an Inevitable Requirement to Enhance China's Global Competitiveness.

According to the World Competitiveness Reports released by the World Economic Forum from 2010 to 2016, China's global competitiveness ranked 26th – 29th^[3] or top 20% among the 144 economies in the world. These ranking results indicated China had certain comparative advantage and had great development potential and prospects. However, according to the evaluation indicator system of world competitiveness, China has few indicators with absolute competitive advantage. These indicators were mainly the scale or volume ones, like the scale of domestic market. China has more indicators with relative or zero competitive advantage, especially "China's technical preparation, innovation and higher education and training were drags on China's competitiveness".^[4] To further enhance China's overall competitiveness, it is necessary to make these indicators become the ones with absolute competitive advantage.

According to the definition of the global competitiveness, "technical preparation" mainly measures the application of new technologies by an economy and the convenience it brought to the economy, including the application and transfer of new technologies, the number of Internet users, and the legal protection of technologies. "Higher education and training" measures the training and supply of talents by colleges and universities, including the scale of colleges and universities, education quality, the training and supply of professional talents, and so on. "Innovation" mainly measures the innovation and R&D ability of an economy, including the quality of scientific research institutions, cooperation between universities and enterprises, the number of scientists and engineers and so on. It can be seen that the development level of engineering education is closely related to the training of engineers and scientists, technical research and development, cooperation between universities and enterprises, and the transfer of scientific and technological achievements. The construction of

world-class engineering education helps to cultivate engineers and technicians with international vision and innovation ability, and improve the global competitiveness.

2. Building World-class Engineering Education is the Basic Prerequisite for a Strong Manufacturing Nation.

The blueprint of Made in China 2025 pointed out that "manufacturing is an important symbol of a country's comprehensive economic strength, the pillar industry of the national economy system, and the leading force of modernization and industrialization." Only with strong manufacturing can we have strong country and nation. However, in the new round of industry revolution, China's manufacturing is "big but not strong", mainly in the aspects of backward technology, serious overcapacity, low profit and low added value. Through the strategic deployment of Made in China 2025, China takes the initiative to cope with the challenges and strengthen the manufacturing industry so as to achieve the upgrading of manufacturing industry.

Engineering Education in China has been providing strong human resources and intellectual support for the national development and construction. Made in China 2025 proposed the basic principle of "talent based". Manufacturing power is bound to powerful talents. Engineering and technological talents are the fundamental prerequisite for building a strong manufacturing nation. China should vigorously carry forward the craftsman spirit to strengthen the training and lifelong education of engineering talents, build a rational and quality manufacturing talent team and improve the social status of engineering talents, so as to promote the realization of the strategic goal of the manufacturing power.

3. Building World-class Engineering Education will Support the One Belt and One Road with Science and Technology Talents

The One Belt and One Road Initiative, which was proposed in 2013, has received wide attention and response of the world. As the initiative continued to develop, engineering and technical talents with a global vision became a bottleneck for Chinese enterprises going abroad. The countries along the Road, especially the developing countries in Asia and Africa, were eager to have depth cooperation with Chinese universities and enterprises to promote the abilities of science and technology talents. The demand, for talents is more urgent. Higher engineering education would play a key role cultivate science and technology talents for both Chinese enterprises and developing countries.

4. Building World-class Engineering Education would help to create a new ecology of Internet + Education.

Internet+ is the usage of Internet as a platform, including the use of mobile Internet, cloud computing, big data, artificial intelligence and information communication technology, to realize the deep integration of various industries and form a new economic and social development pattern based on Internet, so as to comprehensively promote the innovation ability and productivity of the country.

Internet + engineering education will shape a new and equal engineering education mode to change the cognitive style and learning habits of engineering students and thoroughly reform the lifelong learning of engineers. Compared with the traditional education of engineers, the knowledge service which combines the Internet and information technology can break the limitation of time and space and reduce the cost. On the basis of Internet and cloud platform technology, Internet + engineering education can integrate high quality engineering education resources and provide convenient and efficient information tools to effectively meet the need of engineering education.

II、 Practice of Building World-class Engineering Education in Tsinghua University

1. Cultivating the World - class Engineering Talents

The most fundamental task of world-class engineering education is to cultivate top innovative engineering talents. On the road of building a world class university, Tsinghua University is committed to cultivating the leading and innovative talents for all sectors of the society. Over the years, Tsinghua has always integrated teaching, learning and doing in practice education and focused on the students' ability of innovation and practice. In particular, Tsinghua launched "Xuetang program" in 2009. The program selected outstanding undergraduate students from the fields of mathematics, physics, computer science and mechanics, and built a high-end, open and international learning and communication platform for them. The program comprehensively integrated the advantages of all disciplines of Tsinghua and effectively led the overall quality of the engineering education. The computer science program has been praised by international peers as the best undergraduate education. And the graduates of the electronic engineering were globally accepted as best candidates for graduate programs in top universities around the world.

2. Propose Leading Concept of Engineering Education

In the past 107 years, the engineering educationists of Tsinghua have developed a unique concept of engineering education based on China's national conditions and advanced international educational concepts.

After 1952, Tsinghua gradually evolved into a comprehensive university with advantages in engineering disciplines. Jiang Nanxiang, president of the time, summarized the mission of Tsinghua as “the cradle of engineers”. He advocated “real gun” for graduation design, which required students participate in real world engineering projects. In the early period of new China, this philosophy fit the urgent needs of the nation and Tsinghua cultivated a large number of engineering talents for the country.

In twenty-first Century, with the change of industrial structure and the progress of engineering technology, social development has put forward new requirements for engineering and technical talents. Every country in the world were aware of the change, and began to redesign the engineering education programs. The American National Academy of Engineering published Engineer 2020 and envision the future and predict the roles that engineers will play in the future.

Tsinghua has also acutely grasped this historical trend. Engineering education was strengthened with the general education on the basis of inheriting historical ideas. At the end of last century, Tsinghua proposed the idea of fostering talents with “deep foundation, wide caliber, compound type and high level”. In 2014, Tsinghua began to implement “Three-in-One” education model, which included values molding, ability training and knowledge imparting. The goals of engineering education were expanded to training students to have sound personality, broad foundation, innovative thinking, global vision and social responsibility. In 2017, Tsinghua University began to integrate undergraduate enrollment into 16 major categories. Engineering education involved 8 major categories. On the one hand, the reform gave full play to the disciplinary advantage of Tsinghua as a comprehensive to train all-round talents through general education. On the other hand, the integration of disciplines has broken the pattern of specialized division and expanded the employment orientation of graduates. For example, mechanical category included mechanical engineering, measurement and control technology and instruments, vehicle engineering, energy and power engineering and so on. The core courses would be refined and optimized according to the knowledge structure, ability and quality needs of high quality professionals.

3. Establishing World-level Quality Assurance System for Engineering Education

The quality of education is key to the construction of great power engineering education. Tsinghua based on its own development goals, put forward high quality standards and actively accept more stringent assessment and evaluation to ensure that the level of engineering education can be recognized internationally and the engineering education could reach the level of the world-class universities.

Since 2009, Tsinghua has initiated the international assessment of disciplines, to examined and promoted the construction of disciplines through the efforts of international peers. Up to now, 16 international assessments have been completed, 11

of which were engineering disciplines. The international evaluation made benchmark with the development status and trend of the world-class universities. Through the diagnostic evaluation, the development level of the disciplines was tested, the weakness of the disciplines was found. Experts from the world-class universities evaluated the teaching, scientific research, faculty team of the disciplines, and provided pertinent opinions and suggestions. The university and department adjusted policies and support to the disciplines. Through the preparation of self-evaluation reports, disciplines carried out a comprehensive and in-depth review of the status, and constantly found problems and sought solutions. Some disciplines have already carried out two and three rounds of international assessment. And there have been obvious changes and progress.

4. Building World - class Platform for Global Cooperation

Global cooperation is an important feature of world-class engineering education. It is an active choice for universities and engineering departments to integrate high quality education resources and improve international competitiveness. It is of great significance to promote the understanding of different engineering culture, strengthening academic exchange of engineering education, and cultivating engineering talents who can participate in international competition. Tsinghua University was born with distinct feature of globalization. It was a pre-school for students who would go study in America. Many famous faculty of early stage Tsinghua, such as Qian Sanqiang, Zhang Guangdou, Ye Qisun, Zhang Wei, were the outstanding ones from the pre-school.

With the deepening of national reform and opening up and the continuous change of international situation, the global cooperation of Tsinghua has gradually moved from passive to initiative, from going out to mutually communication, from actively participation to initiatively leading. The cooperated countries not only involved the developed countries, but also expanded to developing countries, in order to promote equality, peace and tolerance around the world. The international cooperation projects not only involved students exchange and faculty visit, but also expanded to scientific research and social services. Tsinghua is dealing with the major engineering and technology problems and environmental development in the world with all the world-class universities, enterprises, research institutions and international organizations.

In June 2016, the International Center for Engineering Education (ICEE), officially approved by the 38th General Assembly of UNESCO Member States, launched at Tsinghua. The center was the first UNESCO center focusing on engineering education. It is jointly sponsored by the Chinese Academy of Engineering and Tsinghua University. It will support the UNESCO action plans to carry out multilateral cooperation. For the ICEE will provide engineering personnel training for countries along the One Belt and One Road, especially African countries, to eradicate poverty, promote gender equality and coordinate regional development.

5. Carry on World-class Engineering Education Research

From a worldwide perspective, engineering universities and colleges bear many responsibilities and obligations in the process of development. According to the requirements and characteristics of engineering disciplines, faculties should explore the problems in the process of cultivating engineering talents. Teaching and academic research are always the professional requirements of faculty, and also the spiritual tradition of higher education. Under the background of knowledge economy, scientific research and academic activities related to engineering education are directly linked to the quality and competitive of engineering disciplines. High quality engineering education research is an effective way to improve the competitive of engineering disciplines. Tsinghua has always taken engineering education research as one essential responsibility. It serves the teaching and practice of the engineering education, serves the national engineering education policy decisions, and pays attention to the global engineering education issues. On the process of building a world-class university, the engineering education researches in Tsinghua put more emphasis on serving the strategic needs of the country and promoting global development and social progress.

The engineering education researches in Tsinghua has always been committed to serving the reform of the university, and the reform of the national engineering education. The research areas involved the quality assessment of higher engineering education, report on engineer abilities, and the construction of global engineering capability system, etc. The researches has both thoughts and suggestions on the macro problems related to engineering education system and structure, organization and management, and also the micro questions on curriculum and student development.

Big data era has brought opportunities and challenges for engineering, science and technology. Big data has become a new and important strategic resource. Engineering education research needs more and more support of big data. Big data analysis is changing the thinking mode and research methods of engineering education research. ICEE, with the support of CAE, created a sub center of engineering education knowledge, which is one of the sub centers of UNESCO's international Knowledge Center for Engineering, Science and Technology (IKCEST). The building of IKCEST system platform, will support the UNESCO action plans, and effectively integrate the global engineering education information resources to facilitate the exchange and cooperation of international engineering education.

6. Outputting World - class Online Resources

In the era of digitalized knowledge economy, knowledge is increasingly showing the form of networking and digitalization. Online education has been widely recognized by the society. It has greatly changed the learning methods of engineering students and the on-the-job training methods of practice engineers. It has a profound influence on the traditional concept of higher education, the educational system and the teaching mode.

Engineering disciplines have to take the initiative to adapt to new methods and new technology of information society. High quality online education resources, commercial operation mode, good interactive platform, free global learning, will be an important basis for assessing world-class engineering education. Tsinghua has always been the leader of distance education and online education in China. In 2013, Tsinghua officially joined the online education platform edX and become one of the first Asian universities in edX.

Massive Open Online Course (MOOC) provides an open, flexible and shared mode of communication and learning. MOOC not only provides curriculum resources to the learners, but also the application of learning analysis technology. It is a mix of face-to-face teaching, online learning and mixed learning model, and can reshape the role of teachers to meet the needs of learners' autonomy learning and lifelong learning. In 2014, Tsinghua launched the world's first Chinese MOOC platform, Xuetang Online. At present, Xuetang Online has run number of high quality courses from Tsinghua University, Peking University, Stanford University, Massachusetts Institute of Technology, University of California at Berkeley and so on. The courses covered many fields such as engineering, computer, art and so on. About 7,000,000 users from 180 countries are using the platform for online learning. The daily average access of the online platform is 640,000 and the peak value is 400,000. While actively launching high quality MOOC courses, Tsinghua has initiated and actively organized the MOOC industry standard. The world-class online education can only be realized under the support of the government, the leadership of universities and the participation of enterprises, which will create an open and win-win situation.

In short, building a world-class engineering education is the current and long-term strategy of our country. Adhering to the concept of inheritance, excellence and innovation, engineering education should cultivate world-class engineering talents, carry out first-rate engineering education research, contributing high level engineering education resources, and making world-wide contribution to realize the China's responsibility in the world.

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Video Presentation as a Report in Elementary Physics Laboratory

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Conference Key Areas: Engineering Skills, Innovative Teaching and Learning Methods, Teaching Creativity & Innovation

Keywords: video reporting, engineering physics, laboratory work

INTRODUCTION

Traditional engineering curriculum includes introductory physics laboratory work. It can be implemented either on its own course or integrated to physics theory courses. Students widely agree that the skills learned in introductory physics laboratory are important but achieving those skills usually need more work compared to theory courses. Skills that are connected to introductory physics laboratory are designing and implementing an experiment, making measurements suitable for the task, processing the data, assessing the uncertainty of the results and reporting the task and the results in technically and scientifically proper way. Since 2010, Tampere University of Applied Sciences physics introductory laboratory course has included a laboratory work that students design, plan and implement by themselves at the end of the course. The concept of the own laboratory work has developed

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during the years. During first years, it was reported as traditional written report to the teacher. The idea that students would learn a lot if they were introduced to other students' work, led to reporting these works as posters in a common poster session within the student group. The poster session also included peer assessment of the other students' work. The latest step of development process is to change the reporting of the own laboratory work as a short video. Video gives more possibilities to reporting and they can be peer assessed asynchronously while poster session demands that all students have to be present at the same time. In video reporting, students also learn modern communication and reporting skills.

1 CHALLENGES IN INTRODUCTORY PHYSICS LABORATORY

Typical preferred learning outcomes of the introductory physics laboratories base on designing and implementing laboratory tasks and reporting them in technically and scientifically proper way. The laboratory work can also be used to support and deepen the understanding gathered in physics theory courses. According to Holmes and Wieman undergraduate laboratories that are designed to support theory courses, do not necessary improve grades. Instead, laboratory courses that focus on improve students' experimental and intellectual abilities, can succeed, and offer great opportunities to learn experimentation, reasoning and critical thinking skills. [1]. An example of laboratories with such design are ISLE laboratories [2]. Such learning outcomes are important engineering skills. There are still a number of challenges in the laboratories that rise not only from students or laboratory practices but outside. Laboratory teaching is more expensive than traditional theoretical teaching mainly because facilities are more expensive and the guidance in laboratory needs more teaching resources per student. This may lead to the process that due to financial reasons, the laboratory type of learning is reduced in engineering curricula.

Students' experiences on elementary laboratory courses vary depending the goals and implementation. Experiences of the laboratory have been reported to be negative or dull mainly because tasks, working and the solution methodology have been pre-stated [3]. On the opposite, a survey from Australia shows that physics laboratory work provides students with many important skills that they think they do need in the future. Students saw laboratory work useful, understandable, interesting and enjoyable [4].

Considering the learning outcomes of an introductory physics laboratory course, typical difficulties lie in the core of understanding measurement and interpreting data gathered. Students' view on a measurement may see the measured values as "point-like" or exact, without any uncertainty [5]. The concepts of error analysis are very difficult for students. Applying statistical methods to a set of data may be difficult for university students even after the laboratory course [6]. It seems natural in the context of average person's view on measuring data. The errors or uncertainties are not often seen in everyday life.

One of the key skills connected to laboratory teaching is reporting. Traditionally students write a complete lab report on every measurement task they complete. According to student feedback, the reporting is typically seen as the hardest part of laboratory course. This is obvious, because the most difficult parts like data processing, error estimations and interpreting the results in professional way, need a lot of time and effort. Some practices have been introduced to reduce the students' workload in reporting. In "sElf approach", students focus on different parts of report on different laboratory tasks. Finally, at the end of the

laboratory course a “mother of all reports” is finished on the last laboratory measurement task [7].

2 IMPLEMENTATION OF PHYSICS LABORATORIES AT TAMPERE UAS

2.1 Overall picture on physics laboratory courses

In Tampere UAS, engineering curriculum contains two courses that include physics laboratory practices. The First course “Basics of measuring and reporting” 3 cr, introduces students all basic skills they need to succeed in elementary laboratory. The skills include making good measurements and completing the measurement logbook, the necessary mathematics to complete data analysis and error estimations and the necessary reporting skills to complete a proper report. The course is taught together with physics, mathematics and communications teacher. The design and implementation of the course are described in [8]. In the course students work on pairs and complete three different measurement and reporting tasks which focus on different type of measurement tasks, necessary mathematics and fluency and formalities of traditional written reporting.

After completing the first course, students can enter to the second course “Laboratory works of physics” , 3 cr, which contains four pre-stated laboratory tasks and the last task in which students design, implement and report the laboratory work themselves. In pre-stated tasks, students make measurements in pairs but the reporting is individual, two reports per student. The self-designed laboratory work is planned, implemented and reported in pairs. In the course, students are expected to be familiar with basics of measuring, data-analysis and reporting.

2.2 Self-designed laboratory work, idea and reporting

Since 2010, the physics laboratories have included a final laboratory work that students design, implement and report in pairs. The main goal in of this change was to give students a real opportunity to design laboratory activity in the beginning of their studios, not only just follow laboratory work instructions that someone else has designed. Teachers have only a guiding and consulting role. The students themselves do all major decisions like choosing the subject, planning the measurements, designing the equipment, and reporting. During first years, reporting was made in traditional way. Students wrote a formal written report to teacher.

The idea of different form of reporting rose from the need that the designed laboratory works were so rich with ideas and perspectives, that students could learn a lot from others if they were aware from other students’ work. Therefore, since 2013 the reporting was implemented with posters. The course has ended to the poster session in which students present their work to the others. The poster session format solved the problem with sharing the ideas and learning from others but brought some other negative aspects. The quality of data-analysis dropped, even though students were reminded that all the calculations and other formalities must be made although they are not explicitly written out. The quality of posters and presentations varied also a lot. The poster was not concerned as serious form of reporting as normal formal written report. The poster sessions took also a lot of time in which all students and teacher had to be present. The sessions were also very tight in schedule and did not leave enough time to needed discussions.

To tackle the challenge of quality and hurry in presenting and reporting, a new method was piloted in spring semester 2018. The idea was to report self-designed laboratory work as video presentation. Videos can be watched asynchronously so students can watch and comment others work online beforehand. Teacher can also watch the videos beforehand and the session time can be used effectively just peer- and teacher feedback and assessment. The pros and cons on different reporting methods are presented in *Table 1*.

Table 1. Pros and cons of different reporting methods

Method	Traditional written report	Poster	Video
Pros	<ul style="list-style-type: none"> • Formal • Respected • Familiar 	<ul style="list-style-type: none"> • Presented to peers • Peer assessed 	<ul style="list-style-type: none"> • Easy to share • Asynchronous presentation • Modern way of communication
Cons	<ul style="list-style-type: none"> • No peer assessment 	<ul style="list-style-type: none"> • Difficult to design • Synchronous presentation 	<ul style="list-style-type: none"> • May focus on non-important issues

3 EXPERIENCES AND RESULTS OF PILOTING VIDEO REPORTING

3.1 Background

The student group chosen to pilot the video reporting included 32 second-year bachelor-level students studying ICT engineering. The idea of video reporting was presented to the student group in the beginning of the elementary physics laboratory course. The first four pre-stated laboratory tasks were reported in traditional way and the video reporting was applied only on the last, self-designed laboratory work. Student experience was gathered with survey at the end of the course.

3.2 Implementation

Self-designed laboratory work begun with a planning session in which student pairs were asked to plan their work carefully beforehand. At the end of the session students had a written plan that included following.

- Target of the work
- Time and place of implementation
- List of quantities to be measured and a methods to measure them
- Chart or schema of the measurement
- List of equipment needed
- How the results are presented
- How the error estimations are made?
- Legal statement that reminds that student group must obey national law and is responsible for measurements

After planning there were two laboratory sessions, 3 hours each, to make the necessary measurements. Students can also borrow some measurement equipment outside the laboratory in case of field measurement. The report itself was specified to cover all similar contents that formal written report, but in a form of spoken, presented video. The visual part of video was asked to contain pictures, graphs, charts and other visual elements that support reporting. The video length was asked to be between 5 to 10 minutes.

Students were introduced briefly how to make a video from PowerPoint presentation and using screen capture software. A common YouTube channel was created for video sharing and streaming. The idea of making a video report was positively adopted by the student group. The videos were allowed to be published in any video service and the links to the videos were asked to be sent as discussion openings in course's Moodle discussion forum. Peer assessments were answers to the discussion openings. In this form of returning every video and every peer assessment is public within the student group. Peer assessments were asked to be published within two days after publications of videos. Teacher decided which videos were assessed by each student group and every video got at least two peer assessments. In the final lecture of the course the student group was divided for 2 subgroups and the videos were watched and discussed and teacher's assessments were published.

3.3 Overall results

Overall, students managed well. The laboratory works were designed according the criteria specified in chapter 3.2. Measurements were made autonomously and students finished their video reports. In reporting, technique and the use of necessary software was not a problem for any pair of students. All videos and peer assessments were published on time. The method itself had no such flaws that would prevent its use in the future.

3.4 Student experience

Student experience was gathered with a survey at the end of the course. 16 of 32 possible students answered to the survey. Results from the survey show that technically producing and publishing a video was not difficult for students. This can be seen from answer distributions presented in fig. 1 and 2.

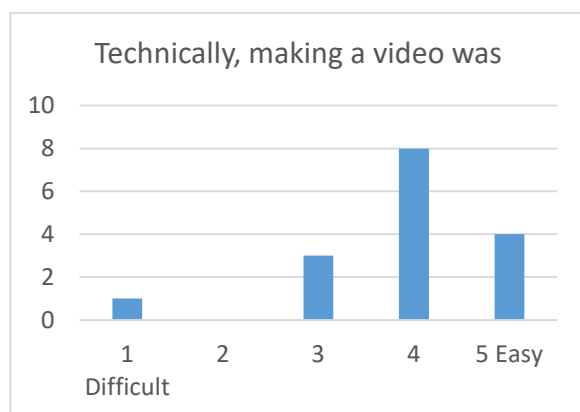


Fig. 1. Producing a video

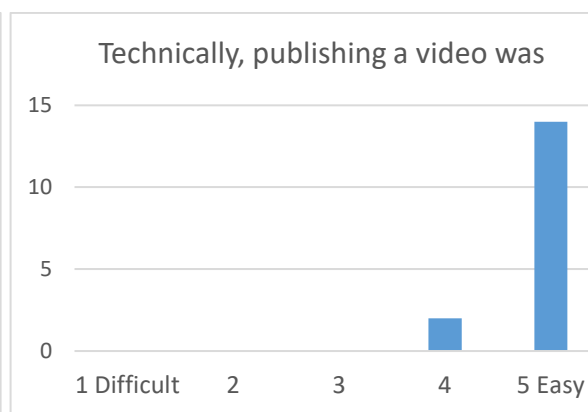


Fig. 2. Publishing the video

Instead, planning and making the contents of the video (core of reporting) was seen a little bit more difficult, but not overwhelming by the students, this can be seen from the answer distribution in fig. 3.

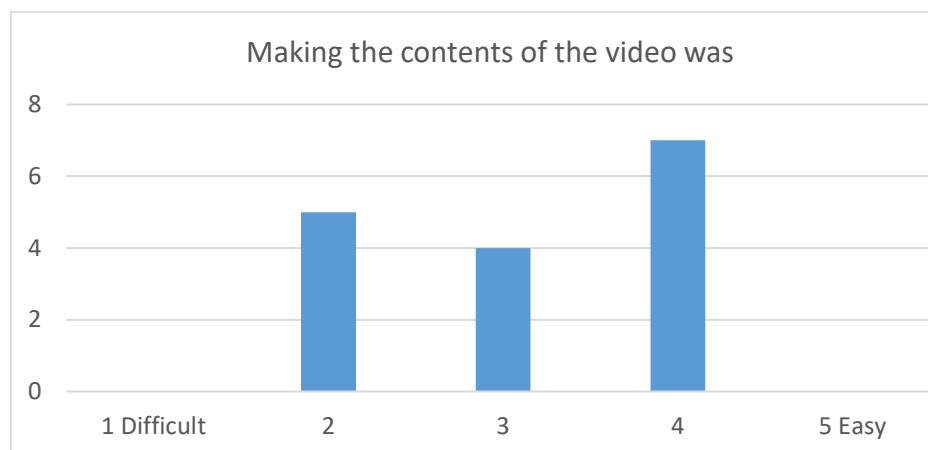


Fig. 3. Making the contents of the video

Students were also asked about their experiences in different phases of making a self-designed laboratory work. Choosing the subject was reported as the most difficult phase, followed by setting up the questions, what to research. Planning and implementing the measurements and processing the data were reported as the easiest parts of the work, but none of these was reported to be very easy. Reporting was experienced to be somewhere between difficult and easy.

Students were also asked if they could recommend (yes or no) this kind of reporting method in a similar situations or so called normal laboratory tasks where tasks are pre-stated. Distributions of student answers are presented in the following figures fig 4 – 5.

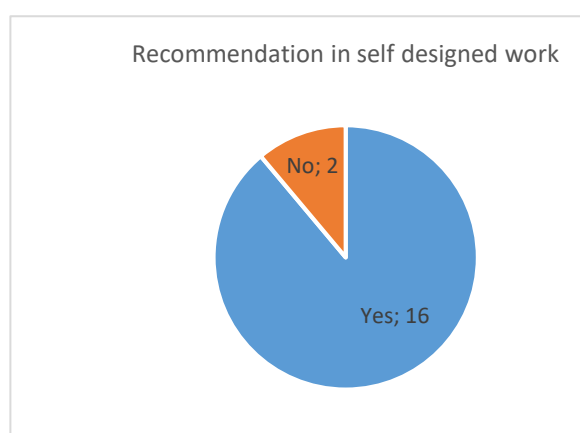


Fig. 4. Recommendation, self-designed

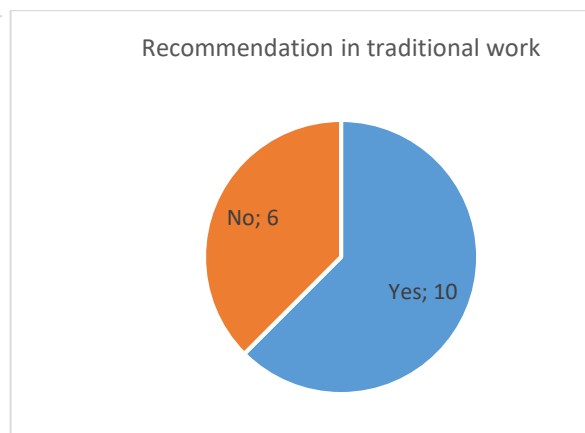


Fig. 5. Recommendation, traditional

From figures 4 and 5 it can be stated that overall, students liked the piloted method of reporting especially in the self-designed laboratory work.

Students were also asked what they would do differently now if they were facing the similar task of designing and reporting an experimental task. The most mentioned issues were

- More careful planning of the work
- Thinking carefully the subject of lab work
- Planning of the measurements

3.5 Teacher experiences

Teacher experience was monitored by discussions with the teacher of the course before, during and after the course. Teacher experience can be summarized as follows.

- In the beginning, insecure feeling about technical readiness of the student group.
- After the instruction session for technical aspects, feeling disappeared.
- The proper content must be highlighted *over the technical aspects*
 - The substance quality of reporting was still not good enough
 - Error estimations missed on many reports
- Technical quality was good
- This method will be used in the future, but special care and effort will be put in contents of reporting

4 CONCLUSIONS

Overall, the piloting of the video-reporting in self-designed laboratory work can be called as a minor success. All students managed to finish their reports on time and system of peer assessment and sharing report videos among student group worked. In attitude level students liked the method of video reporting and recommended it strongly in a similar situations but not as strongly in tasks which are pre-stated.

New different method of reporting somehow took attention away from the core of reporting. There were still some lack of quality in contents of reports, even though report videos were asked to follow the formalities of a written report.

Considering students' answers of what they would do differently now clearly show that even the lack of straight success in the measurements and results lead to the professional growth concerning the whole laboratory work. Students were able to point the phase in which they need to do better in the future. In the case of the lack of success, the reason was found "in the mirror" on the most cases.

Overall, the combination of self-designed laboratory work and video reporting worked quite well on tackling the challenges in laboratory teaching. Task, methodology and reporting was open enough as laboratory work so overall students felt working interesting and enjoyable. The challenge in formalities, seeing the own laboratory work as real measurement task with error estimations and error calculations, still keeps untackled. It seems that it is very difficult for students to perform these measurement formalities unless they are asked to do so.

It is seen that the self-designed laboratory work supports the skills that are needed in engineering profession. Students also appreciate the trust that they are able to design at the early phase of their studies.

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Development of innovative suspensions for a radio-controlled light racing car

Collaborative project into 3DExperience platform

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Conference Key Areas: how learning spaces support innovative T&L, innovation as the context for EE, innovative teaching and learning methods

Keywords: collaborative engineering PBL, 3DExperience, industry 4.0, structural mechanics and design

INTRODUCTION

Engineering Schools currently face the challenge to train their students for the forthcoming Industry 4.0. There is no clear definition about Industry 4.0; however, it is clear that Industry 4.0 companies will be connected through data over the Internet.

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Engineering data in industry exhibits two features which are difficult to convey in engineering education: 1) the data generated by the different apps has intrinsic dependencies and 2) it is iterative. Thus, the geometry designed in CAD apps is analysed for performance with CAE apps and manufactured with CAM apps. Likewise, if the tasks performed with CAE and CAM apps assess CAD data as invalid, CAD data has to be reworked. Consequently, CAE and CAM tasks might have to be reworked. Therefore, keeping track of the data version over which engineers are working becomes critical in industry and it is addressed with PLM platforms. Furthermore, in engineering practice, globalization and customer-supplier relationships impose the collaborative generation of such data in geographically worldwide distributed teams. This need to collaborate adds extra features that are difficult to convey in engineering education such as geographic location difference, time-zone difference, calendar difference, timetable difference, language difference and cultural habit difference among team members' management.

Project Based Learning (PBL henceforth) activities have shown to be effective in teaching the interdependencies between the different engineering domains (design, analysis, manufacturing, etc.). The advantage with this innovative methodology of learning is that there is close relationship with real-life requirements and collaborative industry working methods. What is more, this connection between real-life problems, teaching and collaborative industry working methods makes students' motivation increase, which simultaneously makes knowledge exciting and learning enjoyable; the straightforward consequence is a deeper learning than with traditional approaches. Since 2011, all university programs at the Faculty of Engineering of Mondragon Unibertsitatea have formally assumed PBL as their cornerstone, both for teaching and learning [1,2]; in the same way, the Institute of Technology of University of Nantes is using industrial projects in learning and collaborative interdisciplinary PBL since 2007 for mechanical design and manufacturing collaborative learning for bachelor students.

However, data version management and the natural time limits of engineering curricula constrain the amount of iterations that can be performed in PBL activities. On the other hand, within a single university and a single course, it is difficult to reproduce the collaboration constrains globalization imposed on engineering practice such as geographic separation, time-zone, calendar, timetable, language and cultural habit difference management among team members.

3DExperience on Cloud is a novel and the first software platform on Cloud that integrates the multidisciplinary apps required by engineers:

- CAD: next version after CATIA V6
- CAM: next version of Delmia
- CAE: next versions of ABAQUS, XFlow, Dymola and iSight
- PLM: next version of Enovia

In addition, its social communities engage engineers with non-engineering disciplines and its Dashboards provide fast web access in order to fully review and perform minor edits on the heavy engineering data. In contrast to their desktop counterparts,

3DExperience apps are connected to the Internet and directly store the engineering data objects generated by its apps on the 3DExperience PLM server on Cloud. Thus, 3DExperience on Cloud is an enhanced PLM solution that can help engineering schools in teaching the iterative nature and dependencies among engineering data to students. Furthermore, as it is connected to the Cloud, it enables setting-up collaborative inter-university PBL activities to reproduce the collaborative industrial engineering practices imposed by globalization [3,4].

Therefore, Institute of Technology of University of Nantes and the Faculty of Engineering of Mondragon Unibertsitatea have set-up a PBL activity to research whether using 3DExperience on Cloud can be helpful in integrating these Industry 4.0 engineering practice features into the PBL learning experiences of their students. Both universities aim to improve the employability of their students by the forthcoming Industry 4.0 with the inclusion of such features in their learning experiences.

Moreover, as 3DExperience on Cloud is new and the first software platform of this kind, in contrast to what happens with the desktop counterparts of its individual domain apps, there are very few public resources to assist students in the learning process. Therefore, the main learning resource is its users' guide and the integrated Peer Learning Experience platform, where Dassault Systèmes and a worldwide community of university lecturers publish peer reviewed learning materials about all apps available in 3DExperience on Cloud. However, as there are so many courses within Peer Learning Experience, free course selection by students was identified as a risk for project deliverables and another research question arose. Is it possible to define an autonomous student learning path with Peer Learning Experiences courses?

1 METHODOLOGY

In order to test 3DExperience on Cloud's helpfulness to integrate the Industry 4.0 engineering practice features into a PBL learning experience, Mondragon Unibertsitatea and University of Nantes had to set-up a novel type of PBL. Thus, a decision to make their students collaborate in their regular PBL over 3DExperience on Cloud was made.

1.1 PBL Planning: Buri Racer

The PBL chosen had to be motivating in order to ensure that conclusions are only related to the helpfulness of 3DExperience on Cloud. No doubt, cars are very attractive products to design in the engineering field. Due to that, the chosen product to develop the project is an on-road 8th scale radio-controlled electric four-wheel drive racing "pancar", a new very fast and effective category of radio-controlled racing car, which was born last years with the arrival of the Buri Racer E1 developed by the teacher from Austria Thomas Burger-Ringer [5]. It is a "pancar" type of vehicle with no springs/dampers on its suspensions, only material deformation. This type of car is very light and the transmission is more effective, but the design of the flexible parts is critical for the handling; the car is shown in *Fig. 1* and *Fig. 2*.

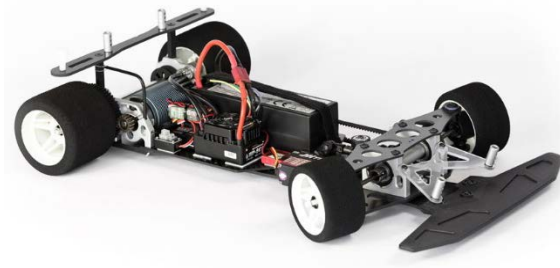


Fig. 1. Buri Racer car [5].

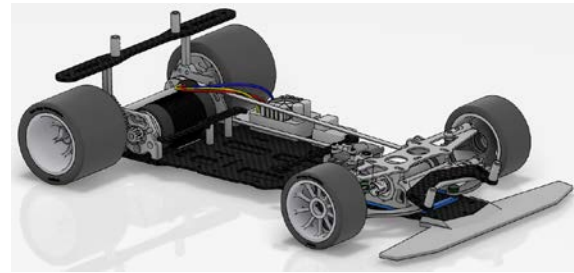


Fig. 2. Initial CAD of the car.

While Nantes team was working on the mechanical design of the rear and front suspensions of the car, Mondragon team was working on the finite element analysis of the car to optimise its design. The teams are shown in *Fig. 3* and *Fig. 4*.



Fig. 3. Nantes team.



Fig. 4. Mondragon team.

One of the technical challenges of the project was the development of flexible parts to work as a suspension system, since usually these kinds of radio-controlled “pancar” cars do not have suspensions at all or springs between chassis parts. Those flexible parts are shown in *Fig. 5* and *Fig. 6*.

1.2 PBL Planning: Tested industry 4.0 Engineering Practices

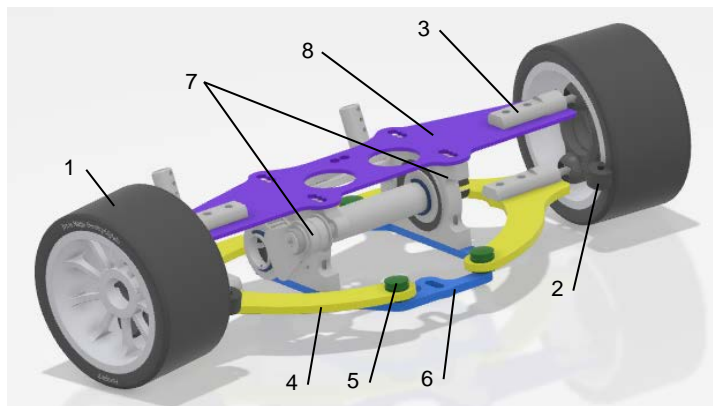
Under these conditions, students were involved in a scenario where the two most fundamental Industry 4.0 engineering practice features were present:

- **Geographical location difference:** Mondragon and Nantes are 650 km far from each other.
- **Data version management:** Nantes students create and iterate over design CAD data, and Mondragon students create performance analysis CAE data that depend on CAD data.

In addition, students would have to manage language difference, as the mother tongue of Nantes students is French, and Spanish and/or Basque for Mondragon students. However, in order to handle this difference collaboration happened in English.

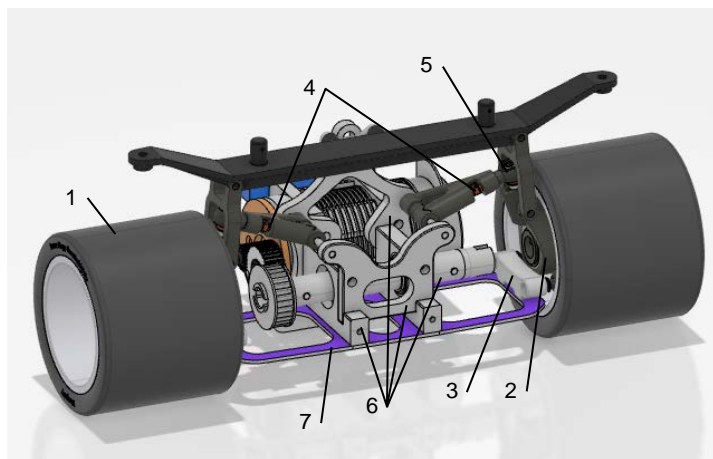
Due to the nature of collaborating universities and student groups other Industry 4.0 engineering practice features, namely, cultural habit difference and time-zone difference management skills were considered not to bias this work.

However, as teams had different calendars and timetables, students had to manage them in some extent. These may have generated some bias on the conclusions.



1. Wheels & rims
2. Knuckles
3. Vice
4. Trapezium
5. Ball-joints
6. Chassis
7. Chassis
8. Flexible part

Fig. 5. Front suspension, flexible part in purple.



1. Wheels & rims
2. Knuckles
3. Vice
4. Upper triangle
5. Ball-joints
6. Chassis
7. Flexible part

Fig. 6. Rear suspension, flexible part in purple.

Project kick-off meeting was on November 10. Before that time, Nantes and Mondragon lecturers had been working on project details and specifications while Nantes students had been working on an initial design of the whole car, as shown in *Fig. 1* and *Fig. 2*. Project finished on February 20.

1.3 PBL Planning: 3DExperience on Cloud Learning Path

Learning path for Nantes and Mondragon students was different because they were going to perform different activities and they had different background knowledge about similar desktop applications.

Nantes students already had previous knowledge about CAD in desktop applications such as SolidWorks and CATIA V5. Therefore, they mainly had to adapt to 3DExperience as a platform and map their previous knowledge to 3DExperience design apps.

Mondragon students had previous knowledge about CAD in SolidWorks, but in-depth desktop CAE application learning had to happen at the same time as learning the 3DExperience on Cloud CAE app.

Thus, in order to support students in their 3DExperience on Cloud learning curve, the following Peer Learning Experience learning path with an estimated duration of 53 hours was designed by lecturers to get the basic 3DExperience and CAD/CAE skills:

1. Gateway to 3DEXPERIENCE
2. CATIA Part Design Fundamentals
3. CATIA Assembly Design Fundamentals
4. SIMULIA Structural Model Creation Essentials
5. SIMULIA Structural Scenario Creation Essentials
6. SIMULIA Composites Simulation Engineer Essentials
7. SIMULIA Structural Model Creation : Geometry and Meshing

1.4 PBL Planning: Relevant 3DExperience Features

3DExperience on Cloud integrates many regular CAD/CAE tools with a PLM and additional features. However, only those relevant features that are different to their counterpart desktop apps are briefly described next.

In particular, in order to handle data version management, the underlying PLM platform (former Enovia, now Collaborative Lifecycle) was the database where all engineering data was stored every time. This helped students keep track of the latest version. In addition, as now CAD and CAE tools are integrated, the CAD data used by Mondragon students to start with CAE analysis tasks was an Abstraction of the original CAD data generated by Nantes students. Abstractions are an important collaborative workflow feature, because they create linked copies of the bodies in an assembly. This enable CAE analysts to decide when they want to get the latest CAD data in their CAE environment by unlinking or relinking the copied bodies.

Additionally to the PLM features, another remarkable feature is 3DMessaging. Initially it looks like a simple text chat feature between users logged-in to 3DExperience on Cloud who decide to be available for communication through 3DMessaging. However, it also has videoconferencing capabilities. Furthermore, through its Co-Review button, it enables a live design review feature that synchronizes the 3D views of the CAD data of the users taking part in the meeting, along with making 2D text and curve annotations over the 3D data and storing such views as snapshots. Finally, it also has a Design Share feature, which enables members of the meeting to submit live design feature changes, committed on Nantes to Mondragon and vice versa, without saving the data.

2 PBL EXECUTION: THE EXPERIENCE

Collaboration in CAD and simulation could be either simultaneous or sequential. First, Nantes team made an initial design and wrote the requirements for the simulation objectives. The 3DExperience software could be used for requirements management

in the RFLP applications (Requirements, Function, Logical and Physical Design) to relate directly the 3D model and the requirement.

To create the initial model, Nantes students worked in a simultaneous collaboration (everyone on the same 3D assembly at the same time), as shown in *Fig. 7*.



Fig. 7. Simultaneous collaborative work on 3D model (Nantes).

Mondragon students, connected to the same database, could then open the models and realize their first simulations to assure that the requirements were well understood.

Distant collaboration was then sequentially achieved, with review meetings of two types: classical videoconference and direct review application in 3DExperience, as shown in *Fig. 8*. The last one is again possible because students access the same database and therefore no files exchanges or distant screen sharing is needed.



Fig. 8. Videoconference meeting and direct review application in 3DExperience.

The workflow introduced in 3DExperience for the numerical simulation is a great enhancement in the industrial framework. A new concept of “representation” of the 3D parts insures the traceability and the updating of the numerical simulations when a part is modified; with this new method, a design team and a simulation team can work at the same time on the same parts.

Planning of tasks was done in the platform too; this enabled students to share all the information at the same place: the 3DExperience dashboard of the project.

At the end, Mondragon team proposed material selections and design concepts to the mechanical designers, which resulted in the manufacturing of the prototype by Nantes team. Final prototype is shown in *Fig. 9*.

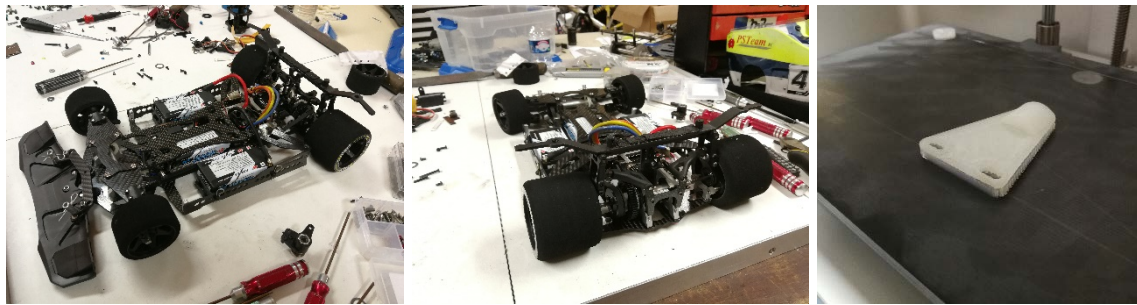


Fig. 9. Carbon fiber prototype with special orientations and a 3D-printed suspension part with nylon honeycomb and fiberglass-fibers (Markforged printer).

3 RESULTS

Once the PBL was over, three surveys were passed on both universities (at each university on their mother tongue):

1. A survey to assess the helpfulness of 3DExperience on Cloud to obtain Industry 4.0 industrial engineering practices was given to students.
2. A survey to assess the usefulness of the proposed Peer Learning Experience learning path was passed to students.
3. A survey to assess the helpfulness of 3DExperience on Cloud to obtain Industry 4.0 industrial engineering practices was given to lecturers.

3.1 3DExperience helpfulness for students

Most of Mondragon students considered that the 3DExperience platform facilitated the collaboration and communication between them and Nantes students; furthermore, they appreciated it as an enriching experience close to the industrial reality.

Nantes students greatly appreciated especially the native simultaneous mechanical design collaboration. The Co-Review app was considered as an improvement for understanding the requirements in comparison with the videoconference meetings. They had troubles with the project management since there was not a team leader of the project, a point on which we have to improve for future projects.

3.2 Peer Learning Experience learning path

Mondragon students regarded the learning path as improvable and they consider that the tutorials are not clear enough considering their previous knowledge about the platform. They suggested enriching the tutorials with real examples for future new users. At the very beginning, the learning curve is very steep and students confirm that it took them two months to go ahead and understand the 3DExperience platform's working philosophy.

Nantes students already knew SolidWorks and CATIA V5; therefore, their learning process was very short (3 hours per course) for the mechanical collaborative design and no more courses were needed on this subject. They appreciated the user interface of 3DEXperience and the database file system, even though at the start a transition period was needed. However, regarding the workflow applications such as project dashboard, planning and workflow, the students did not feel confident enough to use them. This was not expected since these applications are easy to use compared to the high-tech design apps. It shows that the students consider the collaborative work not in their scope compared to the mechanical design skills.

3.3 3DEXperience helpfulness for lecturers

Both Mondragon and Nantes lecturers regard 3DEXperience on Cloud platform is suitable for PBL supervision and highly effective for creating external collaborative projects like this one.

4 SUMMARY AND CONCLUSIONS

In conclusion, the Institute of Technology of University of Nantes and the Faculty of Engineering of Mondragon Unibertsitatea have found 3DEXperience on Cloud appropriate to teach engineering students the Industry 4.0 engineering practice features of engineering data version management and different geographical location.

Additionally, the learning path designed based on the Peer Learning Experience has been found to be useful but improvable with more realistic use cases.

5 ACKNOWLEDGMENTS

The Faculty of Engineering of Mondragon Unibertsitatea would like to acknowledge the financial support given by La Fondation Dassault Systèmes to the “Enhanced Project Based Learning with core realistic 3D simulation” project. Similarly, all authors would like to acknowledge the effort of all lecturers and staff, as well as students of Mondragon Unibertsitatea and Nantes University that have directly or indirectly participated in this PBL.

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Applying Learning Analytics in Problem-Based Learning Engineering Semester Projects

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Conference Key Areas: Innovative Teaching and Learning Methods, How Learning Spaces support innovative Teaching & Learning, Open and Online Engineering Education

Keywords: Problem-Based Learning, Learning Analytics, Moodle, Semester Projects

INTRODUCTION

Learning Analytics (LA) aims to improve the learning process by analysing learning data, and communicating the results of this analysis to both educators and learners. LA has been employed in a few cases for improving Problem Based Learning (PBL) courses but the literature has yet to discuss how PBL project work could benefit by LA. This paper presents a novel approach for enhancing PBL with LA in order to produce a new educational paradigm (PBL_LA). This paper presents a trial that took place in an engineering study in order to draw evidence-based conclusions on the PBL_LA approach. The trial run during one semester and aimed at introducing LA in PBL semester projects. For this trial, we adapted a set of software tools for supporting PBL_LA to Moodle, which is a Learning Management System (LMS), and its analytics tools. In this paper, we present this adaptation and some preliminary results of the trial. Finally, we discuss the potential of the PBL_LA approach for improving learning and teaching in this kind of engineering PBL projects.

1 BACKGROUND

1.1 The PBL pedagogy

PBL is a student-centred pedagogy in which students learn through the experience of problem solving [1]. The goals of PBL are to help the students develop flexible knowledge, effective problem solving skills, self-directed learning, effective collaboration skills and intrinsic motivation [2]. PBL represents also a paradigm shift from traditional classroom/lecture teaching. The role of the instructor in PBL (known as the tutor) is to facilitate learning by supporting, guiding, and monitoring the learning process. Finally, PBL may support group work. Working in groups, students identify what they already know, what they need to know, and how and where to access new information that may lead to resolution of the problem. This procedure enhances content knowledge, while simultaneously fosters the development of communication, problem-solving, critical thinking, collaboration, and self-directed learning skills. PBL was first introduced in the medical school program at McMaster University in Hamilton, Ontario, Canada in the late 1960s [1]. Since then, various universities and other educational institutes have adopted PBL as a model of teaching and learning. From such local adaptations, various PBL models have arisen. In Aalborg University (AAU), Denmark, all university programs have been based on PBL, also referred to as “the PBL - Aalborg model” [3]. When establishing the AAU in 1974, a redeveloped approach to the traditional PBL had already emerged, and the ideals in this involved providing students with an active, participative role, and high degree of engagement in the creation of knowledge, both in lectures and as part of group-based project work. The PBL - Aalborg Model has become both nationally and internationally recognized and a trademark for Aalborg University.

1.2 Application of LA in PBL

LA has the goal of studying and analysing acquired learner data from virtual learning environments with the aim of improving the teaching and learning process. A significant amount of work has already been done in enhancing the PBL methodology by employing LA. Oliveira and Santos in their study [4] established a virtual teaching and learning environment, called PBLMaestro, which has been designed to support the workflow of the xPBL methodology, which implements PBL in Computer Science education. In order to track student progress, PBLMaestro used the Authentic Assessment model [5] in order to evaluate the performance of students in different stages of the PBL approach (problem formulation, problem analysis, implementation, etc). Moreover, this environment used a LA module that allowed the storage and use of learning data, which was generated when students interacted with the modules of PBLMaestro. This module provided teachers real-time data on individual student performance and behaviour, and group collaboration, so teachers could intervene in order to help students during the course. The results of this study showed that by combining the Authentic Assessment model and LA, it was possible to determine and focus on the concepts that students had more difficulty with and identify the groups that performed better in the management process, and in meeting the course requirements. Finally, PBLMaestro provided an individual look on student engagement, participation and dedication in the group. Luckin et al. [6] developed a framework for project-based learning, which is a methodology that combines PBL with collaborative problem solving. This framework was designed for learning, where technology is used either to support learning or to apply LA for capturing learning data collected from project based learning scenarios. They suggested a flexible approach to the analysis of such machine-generated data, where the collected data was combined with data collated by human observers and analysed using the framework. Luckin et al. proposed this kind of data analysis because they claimed that there would always be aspects of PBL activities that take place away from any current technology. They aimed at testing the framework empirically with project-based data and considering what appropriate LA requirements might be extracted.

Tempelaar et al. [7] proposed a dispositional LA infrastructure that combines learning dispositions data with Learning Management System (LMS) student engagement/activity data, and data extracted from computer assisted formative assessments. Their study run in an introductory mathematics and statistics module combining face-to-face PBL sessions with e-tutorials, and investigated the predictive power of learning dispositions, outcomes of continuous formative assessments, and other LMS generated data in modelling student performance and their potential to generate informative feedback. The results of this study showed that computer assisted formative assessments were the best predictor for detecting underperforming students and academic performance, while basic LMS data did not substantially predict learning.

Fidalgo – Bianco et al. [8] studied the use of LA to accurately measure and access teamwork. Their study correlated final individual grades of team members with three categories of interactions in a private forum used to organise and carry out the different teamwork phases, namely based on the agent (student–student, student–teacher, student–contents), the frequency of use (most used, moderately used and rarely used) and the form of participation (active or passive). The exploration of these indicators contributed to the assessment of the individual development within the teamwork context. The results indicated that there was a direct relation between these interactions and final grading corresponding to individual assessment of teamwork activities by teachers. Additionally, the information provided by the

LA system and timely information extraction allowed for corrective measures, and making decisions to improve the learning process of teamwork.

In this paper, we propose a pedagogical approach based on a framework (PBL_LA) that supports PBL by using Learning Analytics (LA) to exploit the data generated during learning. In the next session, we describe the various layers of the PBL_LA framework.

2 THE PBL_LA FRAMEWORK

In order to design the PBL_LA framework, the PBL - Aalborg model and its steps were examined in detail, as well as the main topics of research interest regarding LA. During this study, we identified the concepts to be included in the framework that are the subjects that should be taken into consideration during the design, delivery and assessment of data-driven PBL-based courses. The framework is comprised of three layers.

The Pedagogical Layer consists of all the PBL steps of the PBL - Aalborg model, i.e. group forming, problem formulation, task formulation etc. Within these steps, the PBL_LA approach will study the activities realized by the learners in order to successfully execute each step (e.g. brainstorming, literature search, voting etc.) as well as the evidence that show the level of performance for each student.

The Data Layer consists of all the different data that is usually generated during learning. This data can be derived from students' interactions within different e-learning tools (e.g. forum, assignment etc.), within other types of tools (e.g. task recording, meeting minutes etc.), from teachers' interactions (e.g. grading, assessments, posts etc.) and from the tools used (e.g. login sessions, times spent, content access etc.).

The Analytics Layer consists of the LA methods and tools available for gathering, processing, analysing and interpreting data into meaningful information. These LA methods generate insightful visualizations for both teachers and learners so that they can make sense of the analytics results (e.g. engagement analysis, social network analysis, clustering etc.).

This framework aims to improve the learning experience for both teachers and learners. Teachers will be able to monitor and scaffold students in each step of PBL by making sense of their interactions and progress, while students will receive guidance and encouragement to participate more actively when needed, and thus gradually improve their performance. In order to draw evidence-based conclusions on the PBL_LA framework, we piloted it in PBL semester projects at the Media Technology program of Aalborg University. In the next section, we introduce this program and present how this framework was applied for its students.

3 PBL_LA IN ENGINEERING SEMESTER PROJECTS

3.1 PBL semester projects at Media Technology

Over the past years, engineering education has been challenged to embed creativity and innovation into undergraduate and postgraduate programs, in order to produce graduates who can easily adapt to the needs of a rapidly changing world [9]. Moreover, a number of engineering programs have arisen that transcend the division between technical, scientific and artistic disciplines. The Media Technology (MT) education at Aalborg University, Denmark is such a "creative" engineering study. The MT program links many areas within film and media science, animation, sound design, computer science and psychology to meet the growing need to understand new applications, and to design and develop technology that takes center stage in our lives [10]. Thus, MT is an education that focuses on research and development,

which combines technology and creativity and looks at the technology behind areas such as advanced computer graphics, games, electronic music, animations, and interactive art, to name a few. During the span of the education, MT students are given a strong technical foundation, both in theory and in practice. According to the PBL – Aalborg Model, the MT program curriculum is mapped onto semesters, where students spend approximately 50% of their time on course work (3 courses) and the other 50% on a semester project, where students collaborate in groups. The semester courses support project work, which follows the PBL approach. Each semester is governed by a fixed theme, which is selected to serve as the context, where the courses and the semester project address the learning objectives. Each group of students is assigned a supervisor, who guides the students during the project, and makes sure they are progressing according to the goals of the semester.

3.2 Methods

The PBL_LA framework has been applied to gather, process, analyze, and interpret learning data during the second semester project at the bachelor MT program. The theme of this semester is “Human-Computer Interaction”, so during the semester project the students should foster key competences in designing, developing and evaluating an artefact, such as a desktop or a mobile application, using a user-centered approach. While pursuing this aim, they are able to apply knowledge and skills in mathematics, programming and interaction design. The trial is currently taking place during the spring semester 2018, where 94 MT students are divided in 14 groups. Moodle serves as an LMS for supporting and monitoring student progress during the semester project. We have employed various Moodle activities, in order to implement the PBL_LA framework.

Four forum activities are used for communication between supervisors and student groups, and within groups. Two of them are accessible by all students and supervisors: one is meant to support an open discussion on the semester project in general, and the other is dedicated to announcements from the supervisors (students could not post in this forum). There is also a group-based forum, where students can communicate only with students belonging to their group, and lastly a forum, which students of the same group can use in order to communicate with their supervisor (aimed to replace email communication between groups and supervisors, which could not provide any learning data for LA purposes).

A wiki activity is introduced in order for groups to keep notes of their progress. The groups are required to update this wiki (called “status report”) with the status of the project and an agenda, before each meeting with their supervisor. The wiki structure allows for keeping previous versions of the status report, so at the end of the semester the groups will have an overview of the project progress.

A checklist activity is employed to create a simple Gantt chart containing the main tasks of the project and a few fixed deadlines. The students are able to modify this checklist by adding new tasks and/or new deadlines, if necessary. The task list is meant to facilitate project management for students, and to provide supervisors with an overview of the progress of all groups.

Finally, a feedback activity is used for individual student feedback on collaboration within their groups, communication with their supervisor, and possible issues. Students are required to submit their feedback before each semester group meeting (meetings that take place three times during the semester, where teachers and representatives from each group meet in order

to discuss the overall progress of the semester). Answers to this feedback activity are submitted anonymously, in order to encourage students to report issues.

4 PRELIMINARY RESULTS

During this trial, learning data is gathered and analysed using the standard functionality of Moodle. Moodle keeps log data, and provides action reports for all users enrolled in a specific course. Main actions include the viewing, editing and posting of content. This kind of data is gathered as students use the platform in order to shape an understanding of their overall engagement with the LMS. In order to draw conclusions on their engagement to the semester project, data coming from the aforementioned activities are thoroughly examined using either quantitative or qualitative data analysis. Quantitative data is extracted from the forum and the wiki activities (number of posts and views), and from student access of resources (Table 1). The forum dedicated to a general discussion on the project, and the one meant to support communication among the members of a group has not provided so far any valuable data, since students use normally other platforms to perform these tasks (mainly Facebook), and therefore hardly use them. The discussions in the forum, which is dedicated to the communication between supervisors and their groups, the wiki, and the feedback activities are also analyzed qualitatively in order to identify the topics brought up during the semester both by students and supervisors. For this qualitative analysis, an inductive approach is applied, where consensus on findings is sought among three researchers in order to ensure a deep reflexive analysis, and to strengthen the validity of the findings. The goal of this analysis is to create a list of the various topics raised and their frequency during the semester for each group (internally, and during communication with the supervisor), and then correlate the data in the list with the other type of data gathered on the platform.

Table 1. Number of view and posts in various Moodle activities per student in a randomly selected group (S1: Student 1, S2: Student 2, etc)

ActionActivity/Student	S1	S2	S3	S4	S5	S6	S7	Group Total
Status Report(View)	1	3	45	0	4	36	12	101
Status Report(Post)	0	0	2	0	0	9	0	11
Status Report(Total)	1	3	47	0	4	45	12	112
Discussion with Supervisor (View)	13	5	85	6	6	62	13	190
Discussion with Supervisor (Post)	1	0	4	0	0	2	0	7
Discussion with Supervisor (Total)	14	5	89	6	6	64	13	197
Announcements(View)	0	0	10	0	2	0	4	16
Open Discussions(View)	0	0	2	0	1	1	0	4
Open Discussions(Post)	0	0	1	0	0	0	0	1
Open Discussions(Total)	0	0	3	0	1	1	0	5
Group Forum(View)	0	0	0	0	0	0	0	0
Group Forum(Post)	0	0	0	0	0	0	0	0
Group Forum(Total)	0	0	0	0	0	0	0	0
P2_Overview(View)	1	5	15	0	0	3	0	24
P2_Project Description(View)	4	2	11	0	0	2	0	19
P2_themes(View)	5	7	7	0	0	3	2	24
P2_report Structure(View)	0	7	4	0	0	2	2	15
P2_Sketchbook(View)	0	2	0	0	0	0	0	2
P2_AV_production	1	2	0	0	0	0	0	3
Groups, Supervisors and Themes(View)	0	0	7	0	0	1	2	10

LA are also applied by using two added plugins (tools) in Moodle, namely GISMO and Heatmap. GISMO is a graphical interactive monitoring tool that provides visualization of students' activities in online courses to instructors. With GISMO, instructors can examine various aspects of distance students, such as the attendance to courses, reading of materials, submission of assignments etc. (Fig. 1). The Heatmap tool overlays a heatmap onto a course

to highlight activities with more or less activity in order to help teachers gain insight on the use of the various elements of their courses.

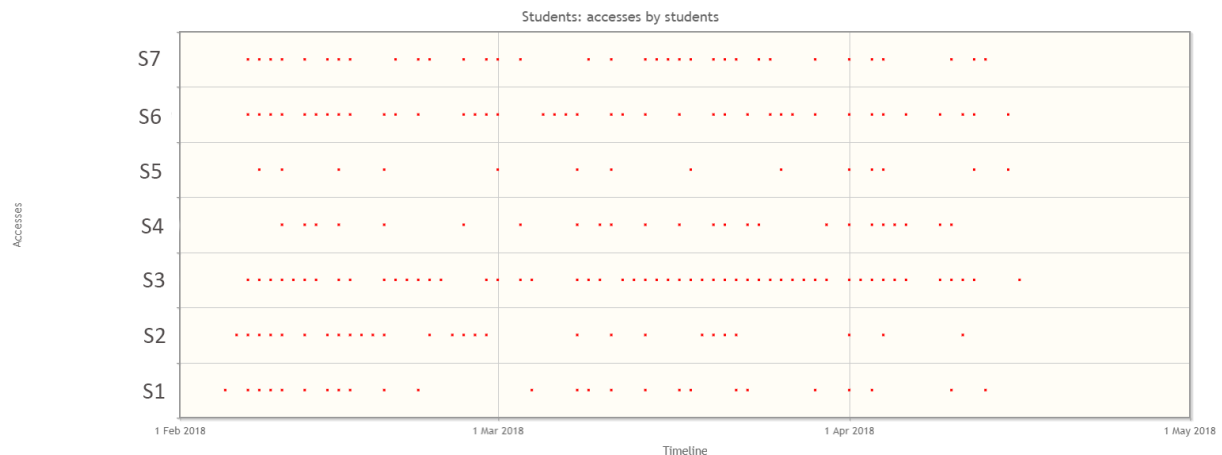


Fig. 1. Learning data as acquired from GISMO around the mid-period of the trial

5 DISCUSSION

This paper presents a trial carried out in PBL engineering semester projects. PBL shifts the focus from understanding common knowledge to developing new knowledge through "learning by doing" activities, and accommodates active participation of students. However, there is a need for this very promising model to exploit novel opportunities and technologies, such as LA, that will unleash new benefits and capabilities. During this trial, we are able to gather learning data on engagement and performance both on individual and group level. So far, students' learning progress during these projects was only analysed and evaluated by the group supervisor. By employing LA, we are able to gain an overview on how students and groups are evolving during the semester. Moreover, by analysing forum discussions, we are able to identify topics discussed between groups and their supervisors, to analyse supervisor engagement, and to keep track of issues that come up during the semester. After the end of the semester, we aim at correlating the data gathered in Moodle with examination results. We believe that the PBL_LA approach will help teachers/supervisors, students, and study coordinators to draw overall conclusions on how semester projects progressed for the first time.

6 ACKNOWLEDGMENTS

The research presented in this paper was conducted under the PBL3.0 project, which is co-funded by the Erasmus+ programme of the European Union under the project number 562236-EPP-1-2015-1-EL-EPPKA3-PI-FORWARD. The European Commission support for the production of this publication does not constitute an endorsement of the contents which reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

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Shaping Engineering Education with the Power of Intelligent Internet of Things Technologies

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ABSTRACT

With the developments of networked sensing and information processing technologies, significant breakthroughs have been made for the Internet of Things (IoT) applications. In order to successfully implement the IoT applications, smart and effective solutions linked to the cross-cutting issues will be an important subject in future engineering education. As we know, incorporating artificial intelligence (AI) into the IoT already revolutionizes the world with the capabilities of improving operational efficiency and helping avoid unplanned system downtime. For instance, the IoT can capture large volumes of data in real time and this immediate feedback is important for adaptive learning systems. Data collected over time can also support AI to understand patterns, which can be useful for predictive analyses such as monitoring for potential future system failures and scheduling maintenance in advance.

Therefore, on the basis of our previous project (focusing on conducting project-oriented learning and using the application development training as a concrete embodiment of the interdisciplinary engineering education), the current project aims at achieving cultivation of creative thinking (Figure 2 (b)) and conducts two representative trainings: (A) Proposing AI-powered application proposals with IoT technologies and (B) Implementing the proposed projects with embedded systems, as depicted in Figure 3. Essentially there are four major steps involved in this one-year project: (1) Do: developing applications of Internet of Things (proposing a specific problem statement), (2) Check: performing capture, storage, and analysis of data (finding insights in data), (3) Adjust: executing data-based learning (validating and modifying the system design via AI-powered feedback), and (4) Plan: revealing insights that redefine the problem. On the topic of education training, we plan to arrange cross-presentation of creative thinking techniques and experience sharing in the field, which may allow the students to leverage AI-powered IoT technologies. This paper presents the preliminary results of this project, which emphasizes on human-centric design process and aims to develop an architecture model for problem solving and application service.

Keywords: artificial intelligence, internet of things, interdisciplinary engineering education.

1. INTRODUCTION

With the developments of networked sensing and information processing technologies, significant breakthroughs have been made for the Internet of Things (IoT) applications. In order to successfully implement the IoT applications, smart and effective solutions linked to the cross-cutting issues will be an important subject in future engineering education. As we know, incorporating artificial intelligence (AI) into the IoT already revolutionizes the world with the capabilities of improving operational efficiency and helping avoid unplanned system downtime. As shown in Fig. 1, the IoT can capture large volumes of data in real time and this immediate feedback is important for adaptive learning systems. Data collected over time can also support AI to understand patterns, which can be useful for predictive analyses such as monitoring for potential future system failures and scheduling maintenance in advance.

For achieving cultivation of creative thinking and the realization of interdisciplinary engineering education, two representative trainings are conducted: (A) Proposing human-centric application proposals with IoT techniques and (B) Implementing the proposed projects with embedded systems. Referring to our previous project [1], essentially there are four major steps involved in this current project: (1) Integrating creative and design thinking with social care infrastructures and local services (e.g., visiting a nursing home, a special education school for the deaf, or a fire station), (2) Developing applications of Internet of Things (proposing a specific problem statement), (3) Embedded system implementations, and (4) Validating the system design via user feedback. On the topic of education training, we plan to arrange cross-presentation of creative thinking techniques and experience sharing in the field, which may allow the students to leverage IoT techniques and describe general issues of people-oriented problems through observation and discussion. This paper will present the preliminary results of this project, which emphasizes on human-centric design process and aims to develop an architecture model for problem solving and application service.

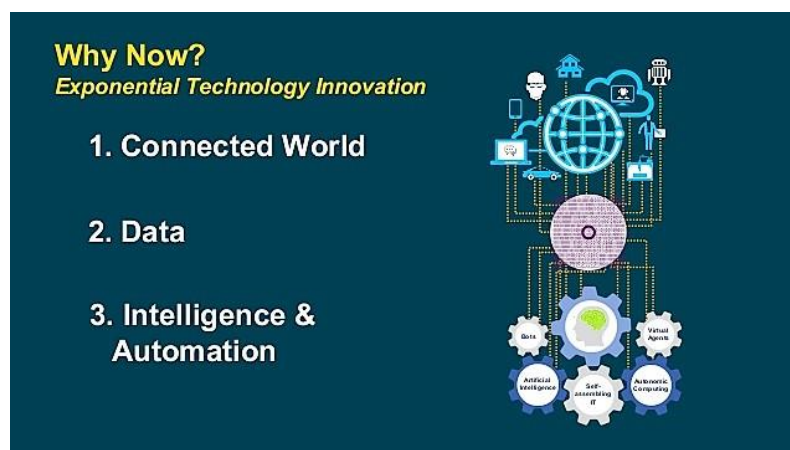


Fig. 1. AI-powered IoT technologies [2].

2. AI-Powered Human-Centric Design Process

Our previous project explores the learning experience by integrating creative and design thinking with social care infrastructures and local services. Using the process

of design thinking presented by Stanford (Fig. 2 (left)), learners can translate their observations into insights, products and applications that can improve human life. Note that although the thinking process of is human-centred, it is a system design viewpoint. Furthermore, the industrial mentor may be consulted to guide the learners from discovering problems, defining issues, proposing possible solutions, and finally finding the best solution by using the Double-Diamond Thinking mode (Fig. 2 (right)). It is to be hoped that through the idea of the concept of creativity training, students can gain experience and skills for proposing general issues, which may provide a basis for defining specific problems (Empathy and Define). Then, through the combination of creative thinking training and engineering education, an appropriate solution may be explored to solve the problem (Ideate, Prototype, and Test).

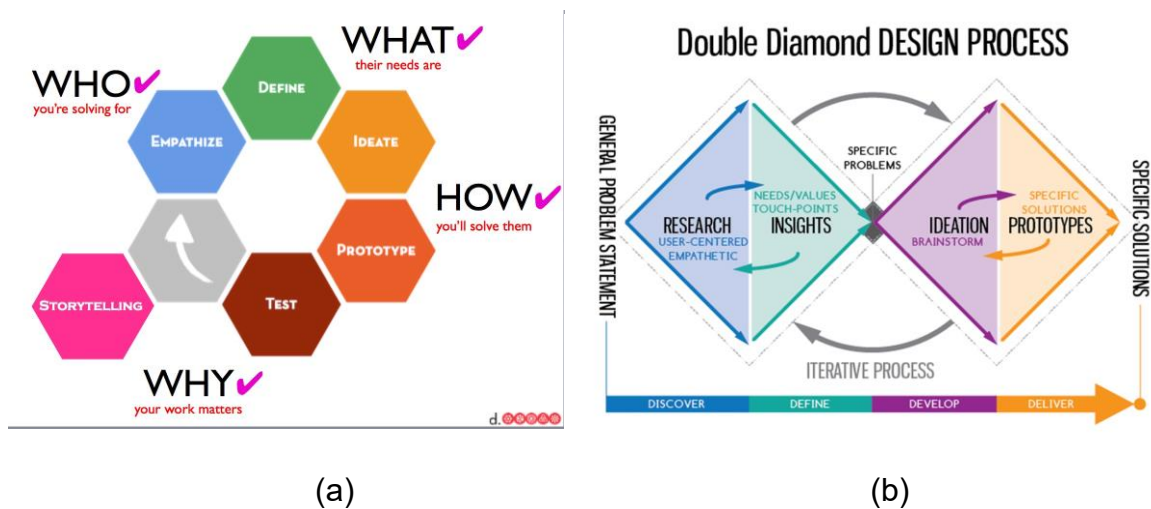


Fig. 2. (a) Design thinking process [3] and (b) Double-diamond thinking model [4].

Therefore, on the basis of our previous project (focusing on conducting project-oriented learning and using the application development training as a concrete embodiment of the interdisciplinary engineering education), the current project aims at achieving cultivation of creative thinking (Fig. 1 (left)) and conducts two representative trainings: (A) Proposing AI-powered application proposals with IoT technologies and (B) Implementing the proposed projects with embedded systems, as depicted in Figure 3. Essentially there are four major steps involved in this one-year project: (1) Do: developing applications of Internet of Things (proposing a specific problem statement), (2) Check: performing capture, storage, and analysis of data (finding insights in data), (3) Adjust: executing data-based learning (validating and modifying the system design via AI-powered feedback), and (4) Plan: revealing insights that redefine the problem. On the topic of education training, we plan to arrange cross-presentation of creative thinking techniques and experience sharing in the field, which may allow the students to leverage AI-powered IoT technologies. This paper presents the preliminary results of this project, which emphasizes on human-centric design process and aims to develop an architecture model for problem solving and application service.

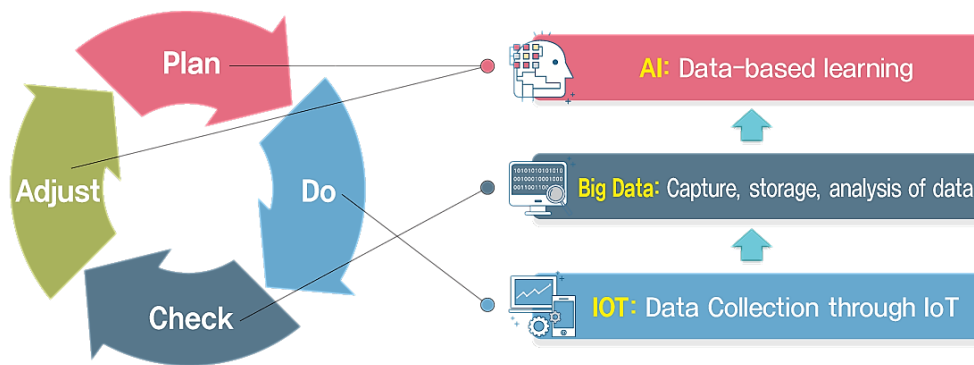


Fig. 3. Iterative process of AI-powered trainings [5].

2.1 AI-powered Application Proposals

On the theme of creativity and design thinking workshops, several lectures and experience-sharing group discussions will be arranged. Related Topics cover: the technology and concept of creativity and design thinking, training procedures, tools, and the need and importance of creative thinking in engineering education. Hope that through this workshop activities and thoughts training, students can cultivate the ability to think creatively in engineering education. For instance, guide students to think about the improvement of health-related quality of life and well-being (Fig. 4), considering sensing and recognition, knowledge processing, decision and support, and learning, which may lead the students to consider the design issue from cross-domain perspectives and may further provide a better solution for the caring of our society.

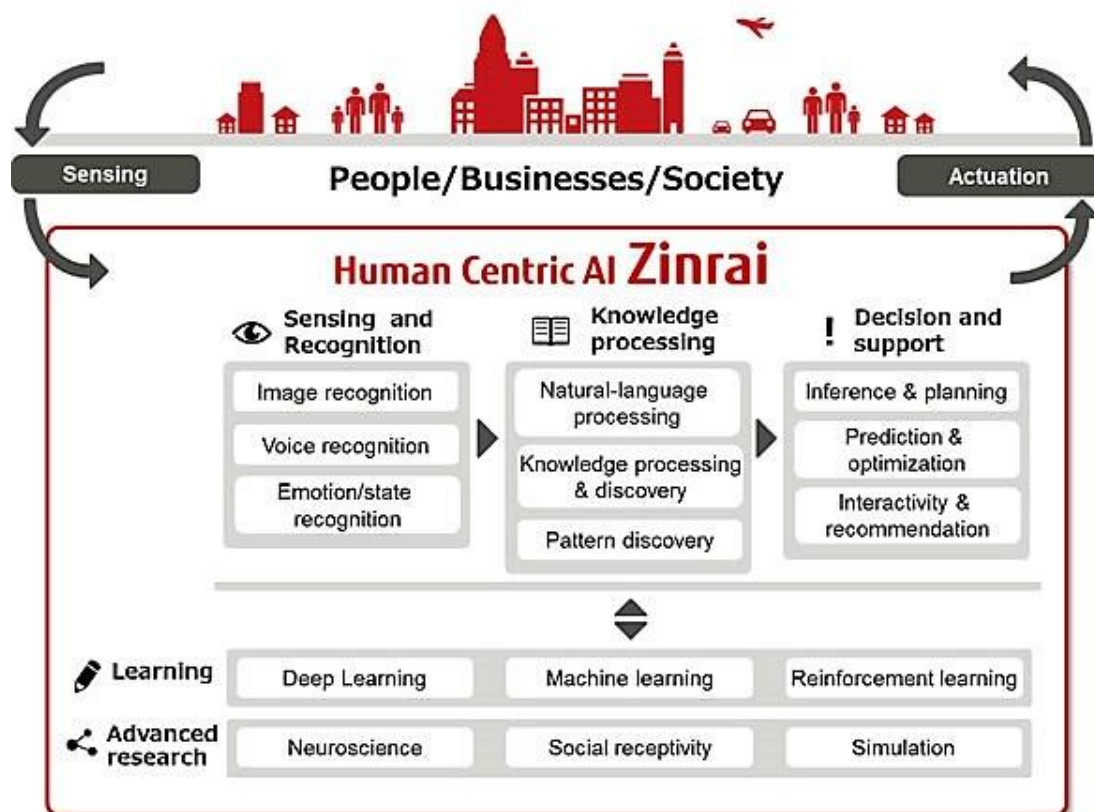


Fig. 4. Key procedures in the design of application tasks [6]

2.2 Intelligent System Implementations

Under the architecture of an IoT application as shown in Fig. 4, we detail on I/O interface, interrupts and control mechanism, process operation w/wo OS, and data flow and storage. In addition to setting up a development environment, students will conduct the labs on building a basic IoT device to sensing data, integrating multiple sensors and performing a complex sensing task, interacting IoT device with IoT gateway, processing data among IoT device, IoT gateway, and the sever end. Fig. 5 depicts possible scenarios of smart systems for achieving smart cities. To validate the system design, the users as well as domain experts are invited to give suggestions on the ideas and the proposals based on student's demonstration, which provides an opportunity for students to review their idea and proposals. The suggestion of the users, the degree of accomplishment, and the discussion among the students are helpful feedbacks to revise the content of the program. Fig. 6 shows a non-linear process of validating the system design.

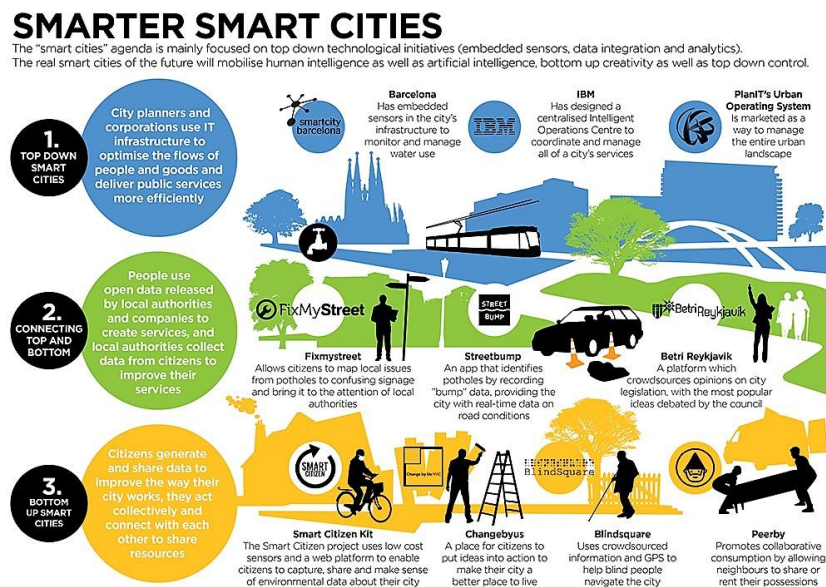


Fig. 5. Possible scenarios of smart systems [7].

DESIGN THINKING: A NON-LINEAR PROCESS

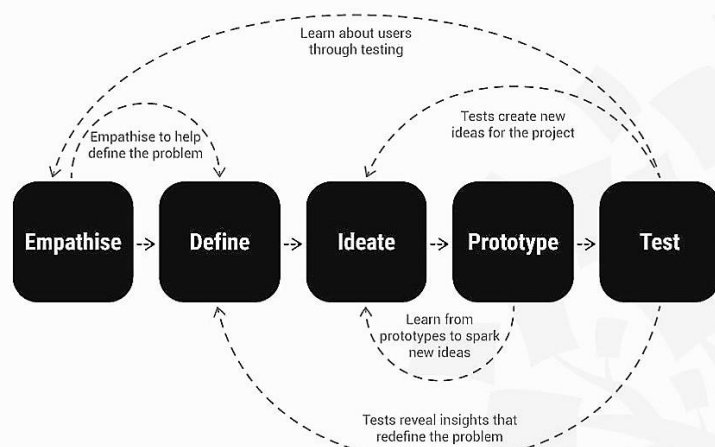


Fig. 6. A process of validating the system design [8]

3. Case Study

A course project may be applied to develop a practical application using IoT technologies. The students are grouped into teams to discuss application architectures from cross-disciplinary perspectives and propose their problem statements, project deliverables, system descriptions, project setups, prototype implementation, test and feedback. Accordingly, each team will deliver the full architecture of the system and the important pieces of implementation details. Here, we use an activity monitoring system as an example to describe the design issues of caring for an aging society. Possible healthcare scenarios for intelligent IoT applications are depicted in Fig. 7, where students may design a system from cross-disciplinary perspectives for environmental/safety monitoring. In this work, an AI-powered healthcare example, focusing on the conventional intravenous drip frame, is explored to demonstrate the project concept.

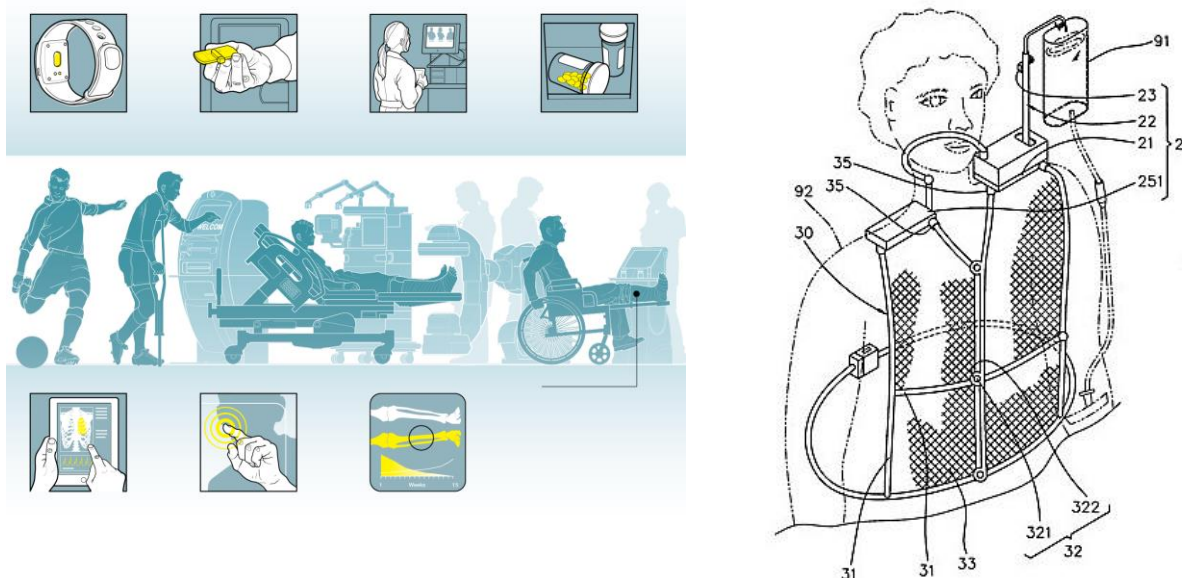


Fig. 7. Possible healthcare scenarios for intelligent IoT applications [9] (left); the balance control of the piggyback intravenous drip frame (right).

3.1 Problem Statement and the Design Goal

Due to the inconvenience of the conventional intravenous drip frame, the piggyback intravenous drip frame is developed to ensure better mobility of the patient. However, the current design of the piggyback intravenous drip frame leads to a lack of balance control and increment of blood returning. To this end, this invention applies proportional-integral-derivative (PID) control techniques and an inverted-pendulum system to build up a reliable system, which can facilitate patient mobility and ensure patient safety with compensating the inclination angle of the piggyback intravenous drip frame based on the motion information of the patient. Therefore, the reduction of blood returning and the balance control of the piggyback intravenous drip frame can be achieved.

3.2 Key Features and Contributions

Considering the conventional design of a drip frame, the fixed drip frame, including pulleys, is lack of the agility and convenience of movement. Although the new creative drip frame such as a shoulder-mounted (or mobile) drip frame (e.g., Taiwan Patent I522137 [10], M360702 [11]) has the mobility function, it can't adjust the position of the drip frame when user tilted forward, backward or other actions, which implies that the drip frame may tilt with user, reduce the height of the infusion tube, and increase the risk of blood return. Another kind of mobile design principle, such as portable intravenous drip pressurization injection device (e.g., Taiwan patent M368452 [12]), is to use additional gravity to drive drip output. However, the device is on the waist, which may be difficult to observe the remaining drip capacity. In order to overcome the above disadvantages, an innovative control strategy of the piggyback intravenous drip frame is proposed based on a motion sensor, a motor with PID control, and angle information, considering the effect of attitude determination and dynamic response performance of a piggyback intravenous drip frame. When the balance control activates, the gyroscope is used to get the acceleration, angular velocity and the tilt angle from the complementary filtering, which allows us to know whether the drip frame is tilted forward or backward (Fig.8 (bottom)). Compared with portable ringer's solution injection apparatus [13], the piggyback intravenous drip frame with balance control has the capability to control the drip frame for achieving the balanced state (perpendicular to the ground) during body tilting, the key features of this system are that the device

- can be moved with the human body,
- can cooperate with shoulder activities and neck activities,
- can correct the tilting angle of the body forward and automatically restore the angle.

That means the proposed system performs a control loop feedback scheme, conducted by a weighted sum of the control terms. Fig.8 shows a practical application with creative thinking and IoT technologies: the system prototype: a piggyback intravenous drip frame with balance control and the system workflow. The design of control system needs further improvement to make it more robust for different conditions in the future.

4. CONCLUSION

As shown in Fig. 9, 100+ Startups are currently transforming healthcare with AI. In this paper, an AI-powered IoT design concept is explored and a human-centric control system has been implemented for balancing a piggyback intravenous drip frame, which may provide an example to echo with the conference theme: "Creativity, Innovation and Entrepreneurship for Engineering Education Excellence."

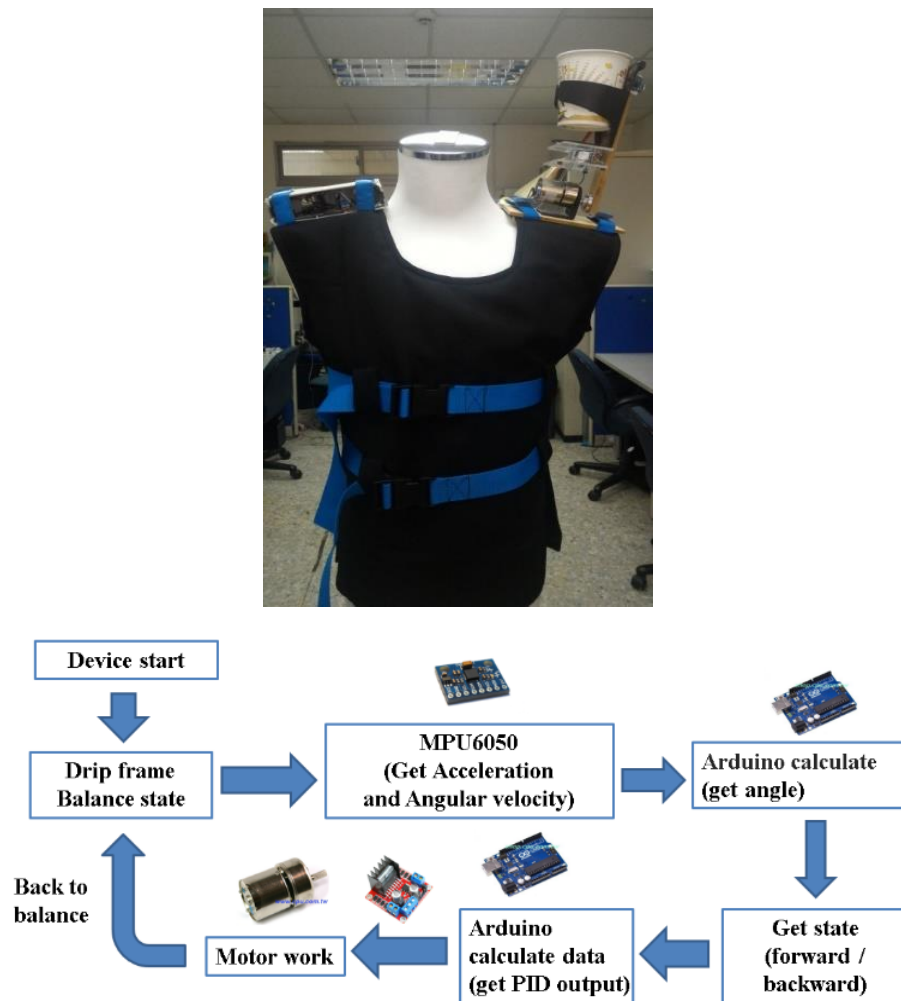


Fig.8. A practical application with creative thinking and IoT technologies: the system prototype: a piggyback intravenous drip frame with balance control (top); System workflow (bottom);

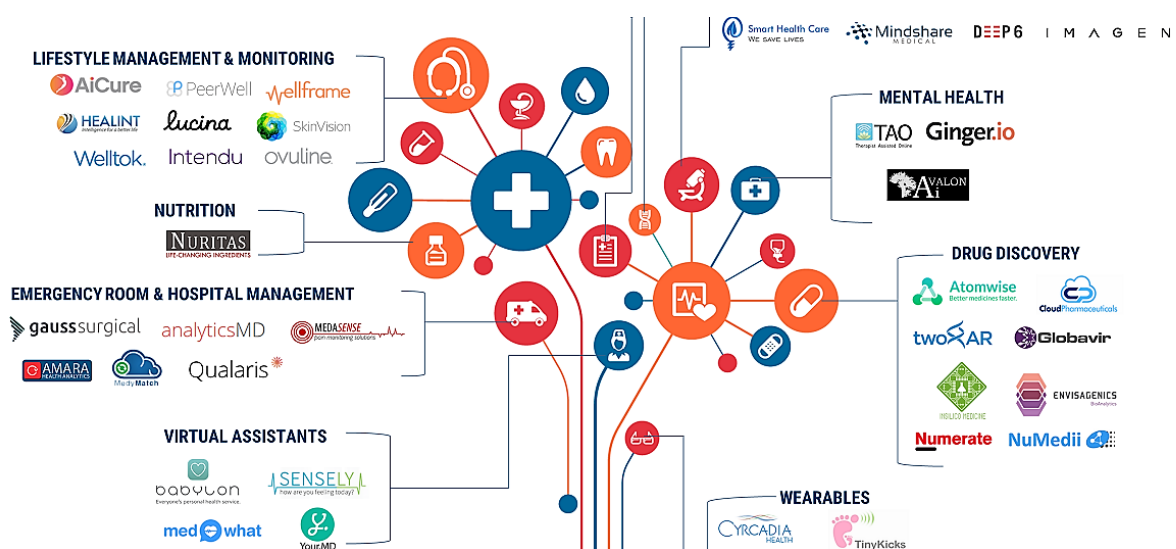


Fig. 9. 100+ Startups in Healthcare with AI [14].

5. ACKNOWLEDGMENT

This research is partially supported by the Ministry of Science and Technology of Taiwan under grant No. MOST-105-2511-S-005-011-MY3, and by the “Innovation and Development Center of Sustainable Agriculture” from The Featured Areas Research Center Program within the framework of the Higher Education Sprout Project by the Ministry of Education (MOE) in Taiwan.

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An Innovative Method of Infusing Global Competencies in Curriculum by Utilizing International Student Bodies

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Conference Key Areas: Curriculum Development, Engineering Skills, Innovative Teaching and Learning Methods

Keywords: Global competence, international student, curriculum innovation

1 INTRODUCTION

Rapidly changing global economy has transformed the way business operate and has changed the character of the engineering profession. Globalization of markets and advancement of information technology have provided engineering companies and alike an opportunity to produce differentiated products and services and reached every possible geographic location on the earth. More and more projects are now distributed across global sites and effective collaboration requires professionals who can work productively with colleagues who are very different from themselves. As a result many companies are now looking for engineers with global competency capable of providing engineering solutions not only in domestic market but beyond domestic boundaries [1]. Global competence is defined as a set of multidimensional capacities which enable individual to examine local, global and intercultural issues, understand and appreciate different perspectives and world views, interact successfully and respectfully with others, and take responsible action toward collective well-being [2]. Globally competent students can combine multi-disciplinary knowledge by asking the right questions, can analyse connected data and explain phenomena which create opportunities to take informed decisions. Globally competent students also recognize the perspectives and views different from themselves and are able to interact and communicate with people across cultures and regions in appropriate ways which foster collaboration and innovative problem solving. However, our college curricula have often failed to adequately preparing students with this very important global competency skill.

Academic, industry and government institutions have recognized the need of global competencies for engineering students. For example, Montgomery (2009) attributed improved student views in cross-cultural group work to internationalization efforts [3]. He noted that most of the project participants have pointed out that the year spent

abroad helped them develop ability to accept challenges and solve problems independently which may not be experienced in the U.S. Grandin (2006) discussed the value added to the engineering students through the experience of engineering work and study abroad, as well as on the lessons learned over the seventeen year history of the University of Rhode Island program [4]. The paper emphasized that to be competitive in global workplace engineers must be educated as global citizens, trained to work in global teams, and prepared to develop and manufacture for a global market. Without these skills, they will fail and their work will be handed off to peers from other parts of the world where such global preparation is already valued and broadly practiced. A series of studies focused on best practices for both scholars and practitioners of global engineering practices [5, 6, 7]. Being able to communicate and work effectively across cultures has been valued by potential employers; in fact, 78% of surveyed employers stressed the importance of all students gaining intercultural skills [8]. The U.S. National Academy of Engineering published two reports - both stress the impact of globalization on the practice of engineering and the need for U.S. engineers to focus on innovation and creative aspects of the profession to be globally competitive.

Various approaches are taken by universities to internationalize engineering education which include various types of study abroad, research abroad or internship programs or a combination of these, e.g. the GEARE at Purdue, the MISTI at MIT, or the IEP at URI. Parkinson (2007) has compiled a comprehensive overview of these different attempts to globalize engineering education via exchange programs, dual degree programs, international project work and internships [9]. The above mentioned programs are very effective to develop global competence for engineering students. However, several constraints such as desirability, affordability, language, safety etc. pose as major barriers for most students to participate in such programs. As a result, statistics show that only about 1.6% of American students studied abroad last year during their undergraduate programs [10].

International student groups bring significant cultural diversity on a university campus. In 2016/17, an estimated 1.07 million international students studied in US [10]. International students and associations promote awareness of cultural diversity and global understanding within the university and the broader community. Engaging local students with these diverse groups of international students through activities, group projects, and discussions can be an effective way of exposing students to learn cultural diversity, practices, ethics, and thereby preparing engineers for the global workforce.

2 PROJECT DESCRIPTION

2.1 Research Questions

This paper focuses on preparing engineers students as a global citizen and problem solver by systematically engaging them with the international student groups. The project has two research questions

1. Can international student groups and communities on the university campus help engineering students learn global skills through active and peer learning?
2. If yes, how effective is it? A comparative study will answer this question.

2.2 Planning For the Project

It requires some planning to systematically engage international students with local students. First a suitable course, ENTC 4600: Technical Practicum, was selected. This

is a senior level required capstone design course, which is offered every semester with enrollment of about 40 students each year. The course requires the student to synthesize and apply subject matter studies in previous required courses and apply them to a realistic problem solving effort. For example, in manufacturing, students will draw upon their knowledge of product design and manufacturing methods to solve a complex problem, commonly designing and developing a manufactured product. In a typical project students identify a product or service need in collaboration with the community or industry and then design and develop it from scratch. In the Fall of 2017, the project is modified as such that students looked at international markets mainly developing countries, identified an engineering and technology related problem (i.e. a product and service needs) with the collaboration of an international student group at X University, and then devised a solution (i.e. designed and developed a product or service) to meet the customers' needs.

During the summer of 2017, author as the instructor of the course made necessary changes in the course curriculum to add the international dimensions through research and development. Author identified textbook, case studies, journal articles, web contents, audio-visual contents, etc. and developed a modified course curriculum. Authors also recruited a group of international students from China and Nigeria to collaborate with students during the Fall semester. The international students were briefed about the goals, activities and expectations of the project. The international students were divided into two groups. The first international student group took part during idea generation and collaborated with the teams throughout the semester. The second group took part as a focus group to provide unbiased evaluation to the solutions.

2.3 Execution of the Project

Two weeks before the semester started students were introduced the new internationalization infused course curriculum. Students were encouraged to research global markets and generate ideas of creative products and services for their country of interest. At the end of first week of class, students were formally introduced to the international student group. After a short introduction, the author explained the goals and objectives of the project, collaboration process and expectations from both local and international student groups. Four project requirements were identified. These four project requirements were: 1) The solution (the product) meets the requirements of the clients' needs in the country of interest, 2) Regional design standards, specifications, practices as well as cultural, economical and social factors are considered appropriately in the design and development of the solution, 3) The solution is sustainable, and 4) The solution has potentials for future enhancements.

A total of 4 groups were formed. For the comparative study, one group was used as a control who had to work on an international project without any engagement with the international students. Quickly students (local and international) started to brainstorm and they spent two sessions discussing project ideas and at the end of second sessions four engineering problem solving projects were identified focusing on Asian nation of China and African nation of Nigeria. Students then put their ideas into design and developed a prototype to meet the customer/community needs making sure that the solution is culturally, socially and environmentally justified. As the students dive into the projects, author taught concepts of engineering problem solving from global perspective using texts, reports, journal articles, case studies, audio, video, etc. Four guest speakers were invited who talked about design and development, international business environment, business plan, manufacturing, testing, and specifications appropriate global communities throughout the semester. At the end of semester

students presented their product and services, and the second international student group evaluated them. Students prepared a report with detail design, manufacturing processes and specifications.

3 ASSESSMENT OF STUDENT LEARNING OUTCOMES

The course has five learning outcomes which are aligned with ABET student outcomes a to h. Two additional learning outcomes were added focusing on global perspectives of engineering problems and solution. These are:

1. Understanding of International Business Environment

The current learning outcome for the course is somewhat “Think Local, Act Local”. Students identify an engineering problem in the community or in industry and then develop a product or service to fit local customers, regulations, and market requirements. The proposed learning outcomes was to broaden it to “Think Global, Act Global”. Students are expected to learn about global business dynamics, economic interdependence, environmental risks, conflicts, manufacturing principles, regulations, logistics, etc. which will enhance students understanding about multinational businesses and global engineering problems, and needs for solutions.

2. Ability to Incorporate Cross Cultural Elements to Engineering Problems and Solutions

Differing population sizes, income levels, demographic, political and cultural factors give rise to considerable differences in market size. Buyer tastes for a particular product or service sometimes differ substantially from country to country. Sometimes, product designs suitable in one country are inappropriate in another because of differing local standards – for example, in USA electrical devices run on 110 volt systems, but in south East Asian countries the standard is a 240 volt, necessitating the use of different electrical design and components. Students have to decide whether and how much to customize their products or services to match the tastes and preferences of local buyers of a geographic location. Students are expected to learn about all these cultural, political and economic forces that drive and are driven by technology and how to factor in those in product design and development. Students also need to consider critical global environmental issues and make sure that sustainable solutions are considered and implemented in their products or service development.

Two summative assessments were utilized in the course – final project judge by a faculty panel and peer evaluation by both local and international students.

3.1 Students’ Performance

The anticipated outcomes of the students’ learning were assessed through evaluation of a series of student presentations and report writings. Students prepared a total of 5 presentations, four item based reports and a final report – each chronologically depicts search for an engineering problem in their country of interest, understanding of various dimensions of international arena, conceptual design focusing on local preferences, a business plan, prototype design, manufacturing process and the final product development. A pre and a post survey were conducted to assess effectiveness of learning outcomes.

The pre survey assessed students’ initial understanding of global citizenship, their knowledge and preparation, and willingness to engage in local, global, and intercultural problem solving. Students were asked Yes/No questions and/or rate

statements based on 5 point Likert scale: 1- strongly disagree, 2 – disagree, 3 – neither agree nor disagree, 4 – agree and 5- strongly agree. Table 1 shows students' responses and rating percentage in key items of the pre survey. As shown in Table 1, most students had no international experience (82%) and unfamiliar with engineering and technology related standards and specifications outside USA (80%). However, about 82% students responded that they understand interplay among regional cultures, socio- economical and political influences in engineering problems and development of solutions.

Table 1. Pre Survey Responses

Question or Statements	Yes	No	Likert Scale Rating				
			1	2	3	4	5
Do you have an international education experience such as study abroad?	18%	82%					
I can communicate effectively at least one foreign language	18%	82%					
I am familiar with SI Units for problem solving	100%						
I am familiar with engineering and technology related standards and specifications outside USA	20%	80%					
U.N. Millennium Development Goals, which USA supports, also reflect the need for a Global Education Perspective to achieve success.					10%	27%	63%
I see the relevance of international issues such as cultural, socio-economical, political etc. in engineering problems and solutions			9%	9%		36%	46%
I believe that in future, I will need to work in environment where the communication with individuals with different background, knowledge and/or language will be necessary				18%		18%	64%
I value diversity and multi-perspective analysis of an issue			9%		27%		64%
I believe understanding sustainability is essential to join the international discourse and work cooperatively in the closely interconnected world of the new millennium			9%	10%		36%	45%
I am preparing myself to be a global citizen			10%	10%	20%	40%	20%

Significant number of students value diversity and believe that in future they will work in diverse environments. More than 80% students emphasize the importance of sustainable solutions and 60% students responded that they are preparing themselves to be global citizen.

A post-survey was conducted to assess students' global learning experience and effectiveness of course program. A similar format as in pre survey was used in developing the survey. Table 2 summarizes students' responses and rating percentage in key items of the post survey. As shown in Table 2, engaging international students in identifying engineering and technology related problems and solutions was a huge success. All students agreed that the course project increased their knowledge and skills to solve engineering problems in global settings. The students utilized their knowledge of mathematics, science, and tools and techniques learned in other technology courses and significantly challenged their critical thinking skills. About 92% students responded that the project increased their interest about different cultures and multi-perspective analysis, and 72% students, up 52% from pre-

survey, said that the project was helpful understanding engineering and technology related practices, standards, specifications, safety outside USA. Since sustainability was a project requirement, at least 65% reported that the course materials and the project expanded students' knowledge about sustainability by balancing environmental protection, social responsibility and economic growth.

Table 2. Post Survey Responses

Question or Statements	Yes	No	Likert Scale Rating				
			1	2	3	4	5
The project increased my knowledge and skills to solve engineering problems in global settings	91%	9%					
Did the project challenge you to use critical thinking skills?	100						
The project prepares me to apply the knowledge of mathematics, science and engineering to design systems, components or processes	100						
The project prepares me to conduct tests and measurements, and interpret experimental results	92%	8%					
Was this experience helpful understanding engineering and technology related practices, standards, specifications, safety outside USA?	72%	28%					
Does this project increase you interest about different cultures, practices, diversity, multi-perspective analysis?	92%	8%					
The project enhances my teamwork and leadership skills						10%	90%
The project improves time, cost, quality and communication management skills						12%	88%
The course materials and the project expand my knowledge about sustainability by balancing environmental protection, social responsibility and economic growth at home and abroad				14%	21%	57%	8%

3.2 Comparison with the control group

A comparative study was conducted to learn any differential experience between the students who worked with the international students versus the control group (who didn't work with the international students). Fig. 1 shows side by side comparison of the five post survey measures. It was found that the differences in students' experience was statistically insignificant at $\alpha = 5\%$ significance level. However, it is evident that in each measure students who engaged with international students had better learning experiences than those who have not. Informal discussion revealed that students in the control group struggled to find a suitable project for their country of interest. They had to "guess" a lot during product design and development because specific information was unavailable. Students who worked with the international students appreciate the interaction and collaboration with international students which helped them to learn tacit and socially complex knowledge such as cultural aspects, social norms, standards, local practices which could be unreachable without such interactions.

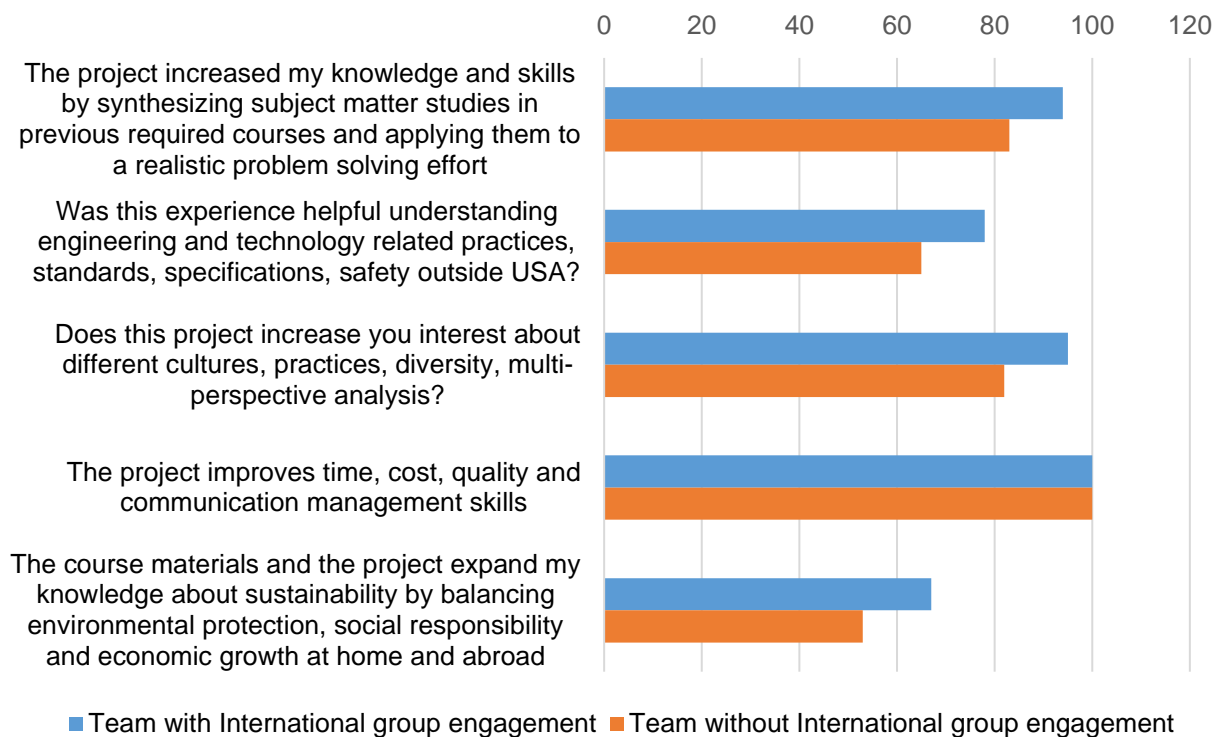


Fig.1. Comparative assessment of students' learning between team with and without international student engagement

4 CONCLUSIONS

If our students are expected to understand and resolve global challenges and compete in global economy, it becomes crucial for educators to address and cultivate student global competence. Global competency is essential for engineers from any country which now competes in an international market for engineering know-how. Engineering students who have international study experience are more likely to be hired and prepared for the global market place. However, very few American engineering students have any international experience. A vast majority of students have little to no exposure to investigate engineering problems and solutions under global lens. This paper presents an alternative yet effective method of teaching students global competency. This method involves systematically engaging students with the international student groups and communities through group activities, team project, discussion and other activities. Based on the data presented, the proposed course modifications greatly enhance students' understanding about global engineering problems, how to develop socially justified sustainable solutions and be a global citizen. The course project significantly challenge students' critical thinking skills and help them understanding engineering and technology related practices, standards, specifications, safety outside USA. This will ultimately increase students' employability and advance their career in global economy.

5 LIMITATION OF THE STUDY AND RECOMMENDATIONS

The major limitation of the paper is that inferences are made based on limited data. More data collection and focused analysis are necessary to further validate the premise. One key challenge was coordination between American and international students and keeping both groups focused. This author recommends extensive planning, focused lecturing and briefing on global skills, developing extensive guidelines for collaboration, and stipends for international students for better results.

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Engineers in the Physics Classroom

Helping engineers become physics teachers

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Conference Key Areas: Discipline specific teaching and learning; Innovative teaching and learning methods; Open and online engineering education

Keywords: Teacher training; Subject knowledge enhancement; Physics; Blended learning

INTRODUCTION

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With shortages of physics teachers in many countries the option to attract engineers for a teaching career has been identified as a potential solution. To ensure in-depth physics teaching, subject knowledge enhancement courses can be offered [1]. We report on the design and implementation of the Dutch subject knowledge enhancement project Natk4all which has been running since 2015 [2]. The project is a joint effort of all physics departments and university teacher training programs of nine Dutch universities. Each year sixty engineers take physics courses taught by subject matter specialists of all universities involved. Quantum physics and Particle physics are typical topics that engineers usually have not encountered during their studies. Students appreciate the more conceptual approach as compared to mathematical approaches in the standard university physics curriculum. The blended learning format offers both online components and contact hours in which theory is clarified and exercises are worked on together. This format suits those combining their studies with a teaching job at a school. The chosen conceptual approach is highlighted via examples.

1 BACKGROUND AND CONTEXT

In many countries shortages of physics teachers urge policy makers and academics to find solutions [3]. In the Netherlands the numbers of graduating physics teachers are also not meeting the replacement needs of schools, with a reported 7.4% of the physics lessons taught by non-qualified teachers in 2015 and - with unchanged policies - an estimated gap of 10.5% in 2027 on a total of 1881 fulltime physics teacher equivalents [4]. Science Faculties at universities are also concerned to see the level of teaching go down at secondary schools as this is an essential cornerstone of a strong science tradition with substantial economic impact [5]. Therefore the Dutch Ministry of Education supported the Natk4all project that would help engineers and non-physics scientists become physics teachers [6].

Before the arrival of Natk4all, engineers were already allowed to enter physics teacher training programs at nine different universities after successfully completing a number of physics courses together with Bachelor physics students. For a substantial number of engineers this was no option due to the strong mathematical nature of these research oriented physics courses, often lacking more conceptual approaches which would fit the needs of physics teachers. Also rosters did not fit with job obligations thus excluding engineers who wanted to switch jobs or were already committed to teaching at schools. The yearly turnout of the nine university programs is 40-50 graduating physics teachers [7] of whom approximately two-thirds actually choose to become a physics teacher. In view of these numbers, clearly none of the nine university teacher training programs was having the economy of scale to design their own tailored subject knowledge enhancement courses for small numbers of students with an engineering background. A consultation study showed great willingness to engage in a joint effort to help engineers and non-physics science students become a physics teacher [6].

Governing design research questions of how the Natk4all project was designed and carried out:

- (Q-1) What physics subject knowledge needs to be taught and at which level?
- (Q-2) How to synchronize intake procedures of all nine universities?
- (Q-3) What characteristics of these courses fit best with the target group needs?
- (Q-4) How to embed a conceptual approach in the courses?

2 METHODS

With respect to the physics subject knowledge topics to be covered (Q-1) there are national and international listings of subdomains available for physics teacher education [8, 9]. An analysis of the Dutch national exam program syllabus further clarifies which topics should be mastered. Also prior intake data were available that could help set intake and matching standards (Q2). Semi-structured interviews with representatives of the Physics department and the Teacher training program were held at each of the nine universities addressing all four design research questions listed above (Q1-4). To ensure ownership of the project the final text sent to the Ministry of Education was agreed upon by all parties with signatures of all deans involved. Also a project contract was agreed upon and a steering committee was initiated with nine representatives which could decide on project policies and which could also act on local issues if needed (Q-2). For the characteristics of the courses such as home-study support and online features an analysis of the target group was made focusing on those already at work (Q3). The teachers assigned to each course by the university partners were gathered to discuss the options to embed a conceptual approach in their courses. Also consecutive teacher meetings were used to share best practices (Q-4). The Results section will discuss both the resulting design and what has been achieved in the period since 2015 when the subject knowledge courses were put in action.

3 RESULTS

3.1 Subject knowledge enhancement course contents

With respect to the physics topics (Q-1) it was clear that most engineers lack expertise in modern physics areas such as quantum physics, nuclear and particle physics and special relativity theory. Mechanical engineers do not need further courses on classical mechanics. Likewise electrical engineers already have in-depth expertise of electromagnetism. As the Dutch physics curriculum allows for electives such as biophysics and geophysics, these were also offered as courses and certified teachers lacking in-depth knowledge of these subjects were targeted. Finally, a course into the history and philosophy of physics was found to be helpful for aspiring physics teachers. With respect to the level of the courses all universities agreed that graduated engineers had already shown master level and they should not be rebuilt into research physicists. So, the first bachelor course in each subdomain would be the required

level. Depending on the emphasis of the topic in the examination program courses were categorised to have either 3 or 6EC size (1EC=28 hrs). Based on 2015-2018 course enrollments Table 1 lists the courses according to enrolment. The exam levels of the courses were achievable by most students with an average success rate of 82% at the first attempt. On average students enrolled in 2.5 (SD=1.8) courses, with some finishing them in one academic year and others taking two years to complete their physics courses. Despite serious advertising, master classes at teacher conferences and other communications we did not manage to engage many certified teachers into our course offerings with respect to the electives biophysics and geophysics (right column, Table 1).

Table 1. Subject knowledge enhancement courses taken by engineering students as part of their preparation to become a physics teacher.

Natk4all courses (% of students taking certain courses)		
50-100%	20-50%	0-20%
Quantum physics (6EC)	History & philosophy of physics (6EC)	Experimental physics (3EC)
Particle physics (3EC)	Mechanics (3EC)	Biophysics (3EC)
Special relativity theory (3EC)	Astronomy (3EC)	Geophysics (3EC)
Electromagnetism (6EC)	Thermodynamics (3EC)	

3.2 Intake of engineers for physics teacher training programs

All universities agreed to use the Natk4all course listing for their intake and matching (Q-2). This consensus was prepared at the Natk4all steering committee and then agreed upon at the national level by all university teacher training departments. This alignment resulted in a matrix for most common engineering programs versus physics courses (Table 2). As not all engineering programs are identical and students may take different electives, some tailoring was allowed for, based on the engineering course list that each student could produce. Some universities prefer their students to handle the subject knowledge enhancement courses first of all whereas other universities allow engaging in both physics and educational courses. A positive by-effect of the matrix was that some engineering students with teaching in mind now take Natk4all physics courses as electives in their engineering programs.

Table 2. Intake matrix (partly) mapping of engineering diplomas on physics courses. Elective courses Astronomy, Biophysics and Geophysics are not in this table.

Natk4all physics courses >>									
vv Engineering diploma	Mechanics	Quantum physics	Electromagnetism	Special relativity theory	Thermodynamics	Particle physics	Experimental physics	History & philosophy of physics	TOTAL (EC)
Mechanical engineering			6	3	3	3	3		24
Electrical engineering	3	6		3	3	3			18
Biomedical engineering		6	6	3	3	3			21
Architecture & building engineering		6	6	3	3	3	3	6	30
Industrial design		6	6	3	3	3	3	6	30
Civil engineering		6	6	3	3	3	3		24
Chemical engineering	3	6	6	3		3			21

3.3 Course design based on user requirements

The initial survey study and a needs analysis with respect to our target group led to a series of design decisions (Q-3):

Scheduling - Students should be able to combine physics and education courses with job obligations. We therefore choose to schedule all courses on Fridays. Students who already have a regular teaching job were asked to arrange with their schools to block this day for them. Also teacher training programs were not using Fridays for their courses.

Central location - Students live all over the country. We therefore selected a suitable and central location for course meetings, a school building in Utrecht in the middle of the Netherlands, next to the railway station.

Blended learning - Balancing home-study and contact hours is important. Relying too much on home-study would lower success rates and would introduce procrastination due to time pressure of school job deadlines. A number of contact meetings is required for peer interaction and teacher support. A blend was arranged of home-study tasks and scheduled meetings every fortnight. Home-study was supported by online knowledge clips and diagnostic tests, simulations and homework assignments. Theory

introduction of meetings were recorded for those not being able to attend sessions and for reviewing purposes.

Overview - To give students good overview each course is supported with a Moodle course site connecting with all resources, assignments and results. After the first year the set-up of these Moodle sites was synchronised to support easy navigation for students across.

Explaining and understanding - Students are preparing for teaching physics. They should therefore have conceptual understanding as just making quantitative exercises is not sufficient [10, 11]. This also relates to the fact that Dutch national physics exams contain numerous questions that require reasoning and explaining. See also paragraph 3.4 for examples.

Math support - In the first year we found out that some students were in need of support on their mathematical skills. The scheduled meetings were immediately extended with an extra optional math hour for those in need of refreshing their mathematical skills. Also online mathematics resources were presented for home-study purposes [12].

Quality assurance – University programs need assurance with respect to the level and quality of courses and exams as they are supervised by accreditation bodies. A committee of three physics experts was asked to check the course and exam quality. Comments were shared with teachers both individually and during teacher meetings on shared issues. The final report was then shared with the universities via the steering committee. Also student questionnaires were used for evaluation purposes. Course appreciation scores are high with an average 7.8 (SD= 0.5) on a 10 point scale (1=very bad; 10=excellent). In particular the course meetings were appreciated for high quality teachers and for peer interaction.

3.4 Conceptual approach

With respect to the conceptual approach that we advocated (Q-4) the survey responses indicate that mastering basic content comes first. Also the teacher training programs indicated that they would include subject specific conceptual understanding issues in their courses [13]. Nevertheless many colleagues were interested to see if we would succeed to combine basic physics coverage with improved conceptual understanding. Students at both secondary and university level should be able to handle questions that require understanding and reasoning, sometimes even without calculations. With respect to the implementation in the courses a number of conceptual exam questions are shown in Table 3. Another example from quantum physics is the assignment in which students present how they educate certain quantum concepts which are new in the school curriculum.

Table 3. Examples of explaining and reasoning questions, taken from different exams.

Course (teachers)	Sample concept question
Mechanics (Mudde & Dekkers)	If a solid box slides down a slope and a solid cylinder with the same mass rolls down the same slope (no friction, no slipping), which one will be at the bottom first?
Quantum physics (Vonk, Schoutens & van Wezel)	Close to absolute zero temperature a cloud of fermions will have lower density when compared to a cloud of bosons. Assume same weight for bosons and fermions. Explain.
Particle physics (de Jong & Kleiss)	How do we know that a neutron weighs more than a proton?
Biophysics (Opstal & Oostendorp)	Explain pressure differences in blood vessel branches.
Astronomy (Barthel & Lamers)	How do we know that there should be dark matter in the Milky Way?

4 SUMMARY AND DISCUSSION

The Natk4all program is a well appreciated set of physics courses for engineers preparing for physics teaching. The blended learning format suits the students who combine a teaching job and teacher training program. The setup and execution of the Natk4all program has received continuous support from all universities involved. As a by-product intake procedures for new physics teachers were synchronised. The conceptual approach aimed for was implemented by the teachers embedding this within a foundation approach covering the content and procedures of relevant physics subdomains at an academic level well above the secondary school exam level.

With 40-50 graduating physics teachers per year the numbers of engineering students engaging in Natk4all courses indicate that numbers will go up if they finish their studies. However the shortage of physics teachers has not been resolved yet. This emphasizes the importance of an integral approach of which this Natk4all program is just one stepping stone. Universities are now looking into ways to allow students to embed teacher training components in their bachelor and master program as an alternative to the capstone trajectory that most have to follow right now. With study loans for students instead of bursaries, 5+1 year trajectories are too long for many. Visibility of teacher tracks is also an issue. Engaging students in outreach activities appears to be a successful way of having students start considering a teaching career.

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Towards a Business Matchmaking Tool for Entrepreneurial Engineering Students and Entrepreneurs

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Conference Key Areas: Fostering entrepreneurship, University-Business cooperation, Educational and Organizational Development

Keywords: Business matchmaking, Entrepreneurship, Web-application, Django

INTRODUCTION

Educational context

The Faculty of Engineering Technology of KU Leuven participates in the Postgraduate Programme in Innovation and Entrepreneurship in Engineering [5]. This postgraduate programme is a joint initiative of faculties of the five Flemish universities that offer programmes in industrial sciences, biosciences, bioengineering and engineering sciences with the support of the Flemish Agency for Innovation and Entrepreneurship (VLAIO). The postgraduate programme aims to ensure that students are better prepared for the practice of their profession by focusing on the development of innovation competences, and enterprising and professional skills aside from technical engineering skills. The need for such a programme for engineers together with several educational methods to develop engineers in entrepreneurship in the context of an educational programme, are already discussed

in more detail in [1, 2, 4]. The postgraduate programme offers students three types of personal training projects: a team project, an in-company project or a start-up project. Discussing all three training projects is out of the scope of this work, but more information can be found in [5]. However, the start-up project is clearly the most important type of training project for the business matchmaking tool introduced in this paper. During the start-up training project, students get the chance to investigate the feasibility of a business idea, to implement a functional prototype as a proof-of-concept of the business idea, and to build up a business network. All of this is done within a safe educational environment under the supervision of business coaches, inspired by the ideas of a lean start-up [9]. Business coaches can advise students on technology and business aspects as they have a technological background as well as expertise in entrepreneurship. The quality of the start-up project is not measured in terms of ending up with a private start-up company, but it's of course not discouraged to do so.

Problem statement

Based on our experience in running the start-up project in the postgraduate programme for several years now, we notice that many of these students do not leave the postgraduate programme with an entrepreneurial adventure waiting to enter. There are various problems identified that can explain this, which will be addressed in more detail below. Another observation that can be made is that some students don't enter the postgraduate programme because of the perception that the focus is only on a private start-up. Some students are entrepreneurial students but don't want to become a full entrepreneur. Actually, a joint start-up with an entrepreneur, starting a new business from the ground up within an existing company or, in general, an entrepreneurial project, are equally well start-up training projects that the postgraduate programme is targeting. This finding is also confirmed by [6].

In the remaining part of this section, we discuss several problems mainly related to the first observation described above. A first problem is related to the initial business idea. At the start of the postgraduate programme, start-up students make a more extensive evaluation of their initial business idea by finding answers to three key questions. The first question forces the students to investigate the technological feasibility of their business idea. This question should be the easiest to answer as all students have an engineering background. Nevertheless, the answer to this question regularly reveals several major problems such as very high R&D efforts to build the product, intellectual property issues or high investment costs. The second question probes if the business idea meets the market, e.g. does it solve a so called 'customer-pain'. Forcing the students to meet with a potential customer often results in an interesting reality check that clearly illustrates that ideas should start from a customer's viewpoint and not from an engineer's perspective. Finally, the third question assesses the economic feasibility of the business idea. The latter question is the hardest to answer for our students as they typically lack valuable economical background expertise. After the answers on these questions are collected and analyzed, many students conclude that their initial business idea needs serious modifications or is not viable at all. Many students get stuck in fixing this issue. In conclusion, the first problem is about the availability of realistic business ideas for engineers as an inspiration source for their own ideas or as the starting point of an entrepreneurial project.

A second problem is related to a minimal set of team roles needed to run a start-up. Successful engineering start-ups need at least a technological expert, salesman and manager. These roles are seldom available in a single person which makes that some students decide they better not enter the training project. A well-chosen

cooperating entrepreneurial team can solve this issue. Unfortunately, the choice of the entrepreneurial team is currently rather limited in the educational environment of the postgraduate programme. Moreover, a few years of experience for some of these team roles can greatly increase the chances of success of the start-up. Hence, the second problem is about the availability of entrepreneurial minded people – having some experience is an extra benefit – willing to collaborate in an entrepreneurial relationship with students.

1 BUSINESS MATCHMAKING FOR ENTREPRENEURIAL STUDENTS

1.1 Business matchmaking approach

To tackle the observations and problems explained in the introduction, business coaches in the postgraduate programme experimented the last two academic years with a business matchmaking approach between entrepreneurial students and real-life entrepreneurs.

A cooperation with VOKA (Flanders' Chamber of Commerce and Industry) revealed that dynamic entrepreneurs often have valuable business ideas on the shelf but not always the time, the technological expertise, manpower or other resources available to translate these ideas in new business activities. Moreover, open-minded entrepreneurs are often willing to cooperate with students in the context of a joint-start-up or an entrepreneurial project within their company. Business ideas from entrepreneurs typically have some important advantages. Firstly, these business ideas are often demand-driven, i.e. based on requests from customers. That's already an excellent starting point to answer the second question of the business idea evaluation exercise. Secondly, an entrepreneur already critically looked at the economic feasibility of the business idea. Although this analysis is often more gut feeling than a deep economic analysis, it surely increases a positive outcome on the third question of the business idea evaluation exercise.

On the other hand, entrepreneurial students are young, flexible, highly motivated, social media skilled and well educated in engineering, but lack an inspiring business case or the experience of a real entrepreneur. These students can help in solving the resource problem of the entrepreneur. Especially their social media experience and knowledge on recent technologies (ICT, Internet-of-Things, Industry 4.0, AI, ...) can be very attractive in the digital transformation process of an existing company. Collaborating together with an entrepreneur creates by default an entrepreneurial team having several essential team roles on board to increase the viability of the entrepreneurial project. Moreover, the new team can profit from the existing business network of the entrepreneur. The entrepreneur can also choose to make financial or infrastructural resources available which again can boost the project. This solves at least partly the second problem described in the introduction.

1.2 Example cases

As mentioned above, the business matchmaking approach is already applied a few times in the past. We briefly discuss here two example cases.

In 2015, a student realized halfway the postgraduate programme that he was an entrepreneurial student for sure but less an entrepreneur. The technical and management skills were available, but taking risks inherently connected to entrepreneurship was not always acceptable to this student. Fortunately, he soon met a young entrepreneur in his business network who was looking for technological expertise to build a new innovative product to commercialize. He accepted the challenge to build this product as a freelancer. This was the start of a long term

cooperation between both. The product became successful and after his postgraduate program, he joined the entrepreneur's start-up as a shareholder and became the technology manager of the start-up. They worked on an improved version of the product and even started the launch of a second product in the same market. This example illustrates that entrepreneurial students should not always target a new start-up, but can become an important entrepreneurial member of an existing start-up.

A second example case was born out of a collaboration of KU Leuven and a local small and medium-sized enterprise (SME). In 2015, KU Leuven studied a proof-of-concept solution for a local SME to automate time registration and tracking of employees on building construction sites using a low-cost smartphone [8]. But many similar SME should have the same problem such that the idea of looking for a business case for this type of service became worth investigating. The owner and manager of the SME agreed on collaborating with entrepreneurial students to investigate the feasibility of the idea as a business product and, if successful, continue the collaboration as a start-up. The idea was proposed to students interested in the postgraduate programme and was picked up by a team of two electronics/ICT students. During the entire duration of the postgraduate programme, there was an intense collaboration between the SME owner, the students and a business coach with meetings every few weeks. A lot of effort was spent in developing a commercial prototype as this became a necessity to convince potential customers. Moreover, forced by legal regulations, a solution had to be developed to secure the privacy of the employees. At the end of the postgraduate programme in August 2017, one of the two students and the SME owner decided to continue their collaboration in a start-up.

2 BUSINESS MATCHMAKING TOOL

The main problem of the business matchmaking approach introduced in section 1 is the ad-hoc nature of this approach. Discovering business ideas from entrepreneurs strongly depends on the business network and the attention for this approach of the business coaches. Many companies are not aware of this initiative and consequently many business ideas are not revealed to the business coaches. There is no structural historical collection of business ideas and even exchanging business ideas between business coaches is not always sufficiently done. A similar situation as for entrepreneurs is true for engineering students. Many of them are not aware of the business ideas from, and the cooperation possibilities with an entrepreneur. Hence, they might miss the chance to start working on a strong business idea or even to participate to the postgraduate programme at all. It's also clear that the ad-hoc business matchmaking approach faces its limits when scaling up to larger numbers of business coaches, entrepreneurs and students. All these observations eventually led to the idea to design a web-based business matchmaking tool as a solution to the above mentioned problems. Moreover, this tool can also be used by students with a start-up looking for additional partners. The next subsection describes the functionality of the business matchmaking tool we have in mind while the final subsection briefly summarizes the technical design of the tool.

2.1 Requirements of the business matchmaking tool

The matchmaking tool should allow users - students and entrepreneurs - to create a profile, to upload business ideas and to send messages to take the first steps towards a potential collaboration. Currently, a LinkedIn login is required to use the matchmaking tool. Using the matchmaking tool without an account limits access to the landing pages. These landing pages are publicly accessible and provide the user

with enough explanation to what the goal of the tool is and who its primary target is. It also has a showcase of past projects with successful results. A user profile consists of a short bio and a list of skills, selectable from a list of tags, to assist a search tool. A business project page has a title, a project type, a short abstract, a more detailed project description and a set of project tags to ease searching. Settings allow to publish the project page anonymously or to hide confidential project information. A selected set of users can be given permission to read the hidden project details later on. The homepage of the tool allows users to search, to filter and to scroll through business projects. Business projects can be marked as favorite by adding them to a favorite list for quick access. Once a business project is selected, the public project details are shown as configured by the owner and a message can be sent to the owner to obtain more information or to discuss a cooperation. The first round of communication happens right in the tool itself using a basic chat-like messaging system. Messages are visualized in a message log for each business project separately. The matchmaking tool is designed with the focus on ease of use and not being too distractive. Big titles, short project descriptions and a system of tags and filters guide the user into selecting the projects in which he or she has an interest or finding another user with the skill-set required to make your own project a success. This makes sure the tool can be used across a vast number of professional sectors.

2.2 Design and development process

The matchmaking tool is created based on the principles that it must be easy, cheap and easy to adapt to how users actually use the matchmaking tool in order to improve the matchmaking experience and success. Therefore, an iterative development process with short loops of user feedback is used. This resulted in the choice of Django [7] as the web framework to build the tool. The main goal of Django is the rapid creation of complex, database-driven websites. Django allows for a lean development process with reiterations based on the short feedback loop. This helps in making sure the right tool is being built and the effort wasted on less required features is reduced to a minimum.

The matchmaking tool is mainly built upon a database, from which all the visual pages are constructed using templates. The database consists of projects, users, tags and message data and is built in a way that it is easy to extend or modify. The database tables and fields are specified as Python classes. Django will create the queries to perform all Create-Read-Update-Delete (CRUD) operations on the database. This means the database definition stays the same no matter what implementation is used. All queries are written as Python functions and translated by Django to the underlying database implementation (sqlite3 for example). By providing a database and templates, Django acts as a Model-View-Controller (MVC) that dynamically builds the web pages. These templates are generic Hypertext Markup Language (HTML) files with a Django-specific mini-language consisting of template-tags which allow for database access, if-cases, for-loops, parsing of strings, etc. This results in a loose coupling between the user interface and the database-driven back-end of the tool. Designing the templates thus is completely separated from the database and other back-end logic and can be done the same way other web pages are designed. The job of the MVC-controller is to make sure all the correct data is handed to the template files. Generated template files can be cached using Django's caching system for faster rendering times of the tool. Django's back-end also provides a number of features to ease developing such as authentication, authorization, sessions and an admin tool.

3 BUSINESS MATCHMAKING PROCESS

The business matchmaking tool introduced in section 2 only has meaning when integrated in a more comprehensive business matchmaking process. The current process contributes to five activities.

1. Collecting business ideas. This includes business cases that are free to use or require an entrepreneurial relationship with the owner.
2. Attracting open-minded entrepreneurs willing to establish an entrepreneurial relationship with students.
3. Attracting students with an entrepreneurial mindset looking for inspiration or a business cooperation.
4. Detecting a business matchmaking in making and facilitate the business matchmaking between the stakeholders.
5. Monitoring the tool to detect and to filter inappropriate usage, e.g. fake profiles, unrealistic business cases or abuse of the message functionality.

For all these activities, a number of actions are planned which will be briefly discussed now. The first three activities require creating awareness of the business matchmaking potential to mainly entrepreneurs, organizations involved in entrepreneurship and entrepreneurial students looking for business ideas or business partners. The business and certainly the student network of the business coaches in the postgraduate programme is a starting point but additionally an intense collaboration is set up with VOKA to promote business matchmaking with students among their impressive business network of companies and entrepreneurs. As VOKA regularly organizes business events and publishes a monthly business magazine, there are plenty of opportunities to launch and to repeat calls and to demonstrate the business matchmaking tool several times a year. Moreover, a web page with different successful example cases will be added to the business matchmaking tool to inspire visitors and to increase the attractiveness of the tool. The fourth and fifth activity strongly depend on the human interaction of the existing business coaches of the postgraduate programme and VOKA. Ideally, every user profile added to the tool is screened on the correct intentions. That shouldn't create a huge problem for student profiles as they already study in an engineering program of KU Leuven and, hence, quite some information can be easily obtained. A short interview is planned with active users – students as well as entrepreneurs – to make sure there is no misunderstanding on participating to the business matchmaking program. Monitoring messages and the message activity should help to detect an early business matchmaking case. In that situation, additional help will be offered to the involved actors such as, for example, the expertise of a business coach or advice related to the cooperation contract.

4 DISCUSSION

Remark that the business matchmaking tool is currently under development. As such, this is work in progress. Nevertheless, a limited survey was conducted among entrepreneurs on a business event of VOKA to obtain feedback on the business matchmaking idea and to map their view on the business matchmaking tool [3]. A number of conclusions can be drawn from this survey (i) most entrepreneurs have one or more business ideas but lack resources to execute them, (ii) the idea of business matchmaking using a digital tool is welcomed positively and many of the business idea owners would like to stay involved when the idea is realized, (iii) entrepreneurs often attach importance to controlling who has access to the publication of their profiles and the business ideas, mainly because of competitors of

the company they run, (iv) the business matchmaking tool should be reliable, and (v) tool usage should be efficient and may not consume a lot of time while still creating a kind of sense of community using digital interaction. This feedback is reflected as much as possible in the design of the business matchmaking tool, for instance, several settings to publish parts of information anonymously are included and only a limited amount of information is required to create a profile or upload a business idea. Moreover, the tool is not designed nor promoted as a time-consuming social media tool.

The business matchmaking tool and process will trial-run from September 2017 to August 2018, but smaller user tests are of course organized before that date and adjustments are made, if necessary. During the trial-run, we target a modest amount (i.e. around 50) of business ideas and business profiles of students and entrepreneurs, and a limited amount (i.e. around 5) of effective business matchmakings such that the corresponding workload, mainly created by activity 4 and 5 of the business matchmaking process, is manageable by the existing business coaches. In the future, other actors involved in business networking and entrepreneurship will be included, which will increase the demands and workload but also the number of business coaches. Nevertheless, it could be interested to investigate if artificial intelligence techniques could further automate these activities, but this is out of the scope of the current project.

Based on the business matchmaking cases set-up in the past without using the business matchmaking tool, we discovered some points of attention. Building a relation of trust between the actors involved in the business matchmaking process, takes time. Before the cooperation starts it's very important to discuss, preferably resulting in a signed cooperation contract, the modalities of the cooperation, e.g. ownership and intellectual property of the results so far, financial aspect, etc., in case the cooperation is terminated at some point in time. Another point of attention is a certain unbalance in the cooperation between a young and unexperienced student versus an experienced and often successful entrepreneur. These points of attention will not be solved by a digital matchmaking tool, but are additional tasks for the business coach to monitor.

5 ACKNOWLEDGMENTS

This work was supported by the Province of Flemish Brabant and Smart Hub Flemish Brabant (www.smarthubvlaamsbrabant.be) in the context of the Connect-ID project.

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Entrepreneurship Education Ecosystems in Engineering and Technology (E4T)

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Conference Key Areas: Engineering Skills, Innovative Teaching and Learning Methods, Fostering entrepreneurship

Keywords: entrepreneurship, ecosystems, incubators, engineering, technology

INTRODUCTION

Vibrant entrepreneurship ecosystems have developed within the CLUSTER Consortium (www.cluster.org) universities with significant contributions to European and global startups and entrepreneurial initiatives. CLUSTER is a consortium of 12 top engineering and technology universities in Europe and 6 top-level associated members from other continents. A subset of the CLUSTER members is involved in the E4T (Entrepreneurship Education Ecosystems in Engineering and Technology) Erasmus+ Strategic Partnership project (2017-1-SE01-KA203-034536) which develops interactive programs for our students to participate in piloting and co-creation of a joint program ingrained within these ecosystems.

The overall aim of the study is to provide more graduates in engineering with entrepreneurial ambition, culture and skills, and to draw on the entrepreneurial ecosystems as a platform for inspiration, as follows: 1) Develop models for

ingraining entrepreneurship education into specific engineering and technology M.Sc. curricula at the partner universities; 2) Drive new course concepts into the policy actions of the partnering universities at the level of the Faculty/Dean/Programme director/individual teacher; 3) Build a network for Entrepreneurship education by implementing a pilot between the CLUSTER Universities within their innovation and entrepreneurial ecosystems; 4) Share best practices for promoting hands-on-entrepreneurial skills within accelerators, local hubs, technology platform and student - driven start-up activities; 5) Piloting of the educational ecosystem network in collaboration with a dynamic set of stakeholders including academic institutions, companies, local, regional and national agencies and most importantly our students as co-creators of their education, 6) Create university-level and transnational training programs for teachers and professors to integrate elements promoting the development of entrepreneurial skills via specific engineering/technology/ science disciplines.

1. BACKGROUND

Universities, education systems and societies are undergoing major structural changes, and future employment of graduates calls for innovative integration of entrepreneurship into their disciplinary knowledge and skills. The Cluster Consortium has responded to the multidisciplinary challenges of future education by building entrepreneurship ecosystems which can support the development of entrepreneurial skills. However, there is not one unique method by which entrepreneurship skills can become integrated into education, rather it is important to recognize that the fundamental challenge is ingraining and embedding entrepreneurial educational contents into the major and minor specific courses that the students pursue.

It is important to recognize that entrepreneurship per se can be viewed as a specific discipline, eg. in business schools, however, in engineering and technology, the core of the educational outcome is based on a strong disciplinary knowledge in technology, engineering and science. Namely, a student in chemical engineering, electrical engineering, mechanical engineering etc. must acquire an understanding of entrepreneurial approaches through a strong foundation in the future applications in chemistry/automation/ mechatronics etc. This foundation, when embedded into an entrepreneurial mindset is the basis for fueling the emergence of innovations. Accordingly, at Cluster universities the aim is to enable each student to become engaged in the respective entrepreneurship ecosystems and to develop an entrepreneurial mindset. The extent to which a student adopts such working skills, will vary. Some may end up as experts of in-house entrepreneurship within companies and industry, some as interlocutors between the needs of society and agencies for delivery of hands-on outcomes of emerging innovations, and some may found a start –up and becoming an entrepreneur. Such skills, adopted by graduates, are a crucial driver for future European economy and welfare.

For universities of technology, engineering and science this poses a specific demand as it is not sufficient to link entrepreneurship studies to content and delivery of education. Rather, content and delivery of disciplinary studies must serve as enablers of development of entrepreneurial skills for future graduates.

The overall objective of the present study is therefore to provide more graduates in engineering with entrepreneurial ambition, culture and skills (eg. proof of concepts phase for startups).

2. OBJECTIVES OF THE STUDY

The specific objectives of E4T are to:

1) Develop models for ingraining entrepreneurship education into specific engineering and technology curricula at the M.Sc. level at the different partner universities. This should happen by embedding and ingraining entrepreneurial skills into the disciplinary studies of students at technical universities. This process will also aim to change the traditional view of top University Management about the delivery of discipline-specific teaching to support teachers in their quest to integrate entrepreneurial skills into engineering/technology/science courses. This should lead to drive new course concepts into the policy actions of the partnering universities at the level of the Faculty/Dean/Programme director/individual teacher.

2) Create university-level and transnational training programs for teachers (professors/academic staff/lecturers) to integrate elements promoting the development of entrepreneurial skills via specific engineering/technology/science related disciplines. This will be achieved by developing learning and coaching methods, tools for providing feedback, and how to manage group dynamics and approaches to assessment of development of skills via feedback from students and stakeholders. Teachers who are interested in integrating entrepreneurship will be provided with approaches into their specific engineering/science /technology courses with clear instructions for the amount of time, resources, student and teacher work, spaces etc. that the teacher and the university should take into account when planning and executing these courses. These quantitative estimates of workload, time and teacher /student input are also used to engage program leaders/deans to adopt such courses into the curriculum, as they will require special arrangements and do differ from traditional curriculum design. By collaborating in the transnational setting, the teachers can support the development of student worldviews, as a key to global entrepreneurship and in cooperation with national, regional and local stakeholders of the participating partner universities.

3) Build a network for Entrepreneurship education by implementing a pilot between the Cluster Universities within their entrepreneurial ecosystems. The partners will in this way share best practices for promoting hands-on-entrepreneurial skills within accelerators, local hubs, technology platform and student - driven start-up activities.

Each ecosystem in which entrepreneurial skills develop is part of dynamic processes that are influenced by local and regional stakeholders, which vary from country to country and location to location. Education in these ecosystems is influenced by a dynamic set of stakeholders including academic institutions, companies, local, regional and national agencies, with the values and ethics of society and culture adding a specific flavor to the ecosystem, which will all be taken into account and analyzed to collect and share good practices.

The main final expected tangible results at the end of E4T lifetime can therefore be summarized as follows:

- A constantly updated report on the state of the art for what concerns the existing entrepreneurship and innovation ecosystems at the partner universities, best practices inside and outside of the consortium and status at technical universities for the introduction of elements of entrepreneurship education in their curricular and extra-curricular activities;
- Articles on Entrepreneurship Education as a result of the carried out activities presenting some recent and relevant analyses based on case studies of technical universities in Europe;

- Success stories/Case studies to be made permanently available on E4T website as well as videos and written testimonials;
- A consolidated programme on entrepreneurship for engineering studies running every year with the support of private sponsors;
- Online facilitation tools to support the trainers in delivering the above mentioned programme and to introduce entrepreneurship education in the curricular activities;
- A number of start-ups created by the graduates attending the programme and working in teams;
- A number of international entrepreneurs profiles active in the labour market;
- A permanent network of universities aiming at promoting entrepreneurship elements in technical studies.

3. COMPLETED STEPS

The first two steps of the study have been completed in April 2018 and the remaining actions are currently being defined under the “Development” phase and will be finalized in June 2018 when the course will be launched.

3.1 State of the Art

The first step in the study focused on a report on best practices and repository on the integration of entrepreneurship education in the curricular and extra-curricular activities of technical universities. E4T has covered both best practices identified within the consortium and at other leading universities around the world in terms of programmes in place, objectives, target groups, teaching methodologies, barriers to the introduction of entrepreneurship education in the curricular activities of technical universities. Such an extensive report with a transnational perspective was so far not available and the same goes for the repository of best practices in entrepreneurship education.

Regarding entrepreneurship education in the curricular and extra-curricular activities, the review showed that all studied Cluster universities have substantial activities ongoing. For example all universities had both accelerators and co-working spaces dedicated to supporting entrepreneurial activities. Some notable examples include the pre-incubator at KTH that aim to support the commercialization of ideas from researchers and students: KTH Innovation. This pre-incubator functions as the main gateway to the university’s innovation support system, which has several incubators and co-working space. KTH Innovation receives ideas from individuals and supports their development, often by linking an initial technical solution to potential target markets and suitable business models. The ideas are evaluated in a systematic process, and supported until it becomes possible to start work on realizing it. They also to some extent educate the founding team with basic entrepreneurial tools. If the idea remains promising, or can be developed into a pursuable start-up, it gets channeled to the main incubator STING (Stockholm Innovation and Growth), or to accelerators at the EIT hubs, or other affiliated entities in the Stockholm startup ecosystem. In total there are more than 13 different entities available in this diverse and loosely connected system, functioning as a nurturing living network of nodes for unplanned interaction, idea exchange, and specific technical specialization.

Other universities, for example Darmstadt Technical University and KU Leuven, appear to have a more integrative approach, converging activities to a central place with capabilities to support cross-discipline interaction. One example is the “Home of

Innovation, Growth, Entrepreneurship and Technology Management" (HIGHEST) portfolio of initiatives at DTU. It includes seTUp-Programm, a 6 months accelerator program, HIGHEST-Summer School (for TU students), workshops by the HIGHEST-Buddies (e.g. pitch-training, design thinking, agile teamwork), and a bi-monthly Founders table. Founders can also get individual coaching, consulting and workshops from HIGHEST Startup consultants. At KU Leuven, the "Leuven Community for Innovation and Entrepreneurship" (Lcie) functions as a one-stop shop for students, researchers, professors and alumni. Lcie connects entrepreneurially minded individuals to stimulate, encourage and support entrepreneurship. Its goal is to foster entrepreneurship at the university, thereby acting as a change agent in embedding entrepreneurship into the curriculum where deemed useful. Lcie plays as coordinator of initiatives, support for activities, and provides coaching tailored to individual needs. More than 400 students in almost 100 teams have received coaching so far. The resulting startups have raised more than 9 million euro of capital and employ more than 75 people. Lcie is now being consolidated and seeks an appropriate governance structure to embed the initiative.

In total, there is currently at least 33 accelerators and 26 co-coworking spaces at the 8 investigated universities, including Kiuas, TeamUp, and StartUpSauna at Aalto University, SSES and STING at KTH, IstartLab at IST Lisbon, Tangent at Trinity, LRD at KU Leuven, I3P, Treatbit and Click at Politecnico, and the European Innovation Academy (EIA). There is considerable heterogeneity among these initiatives in terms of organization, tech-transfer focus, degree of field specialization, openness to the society in general (e.g. collaborations with companies), and collaborations with incubators and venture capital organizations. Most universities report challenges in coordinating all these activities and that the support from university government bodies is fundamental. In addition to these initiatives, all universities also give courses in entrepreneurship and innovation and most have course offerings for all levels of study. However, even though there is a great interest for these courses, many universities face difficulties making them available to the broad population of students, as they have to compete with many other courses for those rare electable credits in the programs.

The international benchmark is still ongoing. Tentative findings include that many of the successful universities appear to have a central entity nurturing entrepreneurial competence and activity that coordinates teaching and support (eg. HEC, TU/e, EPFL, Stanford). Some, but not all, also integrate entrepreneurship research into these units. Occurring at several locations is the approach to have students working on projects in cross-disciplinary teams. In some cases individuals compete to make the team select their business idea, but in others they are given a challenge from a company or a community entity (eg McMaster University). These challenge-driven programs appear to have a large personal impact on those involved, including a feeling of contribution to solving an important problem. An example is the Innovation for Change (I4C) programme, by the Politecnico di Torino, SAFM (Scuola di Alta Formazione al Management) and CERN. I4C is a competition between multi-disciplinary teams that aims to find an innovative solution to some global issue. Eight teams of MBA students of SAFM and PhD students of the Politecnico di Torino work in Geneva and Turin for five months between training sessions and group work. The project involves collaboration with several institutions and companies, exposing the students the challenges on which to focus their efforts to find practical solutions. The teams work with global challenges based on the 17 United Nation Goals for sustainable development. They are supported by SAFM alumni, who have become entrepreneurs or work in large industrial groups, as well as by researchers at CERN

and Politecnico. In their work they can use tools and advanced technology solutions up to the realization of prototypes. IdeaSquare, the experimental structure of CERN dedicated to projects of research and development and interdisciplinary programs, is at the students' disposal to work on these projects. Regarding barriers and challenges to ingraining entrepreneurship into curricular and non-curricular activities, the most important appear to be the resistance to change, both from the administration and from conservative faculty members. Considerable bureaucracy tends to slow down progress of integrating entrepreneurship. It is also often hard to make entrepreneurship a priority for the technical faculty, as their own field tends to come first. It is therefore important to design initiatives to be resilient and focus on the long-term impact. In many cases it has taken more than five years to build the activities that now are strong models to follow. To some degree, it is possible to overcome resistance by acting entrepreneurially and by putting some initiatives outside the university bureaucracy. These can then support the efforts as show-cases of success.

3.2 Creating Awareness

The second work package focused on creating awareness and motivation (students at an early stage, teachers, Deans, Programme Directors, university management) about the advantages and importance of entrepreneurship for engineering students and make the process viable (marketing and sales activities approach) through a bottom up approach. Indeed, Souitaris et al., (2007) show that entrepreneurship courses raise some attitudes and the overall entrepreneurial intention and that inspiration (a construct with an emotional element) of science and engineering students.

Structure of the WP:

- a. Choose success cases/stories
- b. Case descriptions with video and short text
- c. Event format for promoting
- d. CLUSTER symposium in November 2017 can be part of this WP

Dissemination of Best Practices will continue throughout the E4T-project as the goal is to produce novel content on entrepreneurship education ecosystems in the context of engineering. Furthermore, we are working on developing a showcase where an assessment method is developed for analyzing the learning outcomes of entrepreneurship education practices.

The goals of the dissemination in the present study is to raise awareness on entrepreneurial education and to share tools to support the development of flexible models for entrepreneurship education ingrained into our ecosystems. Moreover, we aim increase the availability and easy access of different ways of acquiring knowledge and working life skills through development of an entrepreneurial mindset. Accordingly, our target groups for dissemination are stakeholders of academic education: students, teachers, program leaders as well as support and management of teaching development (Table 1).

Table 1. Aims and outcomes for target groups

Aims	Students	Teachers	Teaching Development and Management

Increasing awareness of the available entrepreneurship education	Increased awareness of courses, accelerators, spaces available at E4T universities offered for the targeted student groups / courses	Building a network between the entrepreneurship ecosystems through the E4T-project	Inspirational material e.g CLUSTER-meeting 2017: key note speakers, workshops, available on CLUSTER and E4T project web pages
Sharing best practices	Learning to work in different ecosystems through pilot program, enhancing student European/Global citizenship	Experience exchange workshop(s) for entrepreneurship teachers within E4T-project	Integrated pedagogical & entrepreneurial support for teachers & courses video material on CLUSTER and E4T project webpage
Making available	Financial support (E4T project) to access European/Global entrepreneurship education	Contacts and possibility in the future to visit different project partners' entrepreneurial ecosystems	Documented experiences on teaching in entrepreneurial ecosystems; how to integrate entrepreneurship into engineering education

Making the above actions visible will allow us to also increase the awareness of deans and university leadership of the needs and the challenges of integration of entrepreneurship education into engineering education, which is not the same as purely offering entrepreneurial courses or programs. Rather, this requires more extensive and targeted multidisciplinary approaches and possibly also changes in curricular structures. Moreover, through this study we also aim to create societal impact by influencing the mindset of our future graduates to become active contributors to the wellbeing of society through an innovative capacity and ability to present new solutions to global challenges. In order to achieve such goals it is important to offer our students the possibility to visit, learn and collaborate with students and teachers from other entrepreneurial ecosystems across Universities in Europe.

Concrete outputs from the above actions (Table 1.) are:

- information on engineering education which integrates entrepreneurship in different formats in our ecosystems
- visibility of accelerators to students who wish to pursue entrepreneurial activities in different European University systems
- possibilities for students and staff to visit and experience inspirational spaces in our ecosystems
- support for teachers to integrate entrepreneurship in teaching

Dissemination of the activities has been carried out as part of the CLUSTER network actions during 2017 and the work will continue as the study proceeds. Namely, the Vision, Mission and Values of the CLUSTER network have focused on Entrepreneurship Education as one of the key actions of the network (www.cluster.org). The topic for the CLUSTER symposium in November of 2017 focused on Entrepreneurship in Engineering Education (<http://cluster2017.aalto.fi/en/>). In order to make the contribution of the symposium visible to the target audience of the E4T project, all presentations of the symposium were recorded on videos and can be accessed through the CLUSTER

webpages. Work on the video – materials in ongoing, and the aim is to create a repository for teaching materials for teachers to access and share. Moreover, distributing information through other media is also under consideration. The CLUSTER symposium panelists included leading presenters in the areas of entrepreneurship education (<http://cluster2017.aalto.fi/en/videos/>) and all sessions of the symposium were delivered as hands-on pedagogical workshops for teachers to share Best Practices in integration of entrepreneurship into engineering education.

4. NEXT ACTIVITIES

One of the main outputs of E4T is the creation and piloting of a specific course on international entrepreneurship aiming at joining forces and offering a mobility scheme to Master students in their final year and to graduates currently enrolled in one of the courses offered by the partner universities to spend a short period at one of the other institutions in order to get exposure to a different ecosystem and specific elements and approaches not available at the home university. The combination of the seven ecosystems, their specificities and the courses/modules offered will be presented as a single product with joint marketing efforts, joint recruitment, joint selection and mutual recognition. This activity will both strengthen the single ecosystems and enhance their visibility on European scale. Indeed, entrepreneurial mobility literature (Filatotchev et al., 2011) show that returnee entrepreneurs can create a significant spillover effect that promotes innovation in other local high-tech firms in the home country of the returnee. Indeed, international commercial expertise and an international reputation open up possibilities for improving the drivers of internationalizing new ventures or newly created global ventures. However, Siegel & Wright (2015) show there is a lack of evidence on the benefits to host country universities that may arise from collaborations with students interested in entrepreneurship who return home. E4T can help to better understand these benefits.

As part of the dissemination activities, the E4T project will be concluded by an “Entrepreneurship Olympics” event in 2020. The plan is that students who have participated in the piloting of the E4T program in the different ecosystems of the partner universities, will present their projects at this event. Stakeholders from industry (including start-ups and established companies), academia and society will be invited to attend and contribute to taking the most promising projects further.

Mathematical Competencies for Engineers

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Keywords: mathematics in engineering, competencies, math skills

INTRODUCTION

Mathematics as generally accepted subject forming background of engineering sciences throughout all disciplines is often questioned with respect to its real role in the engineering study programmes at technical universities worldwide. Many studies presented at SEFI conferences pointed to considerable decline in actual knowledge and understanding of mathematical concepts for engineering students nowadays. SEFI Working Group for Mathematics in Engineering Education, webpage [1], is actively dealing with this problem. Efforts of WG members resulted in introduction of new concepts, mathematical competencies, regarded necessary for future engineers to their successful professional careers. These ideas should be mirrored in new curricula design of mathematical courses for engineering students. Latest third curricula publication by SEFI MWG, see [2], that is available at the WG webpage, provides rough guidelines for design of a reasonable applied mathematics course reflecting real needs of future engineers. They urgently need to obtain several specific mathematical competencies during their studies, which could be used later in their professional scientific work in particular technical discipline, where the need to solve various applied mathematical problems appears quite often and it is necessary for successful fulfilment of the various engineering tasks themselves.

1 GENERAL CONCEPTS

1.1 Concept of mathematical competence

Concept of competence in terms of education has been recently described in various resources. Education and obtaining knowledge are activities connected to process of acquiring specific competencies during the teaching/learning process, specifically related to particular subjects. Definition of mathematical competence appeared in [3], “Mathematical competence means the ability to understand, judge, do, and use mathematics in a variety of intra and extra-mathematical contexts and situations where mathematics plays or could play a role. Necessary, but certainly not sufficient, mathematical competence prerequisites are: a lots of factual knowledge and technical skills, in the same way as vocabulary, orthography, and grammar are necessary but not sufficient prerequisites for literacy”.

There exist many reasons for which the presented concept of mathematical competence was adopted for the third edition of the MWG curriculum document. One of them is the fact that the primary goal of mathematics in engineering education can be emphasized straightforwardly if we are focused on the above defined concept of mathematical competence in teaching engineering students. The ability to apply mathematical concepts and procedures in relevant contexts, and to work with engineering models and solve engineering problems using acquired mathematical knowledge and skills is essential in engineering research. Any competence requires a steady base of knowledge and skills, which is an evident idea strongly supported by many experienced teachers of mathematics at technical colleges and universities throughout the Europe. Current trends in general engineering education also support the concept of competence, which has been frequently used to describe educational goals favouring action-based knowledge over formal knowledge held just for the good performance and effectiveness at exams.

1.2 Mathematical competencies and their meaning

Eight recognised mathematical competencies, as defined in [3], can be roughly distributed into two groups, depending on their character and meaning.

The first group consists of competencies related to understanding mathematical concepts, dependencies, structures and their relations, ability to understand and apply known mathematical statements and to express own ideas mathematically in different ways. These competencies are: thinking mathematically, reasoning mathematically, representing mathematical entities, communicating in, with and about mathematics.

The other group can be recognised as a bunch of more practically oriented competencies, the ability to identify and specify mathematical problems in the practical engineering applications, to solve these problems using adequate algorithms and mathematical procedures by means of available aids and tools. Here one can include competencies: handling mathematical symbols and formalism, posing and solving mathematical problems, modelling mathematically, making use of aids and tools.

Various ideas and good practice examples of innovative competence based curricula structure applied in engineering maths courses have been presented and discussed, based on practical experience, results and deductions of numerous discussions and analyses that were presented orally or as poster contributions of participants at the SEFI MWG seminars held regularly, and addressing intentionally topics covered in this presented third edition of curriculum document. Full paper versions were printed in several issues of the Proceedings available on-line at the MWG webpage.

Many questions are arising in this context: What is the real role of mathematics in engineering education? Which mathematical competencies are most important for engineering sciences? How can we assess mathematical understanding properly?

Bi-annual seminars organized by the SEFI Working Group for Mathematics in Engineering Education at the volunteering universities throughout the Europe strive to find answers to formulated questions. Good experience and practise with various innovative scenarios of mathematics lessons and methodology of didactics are always presented by conference participants, who are real practitioners, mathematics teachers and educators at technical universities and colleges. Several European projects were initiated within the SEFI MWG members' cooperation, for instance the following three Erasmus+ Projects within the Strategic partnership call.

2 NEW INITIATIVES AND GOOD PRACTISE IDEAS

2.1 Project DrIVE-MATHS

Good experience and practise with various innovative scenarios of engineering mathematics courses appered recently in the ERAZMUS + project frame Strategic partnership. DrIVE-MATHS, Development of Innovative Mathematical Teaching Strategies in European Engineering Degrees, is project aimed at developing a novel and integrated framework to teach math classes in engineering courses at the university level. Maths department at the Politechnical Institute in Porto, Portugal is the project coordinator, and partners are from University of Claude Bernard 1, Lyon, France, Technical University in Chemnitz, Germany, and Slovak University of Technology in Bratislava, Slovakia, see webpage [4].

The traditional way of teaching math classes based on a 'teaching by telling', or 'chalk and talk' approach, especially in the first years of the university degrees, proved to be no more acceptable. It is characterized by large classes and single-discipline teaching, based on lecture-based delivery. Recently there has been a growing interest, by the engineering professionals and the bodies for accrediting engineering degrees, in promoting a change in this paradigm. The proposed new teaching paradigm consists in the implementation of slight adaptation of course curricula, more emphasize on the problem-based-learning (PBL) approach, and learning by doing (hands-on). Application of the EduScrum as a pedagogical approach, promoting active learning (AL) by working in real world engineering problems and Jigsaw - as opposite to teacher centred methods will be introduced for basic mathematics courses in bachelor programmes.

In the PBL curriculum, students achieve competences, analyze, identify and solve problems, by relating disciplines to each other. Students develop competences such as critical thinking, agility and adaptability, communication, collaboration, initiative, analyzing and conceptualizing information, curiosity and imagination. They are an active part of their learning process and the teacher acts as a guide by proposing new research directions, methods, and tools. Hands-on experimentation, or learning-by-doing, is an essential part of the knowledge process. It enhances the desire to learn, promotes self-learning skills, and offers an efficient involvement of math subjects and engineering environments.

EduScrum creates an environment where students are the owners of their knowledge, increasing the sense of self-initiative and entrepreneurship. Applying the EduScrum methodology enhances collaborative learning, emphasizing the students' interactions with each other. Students are involved in small groups and work towards a common goal – learning, while being evaluated individually. In this sense, the math curricula teaching will be modernized and updated to include these new methodological teaching strategies. This modernization may contribute to award the EUR-ACE (European Accreditation of European Programs) to accredited engineering degrees at partners' universities.

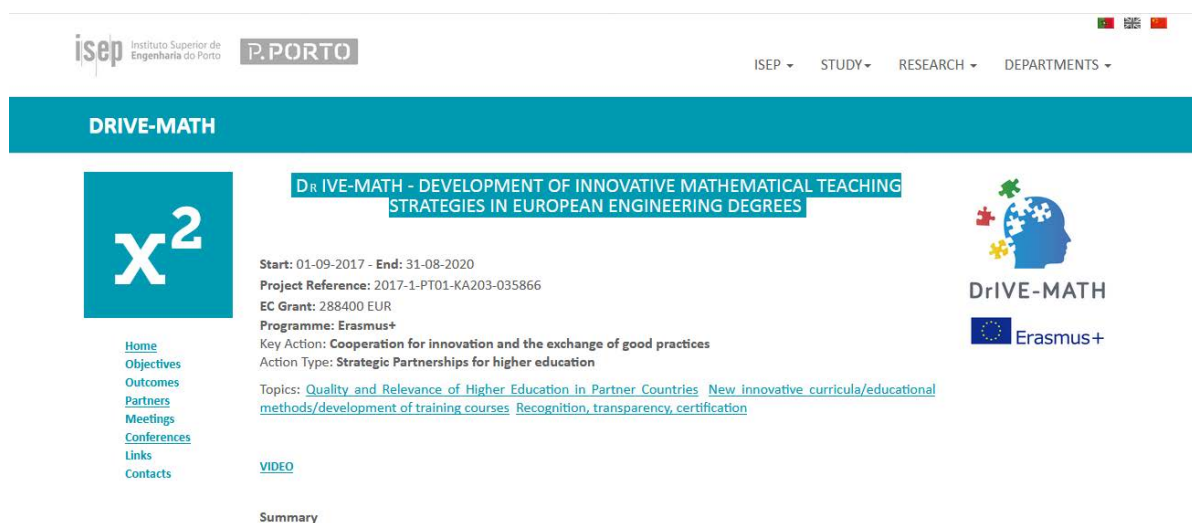


Fig. 1. Webpage of DrIVE MATHS project.

2.2 Project Rules Math

New rules for assessing mathematical competencies form the main idea of the project Rules Math, coordinated by Salamanca University in Spain, with partners at Coimbra Institute of Engineering in Portugal, Dublin Institute of Technology in Ireland, Czech Technical University in Prague, Czech republic, University of Plovdiv Paisii Hilendarski in Bulgaria, Gazi University in Ankara, Turkey, Technical University of Civil Engineering in Bucharest, Romania and Slovak University of Technology in Bratislava, Slovakia, see webpage [5].

Project team is working on development of a collaborative, comprehensive and accessible competencies-based assessment model for mathematics in engineering context, and aims to elaborate and collect the resources and materials needed to devise competencies-based assessment courses. Results will be disseminated to European HEIs through the partner networks and also all over the Europe.

Project will focus on mathematical competencies and not just on the mathematical contents, which was the case in earlier times in other educational projects. Since mathematics lecturers are much more familiar with the content view (the mathematical structure) it is a major challenge for them to deal with competencies-oriented assessment goals. This project may provide material for supporting them in this respect. Furthermore, the development of a new mathematical approach is being demanded by engineering and science trainers to motivate students, and also for students to be motivated with mathematics learning.



Fig. 2. Webpage of Rules Math project.

2.3 Project Future Math

New scenarios of the educational process need also new instructional materials, and development of innovative teaching resources was one of the aims of project Future Math – Enhancing Learning and Teaching of Engineering Mathematics with Technology. Project coordinator is at the Tampere University of Applied Sciences in Finland, and partners are Politechnical University in Madrid, Spain, Technical University of Civil Engineering in Bucharest, Romania and Slovak University of Technology in Bratislava, Slovakia. Project goal is to respond to the requirements of the modern society and to make mathematics' learning and teaching more digitalized, effective and accessible. Additionally, the aim is to explore and develop the most motivational, learner centred methods, techniques and resources for engineering mathematics learning and teaching with the help of technology. All the learning resources developed in the project are made available for free under the idea of Open Source or Open Educational Resource (OER) at the project Mathematical Learning Platform, and are accessible from the project webpage [6].

In addition to the open mathematics learning platform with materials and resources, project aims to develop innovative pedagogical methods and techniques not only to teach and learn mathematics but also to assess mathematics' learning. The key approaches are i.e. collective thinking, collaboration and shared problem solving skills - the skills that are necessary for success in working life. Furthermore, project resources are designed in various styles, so that these materials could respect individual learning solutions. Therefore, different learning types are taken into account in the project's material production. In this way, it is also possible to decrease the inequality among different kinds of learners.

Overall, the one main objective of this project is to increase the global large-scale awareness about the possibilities which new ubiquitous technology offers for mathematics learning throughout MLP in order to make mathematics learning more motivational, interesting and to increase accessibility and the alternative modern methods for mathematics learning.

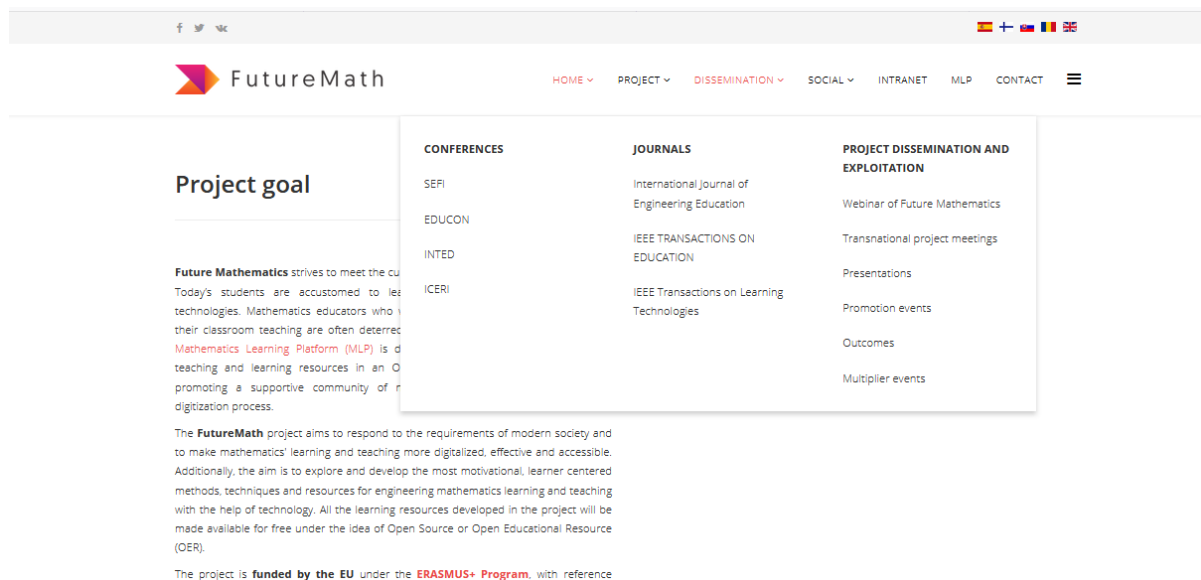


Fig. 3. Webpage of Future Math project.

3 SUMMARY AND ACKNOWLEDGMENTS

Engineering students lack essential competences in a world of rapidly changing and dynamic working environments. The latter require constant creativity, analytical thinking, perfectionism and adherence to tight deadlines. This lack could influence negatively their future careers. Knowledge cannot be perceived any longer as the end of a goal of an engineering study, it has to be felt as an on-going activity of learning-to-think and learning-to-learn. This will promote a new design for an engineer profile, one which encompasses an engineer willing to manage the tools that our lifestyle requires, for all engineering areas.

Researchers in the three quoted projects strive to apply concepts of mathematical competencies into the practise of teaching maths at engineering study programmes,

and introduce new assessment methods suitable for assessing acquired competencies. These changes include also adapted curricula, change in contents and scope of maths courses within technical study programmes in order to be more suitable for the new goals of getting more competencies, practical skills and abilities than theoretical maths knowledge, and for introduction of ICT assisted solutions of engineering tasks comprising mathematical problems.

Mutual dialogue and cooperation between maths educators and colleagues from engineering departments, not excluding practising engineers, is more than invited for finding adequate and acceptable solution of this difficult and demanding task.

There is no engineering without mathematics, and mathematics can flourish only when reasonably applied in technical sciences and engineering practise, for the benefit of both, scientific theory and real technical applications, making our world a better place for living.

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External program evaluations and institutional reviews

A comparative overview and case study

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Conference Key Areas: Quality Assurance and Accreditation

Keywords: QA systems, external evaluations, institutional change, multi-campus

INTRODUCTION

Higher education is constantly changing to adapt to internal and external needs, pressures and opportunities. This in turn has prompted organisations worldwide to develop mechanisms for quality assurance and accreditation so as to stay in control of the quality of higher education [1,2,3].

Even if there is not one quality assurance (QA) model that applies universally, many do have features in common [4]. Yet these frameworks are by no means carved in stone. Revisions are common in response to new insights [5], critique [6] and changes in contexts [1,3,7]. Literature also shows that the way QA is shaped in turn influences policy and processes [2,8].

This paper provides insight in one such revision. In recent years, external QA in the Dutch-speaking part of Belgium has made the transition from a model based on program evaluations to institutional reviews. The paper starts with an introduction to literature on external QA. Subsequently, a comparative overview of two frameworks and a case study in an engineering technology faculty are presented.

1 EXTERNAL QUALITY ASSURANCE IN INTERNATIONAL PERSPECTIVE

1.1 Definition and purpose

Literature reports several definitions for quality and quality assurance, alternatingly inspired by idealistic, academic, pedagogic, managerial and consumerist values [2,6,7,8]. Indeed, it will not be surprising that expectations towards quality assurance

are equally diverse as the stakeholders involved in higher education. In its essence, quality assurance is a means to provide reliable information to stakeholders so as to allow optimal decision-making [5].

QA's twin purposes reveal its dual nature: it is aimed at both accountability and quality enhancement – though not always in equal measure. Continuous enhancement was a consideration from the start. It was dwarfed immediately, though, by attesting efficient use of resources [1,4]. Current affairs played a key role in this. In most countries, QA was introduced as a way to deal with growing concerns about the quality of higher education. Expanding student numbers, rising awareness on dropout rates, and demands for accountability about public spending were their cause. Ensuring that students' qualifications and expectations remained at the forefront of institutional missions, in spite of context changes, had to empower higher education institutions (HEIs) to defend their institutional autonomy. This was achieved by guaranteeing compliance with (minimum) standards, by providing information, and by building trust. Up to this day, successful QA is often a requirement to further operate a program or an institution. In some countries it also affects public funding, whereas in others the HEI or programs simply receive recommendations for improvement [3,7,9].

1.2 Emergence and trends

The U.S. were the trendsetter with regard to external QA. Nowadays similar models have been adopted elsewhere as well, at different speeds. Cross-Atlantic and intra-European influences are still apparent [7]. Frameworks such as the European Standards and Guidelines provide guiding principles and standards to improve the quality of QA models [3]. Several models and combinations thereof are commonplace: program evaluations, institutional reviews, students' ratings of education, performance contracts, and total quality management systems [2,7]. Responsibility for these processes is awarded to either one or more private organisations or to statutory agencies [5,9]. Historical structures, practicalities and context changes affect the way QA is implemented. Even so, similarities remain because of normative influences, coercive legislation and mimetic tendencies to imitate good practices [7].

Current trends are a growing consideration for self-improvement, taking into account institutional diversity, and stronger stakeholder involvement. Many agencies are also opting for lighter, formative procedures in favour of HEIs' own responsibility for QA [3,4]. These are not universal tendencies, though. Radical reforms in opposite directions have also been observed, such as The Netherlands' transition from soft self-regulation to stringent performance contracts [6].

1.3 Impact

The impact of QA can be substantial. The way a QA model is shaped is said to influence allocation of resources, academic autonomy, legitimacy, internal power balance, decision-making processes, political power and consumer influence [2]. It can be a strong driver for internal QA and stakeholder involvement [8]. Notwithstanding, it can also cause bureaucracy and alienate academic staff [1]. Whether the impact is mostly desirable or detrimental depends upon how the system is implemented. Its effects can also be ambiguous as is shown in literature. Minimum standards may be met yet innovation inhibited. Strengths endorsed yet weaknesses concealed [1,3,5]. To be able to concede institutional autonomy, it seems one needs at least sufficient internalisation of standards and managerial capacity [8]. Careful deliberation and guidance on the best way to implement QA are therefore imperative.

2 PROGRAM EVALUATION VS. INSTITUTIONAL REVIEW

The remainder of this paper will focus on two models for external QA in higher education: program evaluations and institutional reviews.

In Flanders, program evaluations were introduced in 2005. In 2015, exactly one decade later, a new QA system was decreed. This offered HEIs the possibility to choose between either program evaluations or institutional reviews with selected in-depth review trails. Every single HEI has opted for the transition to institutional reviews with review trails. A periodic positive advice by a commission of external experts, appointed by a governmental organization, was and still is a necessary condition for initial or further accreditation [10,11].

2.1 Method

The comparative overview is based on content analysis of the frameworks for program evaluations and institutional reviews published by the coordinating Accreditation Organisation of the Netherlands and Flanders [10] and by the delegated Flemish organisation VLUHR QA [11]. The protocols date from early 2015, the same year as the case study discussed in section 3.

2.2 Comparative overview

Program evaluations and institutional reviews are similar in some ways but also differ in many others, as is evident from the summary in *Table 1* below.

Some similarities are easy to spot. Both frameworks include the typical four elements in early U.S. models and current European models as described in literature [3,7]. These are a self-assessment report by the HEI, a site visit by a commission of external peers, compilation of a review report by the commission, and follow-up by the HEI and external authority.

The most fundamental differences are the approach and topics. Again in line with literature [3], program evaluations apply content-related indicators whereas institutional reviews adopt a systemic quality management perspective. The focus in other words shifts from inputs and outputs to processes.

Both models use ordinal scales to rate criteria as well as to give an overall rating. The scales vary in the number of possible outcomes and semantic meaning. Literature identifies two main types of scales: excellence-oriented and compliance-oriented scales [3]. Program evaluations use excellence-oriented scales to rate each topic: standards can be exceeded. In the institutional review's compliance-oriented scale on the other hand, the best value corresponds to adequacy. Both use a compliance-oriented scale for the overall rating.

Both types of assessments focus increasingly on accountability as of 2005, in addition to quality improvement, states VLUHR QA explicitly [11].

Table 1. Comparative overview of external QA models in Flanders, 2015-2016.

	Program evaluation	Institutional review
Aim	Quality enhancement as well as accountability	
Approach	Traditional, Q&A: "Does the institution have a good model?"	Appreciative, dialogue: "Does the institution's model work?"
Reference	Compliance	Own model/story

Assessment framework topics	1) Intended exit level 2) Teaching-learning environment 3) Achieved level	1) Vision and policy 2) Policy implementation 3) Evaluation and monitoring 4) Enhancement policy
Expected input by HEI	Self-evaluation report, list of required appendices.	Critical reflection report, limited appendices.
Composition of commission	4 independent members, incl. 1 student. Expertise in: subject/discipline, professional field, education, international HE, auditing	5 independent members, incl. 1 student. Expertise in: policy, education, international HE, auditing
Panel groups during site visit	Management, lecturers, students, alumni, professional field	Board, management, QA experts, lecturers, students, professional field
Duration of site visit	1 visit, 1-2 days	2 visits, in total 2-5 days
Topic assessment scale	Excellent / good / sufficient / insufficient	Meets standard / partially meets standard / does not meet standard
Final assessment scale	Satisfactory / satisfactory with limited validity / unsatisfactory	Positive / conditionally positive / negative
Timing	Once every 8 years	Once every 6 years

3 CASE STUDY

The Faculty of Engineering Technology of KU Leuven (Catholic University of Leuven) has been involved in both models in recent years. One of its bachelor programs was the subject of the last round of external program evaluations in 2015. Being a newly established multi-campus faculty subsequently made it an indispensable review trail for the university's first institutional review in 2016, to assess whether the HEI's policy and QA system also functioned in a highly complex context.

3.1 Method

Individual in-depth interviews with semi-structured questions were used to explore internal stakeholders' experiences. The interviews were conducted in April-May 2018 with audio recording and transcription afterwards. Subjects were selected based on their involvement in the program evaluation of 2015 as well as in the trail in the more recent institutional review in 2016. Twelve subjects were contacted and all participated in the study: the faculty's vice-dean; several program directors, vice-campus chairs and student representatives; and two educational developers. Some interviewees had also been involved in QA cycles prior to 2015. Each subsection below is introduced by one or more quotes illustrating the interviewees' main thoughts on the topic.

3.2 Topic 1: Preparations and involvement

"You are forced to reflect on why the curriculum is as it is, its strengths and weaknesses. The day-to-day flow does not always provide the same awareness." (Program director/vice-campus chair)

The preparations for a program evaluation were looked back on as a very intensive process. The self-evaluation report in particular evoked many memories. First thoughts centred around it being an extremely time-consuming activity, fear to write something that could be misinterpreted, and respect for those who spent evenings and

weekends working on documents on top of their regular workload. The community and support behind the efforts might not always be equally visible to outsiders. The student representatives recalled it as being initially overwhelming because they were less familiar with the procedure and topics discussed. At the same time they felt they could be of added value by providing a fresh pair of eyes. Moreover, many interviewees immediately countered their initial reactions by saying that all in all, looking back, it had been a strong learning experience, as testified by the quote above.

The preparations relating to practical matters and required appendices on the other hand were not considered worth the effort. If the same program was evaluated multiple times the perceived usefulness also declined.

The preparations for the institutional review were a completely different story. The appreciative approach made it a fundamentally different exercise as the HEI had to look in a critical manner at the own model instead of anticipating which critique was to be expected from external peers. The interviewees also appreciated that they no longer had to be the key players in each step of the preparations. Several regretted though that the feeling of involvement and the learning effect were equally lost.

3.3 Topic 2: The site visit

“A program evaluation feels like an exam, whereas an institutional review is more like a performance appraisal.” (Vice-campus chair)

The commission's visit was often exciting, feeling very much like an examination (as illustrated above). The limited time only left room for selected topics and made it important to give a strong first impression. With program evaluations, it sometimes felt like giving a sales pitch. The commission also did not refrain from asking tough questions or digging for flaws. The institutional review felt more like a dialogue.

The interviewees overall had a positive feeling with regard to the group interviews by the commissions. It could not have been easy for the commission members, reflected many. Yet the commission members were perceived as well trained and performing with neutrality and objectivity. Surely, sometimes one commission member dominated and many had pet subjects. Almost every interviewee mentioned this. This did not bother them as long as it did not influence the conversations all too much. The student representatives appreciated there also being a student commission member.

Three interviewees remarked that the group aspect might be a methodological weakness: the conversation was sometimes highly determined by those who spoke first or by the presence or absence of one participant with a specific perspective.

3.4 Topic 3: Reliability and outcomes

“The info provided in external evaluations is Facebook-honest or Instagram-honest. What you show is yours, with the only difference that everybody is happy.” (Program director/vice-campus chair)

“The commission most of all determines whether you have been honest in your self-evaluation. The steps taken in-house, i.e. identifying points of improvement and taking action, are more significant than the evaluation itself.” (Program director)

The overall reliability was perceived as adequate (e.g. quotes). The interviewees expect a well-trained program evaluation commission to see through cover-ups during

the site visit. Stakeholders will obviously stress strengths rather than weaknesses as their reputation is at stake. Nevertheless, it was perceived an ethical obligation to be honest and safer than to risk being exposed. Subjects did wonder if institutional reviews will prove equally reliable. Opinions were divided on whether the appreciative approach and dialogue will generate mostly distraction from flaws or sincerity.

In program evaluations, the interviewees do consider it necessary for the commission to visit every campus. The wide topic array made the evaluation feel thorough and reliable. The interviewees remarked that the institutional review did not include these two features, but perhaps did not need these either because of the shift in perspective.

The conclusions published in the program evaluation reports were rarely a surprise. Often these mostly repeated what was described in the self-evaluation report. Some interviewees were disappointed that a commission had not noticed or affirmed certain strengths regarded as a major step forward by those involved. The institutional review report on the other hand had not really made an impression as it only discussed the institution's model, not the trails in particular. Factual errors in both reports were no exception. Subjects did appreciate the commission mentioning a strength for each individual campus. Overall, though, because of to the reasons listed above, subjects felt rather dissatisfied with or indifferent about the reports.

3.5 Topic 4: Impact on other processes

“Teambuilding! Fighting for a common goal against a common enemy is very beneficial to grow as a team.” (Vice-dean)

Many interviewees referred to the emotional, psychological impact of the program evaluation in the newly established faculty. Working on the self-evaluation report not only generated awareness on each campus's strengths and opportunities, it also made them consider each other more as colleagues (e.g. quote). Getting a positive evaluation in addition provided very welcome confirmation on the choices made so far.

External evaluations also seem to provide strong leverage to initiate actions and make decisions. At least in the short term. Extensive reforms were more often postponed until after the site visit so as not to create inconsistencies between the self-evaluation report and the situation at the time of the commission's visit.

The institutional review boosted the implementation of a stronger internal QA system. Points of improvement suggested by previous program evaluation commission were often given low priority until right before a new evaluation was due. The institutional review made sure a more continuous QA approach was adopted.

3.6 Topic 5: General reflections and recommendations

“Our internal QA system has taken over most of the strengths of the former program evaluations.” (Student representative)

Asked about their opinion on the switch from program evaluations to institutional reviews, most interviewees argued in favour of the new model. The quote above mentions only one of the reasons for this. The appreciative approach and clustered level in particular furthermore made for a more positive experience and more balanced workload. They also felt the HEI was ready to take its responsibility.

The most adequate level for an external review might be situated somewhere between the program and institutional level, nevertheless, some said. Many cautioned we

should also retain interaction between lecturers and external peers at the program level, and should make programs face the facts in case of real issues. Including peers from the professional field and from other higher education programs in the internal QA system could suffice. Others suggested complementing regular institutional reviews with occasional program evaluations.

4 DISCUSSION

4.1 Conclusions

By discussing experiences with two external QA models, this paper aimed to generate awareness of the potential value of programs evaluations and institutional reviews to support other countries who wish to implement one or both of these. The QA models in Flanders indeed show many similarities to frameworks in other countries, both in their aim and in the way they are implemented [3,7]. The comparative overview and case study presented in this paper furthermore reflected international trends, such as growing attention to institutional diversity and offering responsibility for QA [3,4].

Overall, program evaluations and institutional reviews both have their merits. The case study provided examples on their potential impact. The traditional approach in program evaluations seemed to cause stakeholders to perceive it as a deficit-focused system, focussing on quality as value for money or perfection. The institutional review's appreciative approach on the other hand made it a framework where quality was contemplated as fitness for purpose or transforming. These different perspectives on quality as also mentioned in literature [6,7] made for completely different experiences, as was apparent from the interviews. The strengths of one model seemed to be the weaknesses of the other, and vice versa. Program evaluations commonly provided stronger recognition of the program's own strengths and weaknesses yet were a very intensive process. Institutional reviews then again allowed for more resources to be invested in the internal QA system though may become a remote issue for most stakeholders except management. The main challenge remains to create a model that manages to combine involvement with a feasible workload. A complementary internal QA system should subsequently be able to amplify its strengths and counterbalance its weaknesses to achieve the best possible results.

4.2 Strengths, limitations and directions for future research

An earlier paper already described some challenges posed by program evaluations [9]. This paper discusses the same QA model from a different perspective and compares it to the new institutional review model introduced in the meantime.

A strength of the current paper is its multimethod design. Content analysis and literature review provide insight in QA models. A case study complements this by presenting how these models and their impact are experienced in practice.

The time elapsed between the external evaluations and the interviews offered the subjects the necessary distance to look back in a rational manner. On the other hand, obviously, these remain self-reported retrospections stemming from a very specific context, i.e. a newly established faculty. Future research might investigate whether these models provide similar experiences in other contexts or attempt to measure the impact of different QA models by means of mixed methods.

5 ACKNOWLEDGMENTS

The author would like to thank all participants for the inspiring, enjoyable interviews.

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Playing safe in teaching?

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Conference Key Areas: Teaching creativity & innovation, Innovative teaching and learning methods, Philosophy & purpose of engineering education

Keywords: Fostering of creativity, inventions and innovations, Testing possibilities and limits

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INTRODUCTION

Fluidity and the rapid pace of development in science and technology as well as concern for the welfare of both humans and their environment leads to increasing requirements of adaptability in working life [1]; [2]. This calls for changes to higher education as well [3]. Teaching should not only be individual and one-substance centered; it must rather support collective learning, creativity, and solution-oriented approach in a multidiscipline environment without losing its roots in knowledge-based targets and scientific theories.

There are more sources of information constantly available than ever before and therefore, emphasis is trending towards students' free and active inventing and experimenting. Testing possibilities and limits in utilizing novel technologies and/or in utilizing complex combinations of competencies in student team settings offer memorable learning experiences. This will require creating a culture where aiming for good results, accepting contradicting ideas and taking failure as an opportunity to learn something new all co-exist and prosper.

Typically, the exercises, results and solutions used in university level education are well known beforehand, i.e. safe for teachers, but not ill-defined and/or open-ended problems like those that they tend to be in real life. However, the possibility to go to an unknown area in teaching and learning provides an effective learning context where failure, as well as success, is an option to learn and create something new. A balance of passive retention of information during education along with active, self-motivated investigation of an area by a student can result in a profound difference in both their retention of the experience and their development of an ability to innovate.

In this paper, we refer to innovations, inventions and creativity acknowledging their differences by definition and by research traditions. We rely on the alignment of these terms; inventions may lead to innovations and creativity is a helpful feature in both of this processes.

This paper invites university teachers to reflect and investigate their own teaching, and university teaching in general. How often there are so-called real-life exercises where starting point and problem parameters are not well defined, and a solution is not known beforehand by anyone, not even by teachers? In what extent university studies support students' creativity and inventions?

1 TEACHING

1.1 Working life requirements

In recent years, there has been a lot of discussion about working life skills in education. The core of engineering education lies on numerical skills, i.e. knowledge in science, technology, engineering and mathematics. In addition to that, working life skills such as problem solving, initiative, communication, collaboration, IT and media skills are needed [4]. Critical and analytical thinking, creativity and innovation skills, ethics, leadership and desire to lifelong learning, among many others are also often considered as requirements of working life today [5], [6].

During studies, the role of student is to learn the issues being taught. Students are sometimes considered as a kind of passive product of universities, in a strictly defined frame. Modern easy access to and a culture of reliance on online sourced information can lead toward a more passive acceptance of the flow of information without the need

for active participation of acquiring it, leaving the student without sufficient resources to cope with contingencies in life and the workplace. In working life, however, graduated students are expected to be not just well informed, but also innovative and creative.

There are more than 600000 engineering students in Europe [7]; would it be possible to support and exploit their innovation potential before the graduation instead of after? A university oriented as a supporting environment may provide good baseline for invention production, as there are presumably numerous different disciplines with sources into the knowledge of the latest technological developments available.

1.2 University courses

Worldwide development of education systems is in need of better ways to respond to the changing world. It is not enough just to learn standard requirements. In fact, it is even more important to equip the learners to take an active role, initiate investigations, be creative, seek new knowledge and manage risk as they face new challenges. Key and fundamental engineering competencies for the future are best developed through education given in university courses. Therefore, working life skills are often taught in separate courses, or integrated courses where theory and practice meet.

In basic courses, the instructor is very familiar with both the problem and the solution. In more advanced courses, the instructor knows at least the process of how to move towards the solution. However, the presumption here is that the solution exists and is reasonable. Quality systems related to teaching often mean, for example, well defined learning outcomes, and clear and safe standard processes in teaching; that is, the desired learning outcome is set beforehand and is known to be provable.

Situative perspective on learning has gained more interest during the recent years. The focus there is not on mental structures of individual learner as such but on learning in activity systems that comprise several people and a variety of technologies being available [8]. This view stresses the importance of the surrounding context in problem solving and there are notions that skilled problem solving incorporates the environment, i.e. people, things, and information, into the actual technical problem-solving system [9]. This view is present with courses where the surrounding world plays an important role in the courses, as a source of problems, as a catalyst or as a source of solutions and resources. The situational or contextual view means that problems and exercises are ill-defined and open-ended and they carry the complexity and dynamism of real life with them. The student's investigation into that fluid environment is forced into a more active, rather than passive behaviour, and as such is more likely to internalize the experience, especially given what happens when the student inevitably fails. This prompts further investigations, questions about the reason for the failure, which cements the experience in the student's mind and drives innovation.

In this paper, we go even further and posit that students might not just try to learn working life skill or methodologies supporting innovation in the university in order to use the skills later at work, but they actually could produce new ideas and inventions during their study time. The world would not happen later; it would already be present at the university.

2 INVENTING

2.1 Offering possibilities

One way to offer possibilities to produce inventions and innovations is to increase student participation to R&D actions in universities: a student's role is changed to be more active if he/she is a part of a creative team [10]. Learning processes will be turned from standardized individual substance teaching or memorization to a collective learning, creativity and solution orientation, without losing strong theory basis or learning goals. The learning outcomes that are defined beforehand will be connected to open, innovative and practice oriented testing. Thus, theory and practice will integrate strongly.

When multidisciplinary and multi-professional teams that include several different nationalities solve ill-defined and open-ended problems, moving ahead to the solution requires and simultaneously develops a variety of different skills. Besides substance know-how, other skills like communication, team working, problem solving and creativity are important in working life, as well as other sectors of life in general.

When facing a totally new type of problem, there are no right ways to proceed or right answers that are known beforehand. This means that students have all options present: failure is always a possibility as well as are remarkable success. Besides that, everything in between can be interpreted as partially successful results in the sense of learning the tools needed to succeed. In all different options mentioned above, students have a possibility to learn - sometimes even unexpected things, and opportunities to invent novel solutions. Of course, this kind of arrangement at a university course means that a course instructor has all the same options in his/her teaching work.

2.2 Combining social aspects and technologies in fostering creativity

Importance of exploration and possibility to fail are recognized in research on innovation and creativity, and the concepts of "failure value" and "fast failure" are used to highlight the elementary importance of learning. The first theoretical process models of innovation and/or creativity were linear, but those processes are nowadays considered nonlinear and interactive.

The famous system model of creativity [11] proposes that creativity is a dynamic, reflective interaction between an individual, a domain and society. In our setting, a domain could mean, for example, a specific branch or field of technology. The co-existence of two aspects, social and science based, has been present for decades in innovation research, and fostering innovation means that there are impulses coming from these two directions, social and science, i.e. technology.

In order to foster innovation, it is important to integrate different types of backgrounds, knowledge, competences, experiences and technologies together. If the participants represent different kinds of technological knowhow, there are more possibilities to learn and innovate, but it should be noticed that people like to work in groups made up of members that are similar in some way to themselves. Ability to work in differing and heterogeneous groups seems to be rather uncommon, and the role of a facilitator or broker is sometimes relevant. It may be counterintuitive that non-homogenous or a diverse group of members would be a productive model to encourage, but it is possible or even likely that diverse outlooks or points of view can support or help produce

innovations by causing the students to defend and clarify their positions or ideas to their team members. Individuals who have a different point of view may disagree with their team members and will question them, and while it can cause friction or discord, it can also be a powerful source of innovation. A group of people all of like mind won't have as much motivation to do that, and may follow more of a herd mentality, which is by definition not innovative. In any case, success in innovation depends on the flexibility of the organization and their ability to interact with environment [12].

Ability to follow and scan the environment is a central doctrine in business studies, e.g. marketing, and it is visible in successful innovation processes. A previous study [13] stated that achieving something new often requires going outside the established channels. This is challenging to a university system, which very much builds on the division of different fields of science in both research and education. Crossing those borders is not common or encouraged in the pigeon holed world of universities. It is also generally found that the more radical and risky ideas are, the more there will be organizational resistance [14].

Previous research on innovation, invention or creativity proves that organizations seldom push themselves into directions of accelerated creativity. We might assume that this could also be the case in university courses. Pushing inventing or creativity further may be more likely to be limited and only competence in the controlled and known be encouraged.

We have focused on the two aspects of fostering creativity and inventions: the human side, i.e., the increase of potentially complex skills, and the technology side, where the usage of novel or unfamiliar technology increases. It should be noted that this setting is contextual in its nature, meaning that the increase of skill or technologies, and most of all, the complexity, novelty or unfamiliarity of them is judged in that specific context, for example within a specific course or a study program.

Figure 1 illustrates how the likelihood of creativity and invention changes as a function of novelty or unfamiliarity of technology used, and combination of skills required.

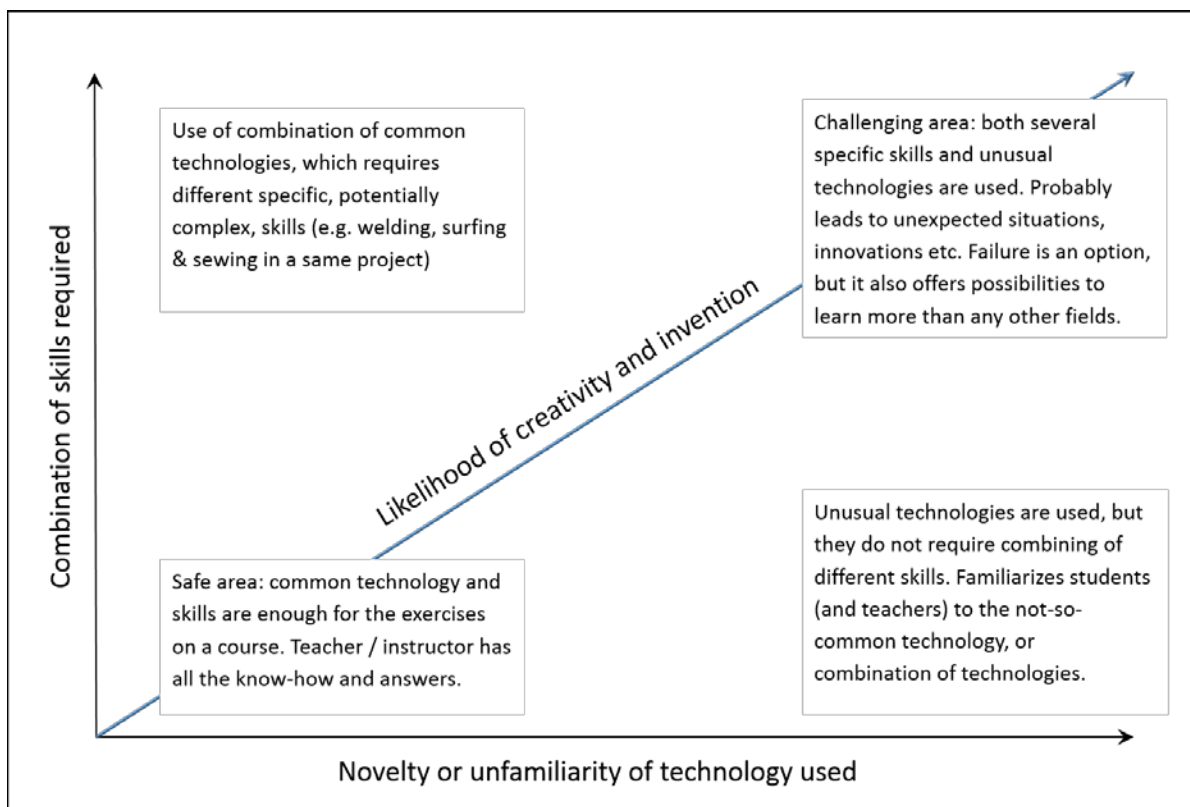


Fig. 1. Possibilities to learn, be creative and invent increase in relation to novelty and unfamiliarity of technology, or/and combination of required skills.

3 PLAYING SAFE?

In this article, we suggest that a possibility to be creative and invent already during studies will develop students' skills in several areas and equip them to working life challenges. Nevertheless, there is a doubt that the current engineering education does not allow students to learn the usage of their creativity and invention potential in a best possible way.

Nowadays, quality systems require well-defined learning outcomes, which definitely has its advantages. Eventually, however, university teachers decide what and how their students will learn in their courses. Increasing the number of possibilities, i.e., complexity of course exercises will complicate both students' and teachers' work during the course. This might draw teachers to play safe, and use the good old exercises that are familiar to them. However, some teachers certainly challenge their students and themselves, too.

It would be interesting to investigate the big picture of engineering education across the continent. How does current teaching support the development of the creativity and innovation potential of engineering students who will have the world in their hands after a decade or two?

3.1 Challenge to university teachers

We would like to challenge teachers to reflect their own courses. Are their students mostly equipped with the old solutions or are they supported to find also new ones - solutions that teachers cannot even think of? Surely, there are some courses that

support the development of working life skills, creativity and innovation, but how often will the teaching and learning still remain in a safe area that offers nothing new or risky? What are the barriers preventing or retarding the progress of having courses going to the direction of unfamiliar technologies and complex combinations of skills?

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Practice makes perfect!
Developing an internship process in Finnish universities

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Conference Key Areas: Engineering skills, Educational and organizational development, curriculum development

Keywords: internship, working life period, working life skills

INTRODUCTION

An internship can bridge theoretical knowledge with essential working life skills, improve student's confidence towards his/her own profession and know-how, and advance further studies and networking [1]. According to several studies, e.g. [2]; [3], an internship period or other comparable work placement period during university studies will enhance students' career development later.

Generic working-life skills, for example team working, problem solving and communication skills play an important role in employment after graduation [2]. Substance skills are not adequate if a person cannot adapt them in a working life [4]. Even getting used to regular and target-oriented working will enhance employment in general after graduation [1].

An internship period is often the first familiarization with the own subject field line of work, and students may think that the internship period is the only way of learning working life skills. However, students do not always recognize the generic skills they have gained during their working life period, and do not realize the usefulness of them. Therefore, generic working life skills should be part of the learning outcomes of internships, as well as the whole university degree [2].

Internship practices can be very different between universities, and even inside the same university between degree programs [5]. The situation is alike in Finland [6]. Based on these facts, a national group of education developers wrote an internship guide [12] and recommendations for universities, students and employers. In addition, different ways for improving students' working life skills were developed and piloted. The actions were implemented in the project 'Bridging the Gap between University Studies and Working Life' by European Social Fund. This paper discusses the implementation and results gained through two different pilot cases for promoting and implementing internships.

1 INTERNSHIP AS A PART OF A UNIVERSITY DEGREE

Universities do not have general rules for internships. According to the survey [6], the internship practices are not similar even inside the same field of education. Some degree programmes did not even have general written guidelines for implementation and reporting of students' work placement periods. When general rules are missing, operation models may be very person-dependent.

The way an internship period is integrated to the university degree has an effect on how beneficial students consider it [7]. The problem is that universities may offer many components enhancing employment, such as internships, but students do see them as separate from the degree studies. Therefore, universities should consider work placement periods as one of the key tasks [8].

1.1 Teaching of working life skills in universities

Typically, working life skills are divided into two categories: generic, transferable and soft skills, and core or hard skills and key competencies. Working life skills can be boosted in universities by three different models: specialist model means teaching working-life skills in separate courses, integrative model includes courses where theory and practice are both present, and networking culture model, which takes working life skills into account already in the curriculum planning [9]. All three models are used in Finnish universities, where internship periods are mainly, but not always, mandatory in engineering degrees.

1.2 Learning outcomes of internship periods

To get the best learning outcome from the internship, it is critical to prepare well beforehand and pay attention to the quality of internship during the period [10]. In addition to preparation, setting learning objectives and guidance during the period, an internship should include reflection, i.e. what student has learned during the internship period [7]. According to [11], students as well as other people involved in internship should reflect their actions all the time to get the most out of it. Reflection should be included to the learning objectives and into the reporting guide for internship. In Finland, only about half of universities had learning objectives and reflection guidance in their internship reporting requirements [6].

2 RESEARCH DESCRIPTION AND METHODOLOGY

A survey about internship practices in six Finnish universities [6] forms a background for the actions described in this paper. The survey included 96 different degree programs. Based on the results, the internship process was modelled and presented in an internship guide [12]. Many development pilots were started for teaching working-life skills in several universities, also. In this paper, two cases different with each other are presented as case examples. The research made along with the pilots targeted to developing the next implementation better and finally turning it to a permanent, good practice. Critical reflection method [13]; [14], was applied by teachers when they tried to understand internship as a phenomenon. The feedback from students was also in an important role, and it was benefited in planning of the next implementations.

Case survey was used as a method for studying internship periods. Case survey is heading for understanding the phenomena in the current case but also in general. Student feedback was collected and analysed; both quantitative and qualitative analysis were used, depending on a course.

3 THE PILOT CASES

3.1 Summer Project Camp (SPC)

It is challenging, especially for foreign or beginner level students to find an internship place for degree programmes where internship is obligatory. To support these students, a novel model that integrates studies and internship was developed in Lappeenranta University of Technology (LUT). During a summer holiday period, students were working in teams solving problems of their own study field, and at the same time they learned working life skills. The chronological process in SPC is shown in *Fig. 1*.

The first SPC was piloted in summer 2016 with software engineering, computational science and technical physics students. The second SPC was arranged in summer 2017, developed based on experiences gained from the previous camp.

In SPC, the working time was 7.5 h/d. Students were working in teams, in the reserved premises in the university campus area. Students had a superior in the camp – like in an ordinary work place. SPC rules, guides and documents were on a virtual operational environment. Students also returned their weekly working time reports and internship reports electronically.

Bachelor level SPC students had an opportunity to two study two university courses as their job. Responsible teachers were not present all the time, but available when students had some questions about the course substance. SPC superior oversaw the atmosphere, presence of participants, working conditions and progress of work. Superior also interviewed all participants in the beginning of SPC, had development discussion with them, and arranged regular information meetings about many themes of working life skills. The themes were selected especially from the IT business viewpoint, and included e.g. flexible working hours in companies, vacations, salary, taxes and tax deductions, contract of employment, commenting of coding, version management and quality criteria, Belbin team roles, leadership etc. In addition, students gave snapshots of their progress in work.

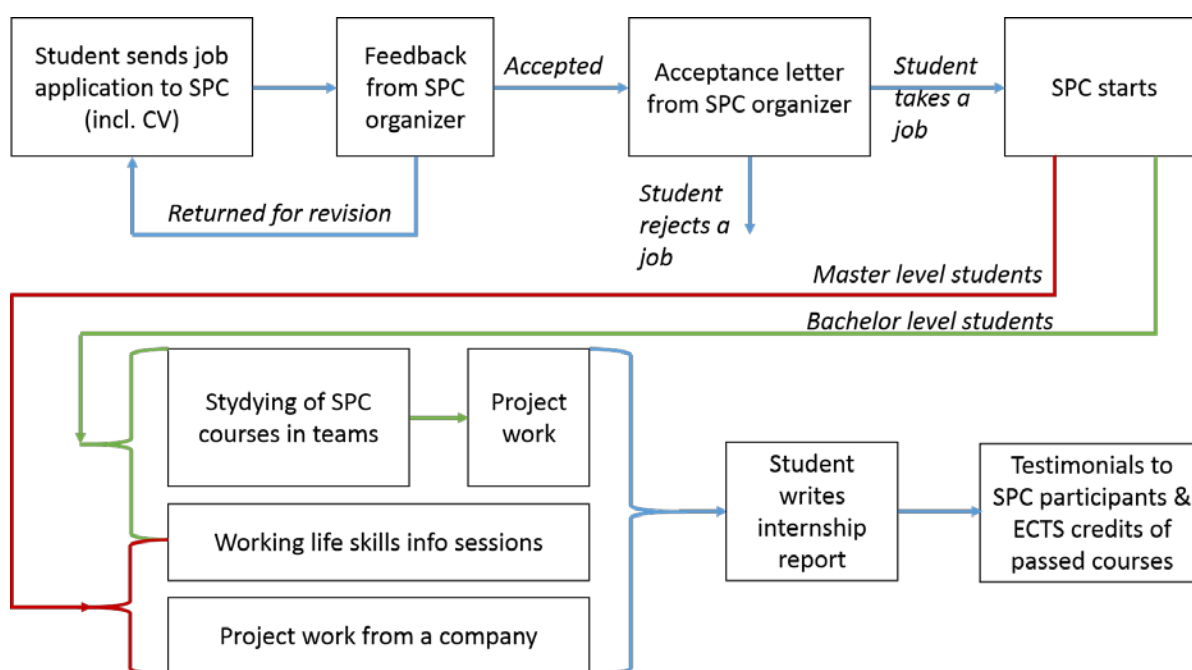


Fig.1. Summer Project Camp process. Students sent applications to SPC on March, and they got feedback. Revision of non-accepted applications was possible during April, and the organizer sent acceptance letters on May. The camp was running during June and July. In the end of SPC, students wrote their internship reports. After the camp, all participants got testimonials from SPC.

SPC implementation was studied and developed in practice based on written and oral feedback and reflections presented in Table 1. Feedback from students was gathered via questionnaire form and in development discussions. In addition, students' internship reports were investigated in order to understand how their working life skills had developed during SPC. Responsible teachers were interviewed in the end of SPC. They were also reflecting their work and reacting to their observations already during the camp. After a camp, a report of the whole SPC was written, including analyzed

feedback and reflections of teachers and general supervisor. The issues that raised from feedback were taken into account in the next year's implementation.

Actions made based on 2016 feedback: The rules of the camp were weighted already in the beginning of the next SPC. The importance of scheduling was emphasized. There was more supervision available during the whole SPC 2017. The two implementations of SPC show that the model is working well. Students experienced it as beneficial and their working life skills increased during the camp. Supervisors were satisfied with the realisation of SPC activities and results, also. The idea of SPC was widened also to some other degree programmes on summer 2018.

Table 1. Feedback and reflection from students and supervisors on SPC 2016-17.

Year	Students say they have learned	Development suggestions from students	Feedback from superior and teachers	Self-reflection from students, superior and teachers
2016	<ul style="list-style-type: none"> - project planning - project work and management - overview of work life - co-operation with project manager and customer 	<ul style="list-style-type: none"> - more supervision needed - working-life infos were good, but they interrupted the work flow 	<ul style="list-style-type: none"> - students were surprised how demanding the project work was - some students did not follow the daily schedule 	<ul style="list-style-type: none"> - definition of own work is important - independent work & benefits of team work - clear scheduling enhanced work progress
2017	<ul style="list-style-type: none"> - conceiving the wholeness of the work - importance of planning - scheduling - project work - team work - issues from working life infos 	<ul style="list-style-type: none"> - Widening the SPC idea also to other degree programmes at our university 	<ul style="list-style-type: none"> - no conflicts on teams - project work was still demanding, but students did not consider it as too heavy but instead, as beneficial 	<ul style="list-style-type: none"> - Working life infos were held in separate meeting rooms and informed well beforehand, which seemed to work well.

3.2 Renewal of internships in faculty of information technology and electrical engineering in the University of Oulu

The main objective for the internship renewal process was to improve the instructions and documentation used in all internships and similar kind of working life periods in the faculty. Previous documentation had little to none emphasis on the personal development of the student. In addition, the link between university studies and the tasks during the internship was weak. The students rarely experienced internship as a normal course with learning objectives and outcomes.

The renewal was implemented by running an internship pilot during the summer and fall of 2017. The pilot was offered as an alternative to all of the students in the faculty in both bachelor and master's phase. In total of 35 students participated to the pilot. The implementation was based on the guidelines presented in the guide [12].

In piloted internship, the amount of documentation was increased and only ongoing internship could be reported. The documentation was divided to three main phases: internship plan with personal development goals before the internship, weekly reports of progress during the internship and finally a longer report and reflection focusing on the learning outcomes and personal development immediately after the internship. The

final report was divided into five main categories: 1) Finding and applying for a job, preparing for internship, 2) Employer and the organization, 3) Duties and tasks during the internship, 4) Fulfilment of the plans and personal development and 5) Future plans.

The suitability of the documentation was estimated by comparing report model used in the pilot and the final reports used in the previous years. The reports were viewed especially from the perspective of the students' ability to identify his/her personal development and the link between university studies and working life. In the pilot some of the students were also interviewed and in some cases the student also received feedback from the employer about the new way of documenting the internship period.

The most significant difference between the renewed and the old version of internship was the composition of the final report. Previously the students mostly described the workplace and its operations while only few sentences were used to describe the actual tasks carried out by the student. Personal development was also either completely disregarded or mentioned in a single sentence. Using the new documentation clearly helped the students to compare university studies to expectations from working life, identify personal strengths and development areas and overall feel more ready to proceed in the working life after graduation. Weekly reports were specially mentioned by many students to have been the most valuable tool for themselves during the piloted internship. Many of the employers also commented that the weekly reports were useful to them and helped the supervisors to get better understanding about the progress of the student.

4 DISCUSSION

In this study, we mapped how target-oriented and supervised internship, including reflection, benefits university students. Two different cases for promoting and implementing internships were executed. One of them was internship course and one was an internship period carried out in the university context with working life conditions. The feedback from both two cases show, that target-oriented internship period and students' reflection of their learning will help students to understand better their own skills and development. They also recognise better the things they have learned during the working life period, and understand the significance of internship as a solid part of the university degree, and how it may ease employment after graduation.

Especially students who had positive attitude to reflection, benefited by finding their own strengths and interests. On the other side, reflection helped also those students who regarded it with criticism. However, superficial reflection correlated to weaker identification of gained working-life skills.

The feedback from the cases showed clearly that students felt that their working-life skills and recognising of their own skills had developed. This is a significant change compared to previous studies (for example [2]) that showed students difficulties to recognise and value their generic working-life skills. Based on our study, working-life skills could be promoted by adding reflection to internship or other working life practice periods.

The two cases were different from each other both in execution and evaluation, and therefore their results cannot be compared. Some students gave feedback about the substance, and some students concentrated on evaluating their own learning and development. Both cases, however, highlighted that according to students' experiences, their self-knowledge, know-how and understanding their own targets for future working life had developed during the course or period.

As a follow-up study, it would be interesting to investigate if employers see that students' working-life skills have developed due to the novel courses or camps, and are students better capable to link their further studies with working-life skills, after this experience.

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On the User Experience of Moodle as a Tool for e-Learning in Theoretical Computer Science

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Conference Key Areas: Teaching Creativity & Innovation, Innovative Teaching and Learning Methods, Open and Online EE

Keywords: User Experience, Moodle, e-Learning, Theoretical Computer Science

INTRODUCTION

In introductory courses on theoretical computer science the failure rates and the level of frustration amongst the students are often very high (e.g. [1], [2]). This article reports on a study in such a course where supplementary e-learning units were used to improve motivation and the acquisition of competencies. Instead of designing a new platform, we decided to base our project on existing tools that are easily accessible for this approach. The open source learning management system (LMS) Moodle² was chosen to provide students with the learning units. These units consist of learning content, interactive exercises and bonus pages. The learning content was available both as videos and texts. The bonus pages could be unlocked by achieving sufficiently high scores in the exercises. To provide alternative ways through the so-called lessons

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containing the learning content, learning paths were used to support individual learning in our heterogeneous group of students more effectively.

In such an approach, the user experience (UX) of the used platform plays an important role as it can complicate or simplify the usage for the students. The developers of Moodle state themselves that usability as part of the UX is an important part of the platform [3] and several studies were conducted to establish a better understanding of the usability and the whole UX of learning management platforms. In [4] Machado and Tao compared the UX for Moodle and the well-known LMS Blackboard. The overall results suggest that Moodle has the better UX for the user. Graf and List [5] examined several platforms and found that Moodle outperforms the other platforms concerning adaptivity and usability. In contrast, Kirner, Custodio and Kirner [6] conducted a study with usability experts resulting in all other platforms used in this study outperforming Moodle concerning usability. The usability and the whole UX of a platform with such a wide range of possible uses is hard to grasp. Therefore, in our study we focus on a specific and important use case and try to determine its UX. The main contribution of this paper is the presentation of an approach for learning units which is applicable in many disciplines and affordable as it is based on an open source platform and ensuring the UX quality of this approach.

In this article, we first discuss the requirements for the used system, then the design of the learning units and underline in which points our usage deviated from the standard Moodle installation. After a short overview of the study's structure, we further present our findings concerning the UX of our learning units and give an outlook on further possible research issues.

This publication is based on research funded by the German Federal Ministry of Education and Research (BMBF) under the project number 01PL 17024.

1 REQUIREMENTS AND DESIGN

1.1 General requirements

Our approach was to use a system that was easily accessible, familiar to our students and that supported the use of learning paths and interactive exercises. Moodle is well-known and popular with almost 100.000 registered installations [7] and used in our university as the mandatory platform for course management. Therefore, the students are already familiar with using this platform in general, although for another purpose. As it is open source, no additional costs were involved.

The learning units were created using design recommendations based on the Cognitive Load Theory (CLT) by Sweller [8] and several theories based on the CLT.

1.2 System design


We conducted two separate studies with similar design in two different courses. Our intention for this was to demonstrate the flexibility of the approach. The first course was an introductory course for theoretical computer science about formal languages and automata (FLAT), the other one was a more advanced course on modelling


concurrency, bisimulation equivalence and fixed point theory. Due to the study's structure, two learning units were created for each course, covering the learning content of two course weeks each. A learning unit consisted of several blocks similar to the one presented in *Figure 1*, covering one subtopic each. A block consists of a headline, a short overview of this subtopic, one or more lessons (marked by three blue linked boxes) containing the actual content and several multiple-choice-exercises, additional exercises (marked by the red checkmark) and a bonus page (here it is still greyed out), which could be unlocked if at least 75 percent of the exercises were answered correctly. Any exercise could be done repeatedly to improve the results.


Schwache Bisimulation

Mit starker Bisimulation haben wir eine gute Möglichkeit kennengelernt, Prozesse zu vergleichen. Aber geht es vielleicht noch besser? Abhängig vom Blickwinkel, der gerade nötig ist, schon.

In diesem Teil der Lerneinheit wollen wir uns anschauen, wie wir von Handshakes als Teil des sichtbaren Verhaltens abstrahieren können, also wann es okay für uns ist, wenn tau-Aktionen unsichtbar sind. Dafür sehen wir uns die Definition und die Eigenschaften von schwacher Simulation und darauffolgend schwacher Bisimulation an und wie wir damit Beweise führen können.

 **Schwache Bisimulation**

 **Aufgaben zu schwacher Bisimulation und Bisimulationsbeweisen**

 **Bonus - schwache Bisimulation**

Eingeschränkt

Nicht verfügbar, es sei denn:


- Sie haben die erforderliche Punktzahl in Schwache Bisimulation erhalten**
- Sie haben die erforderliche Punktzahl in Aufgaben zu schwacher Bisimulation und Bisimulationsbeweisen erhalten**

Fig. 1. One learning unit consists of several blocks similar to this one.

Figure 2 presents a cutout of a typical content page of a lesson with a headline, buttons to view this content as a video or to view the graph of the lesson structure and below the actual content. *Figure 3* presents another cutout of the end of the same page where the buttons below offer the possibility for users to decide whether they want introductory exercises for the next content part (left) or rather want to go straight to the explanation (right).

(A) Einführung

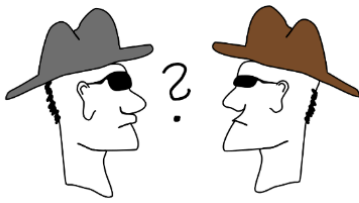
ALS
VIDEO
 ANSEHEN


GRAPH
 ANSEHEN

Mit der starken Bisimulation haben wir ja jetzt da
damit auch gut Beweise führen. Was wollen wir n
außen. Bei starker Bisimulation können wir aber i
Prozess $\tau.0$, bei dem nur eine Handshake-Aktion

Es kann für die Betrachtung aber durchaus einen
stellen wir uns mal zwei Geheimagenten vor, die r

Fig. 2. Part of a lesson content page with options for video content or the lesson graph



Dabei kann man sich leicht Szenarien vorstellen, bei denen
sondern auch solche, bei denen es schon Probleme gibt, w

Idealerweise sollte eine solche Art Prozesse zu vergleichen
alle Eigenschaften gelten.

Machen wir uns also auf den Weg und sehen uns als nächst

Erstmal eine Übung (B)

Gleich zur Erklärung (C)

Fig. 3. Part of a lesson content page with options to do an introductory exercise first or to jump straight to the next explanation

SEITENMENÜ

- (A) Einführung**
- (B) Übung zu schwacher Simulation**
- (C) Erklärung schwache Simulation**
- (D) Aufgaben zu schwacher Simulation**

Fig. 4. A part of a navigation menu in a lesson

p_1

$\downarrow a$

p_2

$\downarrow b$

p_3

q_1

$\downarrow \tau$

q_2

$\downarrow a$

q_3

$\downarrow b$

$\downarrow b$

q_4 q_4

Gilt $p_1 \sim q_1$?

☐ **Ja**

☐ **Nein**

Fig. 5. Exercise in a lesson.

Within a lesson the user can always see a navigation menu, as in *Figure 4*, to simplify jumping directly to another part of the lesson, if desired. *Figure 5* presents an exercise, a simple multiple-choice-question. When answered, the system presents the users with a feedback text to give a better understanding why their selected answer was correct or incorrect. Especially the latter design - with an appropriate level of detail and an encouraging wording - takes considerable effort in preparation.

1.3 Changes in Moodle

Only minor alterations in Moodle were made for the learning units. This allows for similar units to be created for another course as easily as possible. In the lessons a button (as in *Figure 2*) was added for each content page to view the textual content as a video and to navigate from the video page back to the textual content. This was necessary due to our requirement to make content available as both text and video. Embedding the video in the textual page would have led to a longer loading time of the webpage. As, during the test phase, some students were occasionally confused about the different available paths in a lesson we added another button that opened a simple graph showing the structure of the lesson. Several modules of Moodle were *not* used in our learning units (competencies, other types of exercises, ...); this was mainly due to the idea to keep the learning with these units simple and not to overload the units, neither for educators nor for students.

2 EVALUATION

2.1 Methodology

As the first rollout with the advanced course only had a very small number of participants we focus in this article mainly on the results of the introductory course. The study was conducted in a repeated measures design where, after an initial survey, the students were divided into two groups A and B to balance out gender differences, previous knowledge and motivation. For the first two weeks, group A was allowed to use the first learning unit; then, after another survey measuring motivation and competencies for both groups and UX of the platform for group A, group B was allowed to use the second learning unit for two more weeks. This was followed by another survey similar to the one before. So the students had the possibility to use the platform for two weeks before they filled out the corresponding questions. More information about the questionnaires and more details of the study can be found in [9]. For the current article we concentrate on the measurement of UX.

The UX was measured using the User Experience Questionnaire (UEQ) [10] and additional open questions which were analysed through qualitative content analysis [11]. The UEQ measures the UX on six scales: Attractiveness, Perspicuity, Efficiency, Dependability, Stimulation and Novelty. It consists of 26 item pairs (e.g. annoying/enjoyable) that each mark the extremes on a seven-point likert scale. Due to a technical error one of these item-pairs (belonging to the scale novelty) was not used in the surveys.

Additionally, students could participate in short interviews after the study was finished where they were asked, *inter alia*, for advantages and disadvantages of the platform. These interviews were analysed through qualitative content analysis as well.

2.2 Results

One set of answers of the UEQ was not evaluated due to a high number of inconsistencies in the answers. After this cleanup, there was a total number of $N=45$ of filled out UEQs. Our findings are summarised in *Table 1* and presented in a more graphical way in *Figure 6*. The official UEQ-Handbook [12] states that a value less than -0,8 is seen as a negative evaluation. A value between -0,8 and 0,8 represents a neutral evaluation and a value larger than 0,8 represents a positive evaluation. The scales for our learning units therefore all have a positive evaluation except for Novelty, which is evaluated as neutral. Possible explanations are the missing item-pair which might have changed the mean or because the students already were acquainted with Moodle in general beforehand, so for them it was not a new platform in general.

Table 1. Results of the UEQ

Scale	Mean	Std. Dev.	N	Confidence	Confidence interval ($p=0,05$)	
Attractiveness	1,441	0,961	45	0,281	1,160	1,721
Perspicuity	1,131	0,986	45	0,288	0,843	1,420
Efficiency	1,028	0,928	45	0,271	0,757	1,299
Dependability	1,035	0,795	45	0,232	0,803	1,268
Stimulation	1,265	0,819	45	0,239	1,026	1,504
Novelty	0,689	1,001	45	0,292	0,396	0,981

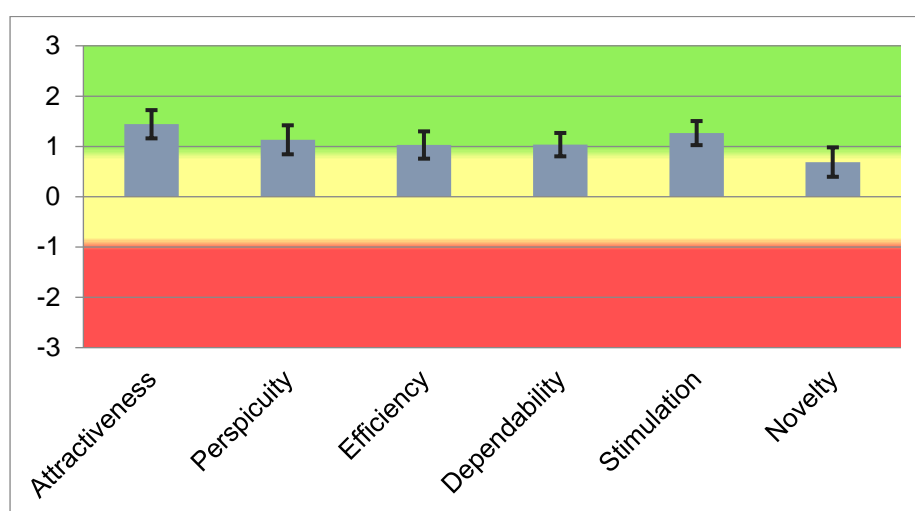


Fig. 6. Graphic representation of the results (figure created with official UEQ-Tool [12])

Figure 7 presents our results compared to a benchmark based on data from 9905 persons from 246 studies on different products [12] made available by the developers of the UEQ. Here our learning platform is above average for the scales Attractiveness, Perspicuity, Efficiency and Stimulation and below average for Dependability and

Novelty. Dependability measures if the user feels in control of the interaction [12]. As the value for Dependability is still good in general we will not interpret this further.

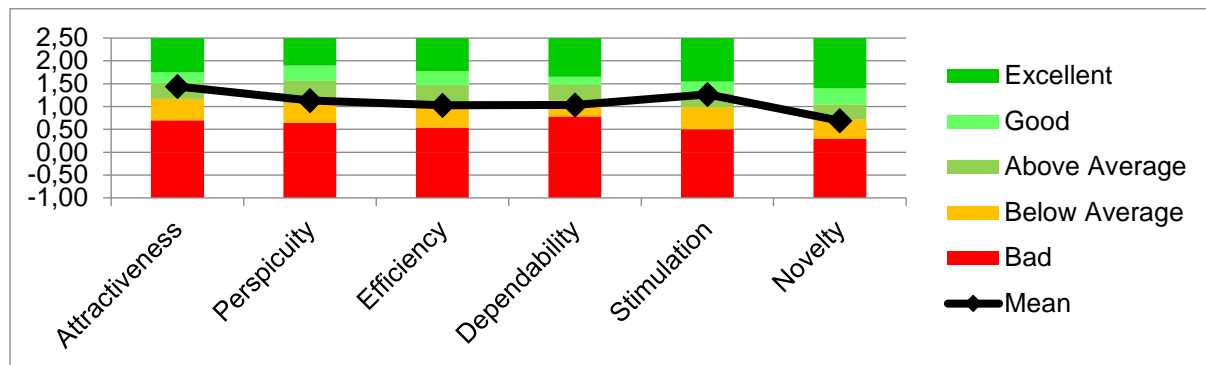


Fig. 7. Result compared to a benchmark (figure created with official UEQ-Tool [12])

The open questions in the survey were filled out by 29 participants in total. Their answers to the two questions on problems handling the learning units and possibilities for improvements differ strongly, but more than half of the participants mentioned problems with the navigation when asked for the handling of the platform. In further development, this should be considered.

In the additional interviews students were mainly asked on their motivation to participate in the study and the pros and cons of the platform; the UX was not a specific target of the questions. Overall the feedback of the 8 participants (5 from the introductory course, 3 from the advanced course) was positive with all of them stating that the learning units were useful when trying to understand the course content. Negative feedback came less frequently and differed more. One student, for example did not like the navigation of the platform, another one did not like that the content of the videos was identical to the textual explanations. We did not get negative feedback on specific points by a majority. As navigation was no major point in the interviews, we assume the negative feedback to be due to individual preferences.

3 SUMMARY

The study reported in this article gave an insight on the UX of Moodle for the complementary use in a university course for a special use case. On the whole, the UX of this approach turned out to be well. Although, in the open questions several participants mentioned problems with the navigation this was not reflected by the questionnaire and therefore probably did not strongly influence the UX. A similar use case that should be investigated for Moodle (or other LMS) is how the addition of other modules influences the UX. H5P³, for example, allows for several other types of questions, especially questions inside of videos. Other use cases for LMS that could be interesting to look into are the UX in blended learning scenarios, MOOCS, flipped classroom scenarios or for exercises and assignments in more classical teaching situations. An advantage of the approach reported in this article is the transferability into other contexts and topics. As we used an open source platform and did not need

³ <https://h5p.org/>

any tools specific for theoretical computer science, this approach can easily be used for courses of other disciplines.

The studies are about to be repeated at several other universities to confirm the results and find out more about how motivation and the acquisition of competencies are influenced by supplementary use of learning units.

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Updating Mathematics Education for Engineers.

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Conference Key Areas: Curriculum Development; Discipline-specific Teaching & Learning

Keywords: Mathematics; surveys; employability.

INTRODUCTION

Engineering industry has changed greatly over the last 50 years during which time there have been many technological developments in engineering, and a significant increase in the IT based tools used in industry. For analysis, CAE software, specialist programming environments for numerical analysis and powerful statistical packages have become the workhorses of engineers who, half a century ago would have used slide-rules and log tables.

The mathematics curriculum for Undergraduate Engineers has, however, changed little, so it is important to consider whether this curriculum is still relevant to engineering graduates and the industry that they hope to graduate into. In mathematics classes around the world it is common to hear students mumble under their breath, “when will I ever use this in real life?” while they copy down another complex problem in algebra.

The initial literature search suggested that the issue is much broader than defining an appropriate curriculum. Teaching methods have a huge influence on students’ ability to relate mathematics within engineering and design modules. Also, entry levels of understanding have been the subject of much research. Apart from an anticipated range in intellectual abilities, there is huge variety in the topics that have been covered, even within a given pre-university qualification.

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1 SCOPING

The importance of defining limitations to the study became clear at an early stage. The research phase would include interviews with various stakeholders and the findings of this phase would inform the design of two surveys of undergraduate students and of practising industrialists to acquire new data. Mind mapping techniques were used to plan the project and target objectives that would be both useful and achievable.

The project objectives reported in this paper were to:

- investigate if the mathematics taught throughout undergraduate engineering education, matches the mathematical skills and knowledge required by industry employers;
- consider the appropriateness of GCE A-Level mathematics qualifications as preparation for undergraduate engineering study;
- make recommendations for the future content and teaching methods for mathematics in undergraduate engineering education.

For reasons of space, this paper includes only a selection of the available results.

2 INFORMATION SEARCH

2.1 Teaching, Learning and Student Motivation.

The study of engineering science and mathematics at university has traditionally consisted of lengthy programmes. Traditionally, lectures were a one-directional presentation of material, during which student activity is primarily restricted to taking notes, although occasionally a student may ask the lecturer a question. Some have adopted innovations such as clickers or personal response systems as ways of increasing the level of student involvement. Lectures introduce a large audience to certain mathematical concepts and procedures and provide students with a familiarity with the topic.

Unfortunately, even the most skilled teacher is relatively ineffective using this passive teaching method alone, and consequently, lecture materials should be supplemented by small-group tutorials or by some form of hands-on activity, such as coursework assignments, workbooks, IT based exercises or group projects. Furthermore, today's students are usually provided with a significant Virtual Learning Environment (VLE).

Student engagement is an essential part of the learning process, and universities need to provide motivators beyond the awarding of marks [2]. The choice of an engineering degree implies that students are interested in the practical applications of mathematics; if they were simply interested in mathematics they might have chosen to do a degree in that subject. Savage et al. [3] support the need for real applications and suggest that the high workload of undergraduate of engineering students can lead to reduced interest unless their intrinsic motivation can be

maintained or developed in some way. Innovative teachers like Robinson [5] have demonstrated improved student engagement by building their syllabus around group projects that are closely related to the cohort's interests. Teaching mathematics to Sports Technology students was always a challenge, but concentrating on sports-applications such as modelling the velocity of a downhill skier or the effects of lift and drag on golf balls provided the necessary connection. As well as sparking genuine interest, these projects also encourage the development of other skills required by industry such as reporting, presentations and teamwork.

The power and availability of graphical and numerical analysis tools suggests there may soon be no option to perform calculations on paper, so more focus needs to be put on the use of technology in mathematics courses for engineers. There is evidence, however, that the use of calculators has become a substitute for mathematical thinking [6] and it appears that some students view computational aids as a way of bypassing the need for understanding [6]. Anecdotally, students are inherently poor at realising whether the answer a computer gives is sensible or realistic and they need to learn to have an appreciation of what the answer should be, so we must ensure that the habitual use of calculators does not replace or erode basic or fundamental mathematical skills.

2.2 Course Content and Competences.

The SEFI Mathematics working group [7] sets out, in detail, eight mathematical competences that need to be attained by students. They list: thinking mathematically; reasoning mathematically; posing and solving mathematical problems; mathematical modelling, representing mathematical entities; handling mathematical symbols; communicating in and with mathematics; using aid and tools. It is, however, important to have a clear understanding of the relationship between mathematical contents/topics and competencies in order to recognize the role contents play in competency-based curricula. The same document contains an exhaustive level-based curriculum for mathematics.

2.3 Pre-University Mathematics in the UK

Most engineering degree programmes in the UK specify entry requirements that include a secondary qualification in mathematics. For many, the predominant standard is the 'General Certificate of Education Advanced level' or 'A-level' for short. There is a view that many students struggle with the transition from A-levels to undergraduate study, and that there is a discrepancy between the end of A-level study, and the start of degree level study - sometimes leading to a significant skills and knowledge gap [4].

A levels were first introduced in the UK in 1951 although they have changed considerably since then. They gradually evolved from a two-year linear course with an exam at the end, into a fully modular course by the year 2000. This is a key area of concern for universities as it means that a cohort of students with exactly the same A-level grades may have a variety of mathematical knowledge because

students have opted for, or been required to take dissimilar modules. For example, some may have concentrated on mechanics while others majored on statistics. Consequently, only a small core of material can be assumed for all students, with inevitable repetitions for others. In particular, researchers[8] around 10 years ago, provided evidence that universities could not assume that entrants had the level of familiarity with concepts in basic mechanics that were taken for granted in the past, although not all degree courses were modified to take this into account.

In recent years, the UK Department for Education has initiated a number of key changes to secondary education qualifications, the most significant of which is seen the reversal of modular A-Level qualifications to make them 'linear'[9]. In theory this means that there should be more commonality in their future A-Levels maths knowledge, skills and abilities. Reformed A-Levels in Mathematics, Further Mathematics and Statistics came into effect for students starting their 2 year A-Level course in 2017 [10], which means the first students with these reformed A-Levels will start university in 2019. The number of students entering top UK universities with other qualifications such as the international Baccalaureate, Scottish Higher or vocational BTEC qualifications is relatively small but simply adds to the mix.

2.4 The use of mathematics by engineers in Industry.

It is generally assumed that the majority of undergraduate engineering students will wish to pursue a successful career in engineering or industry, and as such they will need to be equipped with the appropriate skills to do so. Conversations with employers suggest that most are looking for a balance of skills, and that it is more important for graduates to have a holistic awareness of mathematics, than knowledge of specific mathematical topics. They need an appreciation of approximate scales and orders of magnitude, engineering principles based on mathematical ideas, and the ability to perform mental calculations [11].

Industry seeks undergraduates with both sound scientific knowledge and the transferable skills to apply it in a practical environment. Universities have traditionally focused on the specific technical and scientific skills of engineering rather than their applications and the "soft skills" such as communication and teamwork that industry requires [4]. Through their extensive survey work, Goold and Devitt [12] found, while almost two thirds of engineers use high level curriculum mathematics in engineering practice, mathematical thinking has a greater relevance to engineers' work compared to curriculum mathematics. Furthermore, mathematics in engineering is becoming increasingly reliant on technology. Graduates will certainly need familiarity with the relevant IT tools, as well as the ability to interpret the results they produce.

3. SURVEY CONSTRUCTION

The survey designs were based on lessons learned within the information search phase and constructed around the following ideas. Many of the questions had deliberate similarity across the two surveys so direct comparisons could be made.

1. Local survey of undergraduate engineering students.
 - a. Effectiveness of the present Teaching and Learning methods.
 - b. Pre-course preparation for study.
 - c. Perceived appropriateness of the syllabus.
2. Survey of practising engineers in industry.
 - a. Mathematics content of engineering degrees.
 - b. The use of mathematics in industry.

The surveys mainly comprised a set of qualitative questions using a 5 point Likert scale but also contained some free text questions and space for additional comments. The surveys were designed to be anonymous.

After obtaining ethical clearance, the two surveys, were built online and trialled using several independent and unconnected persons. Their comments provided useful feedback to improve the questions and about time taken to complete it. The surveys were distributed by a variety of means including the use of social media and followed up four weeks later with a reminder.

4. RESULTS

4.1 The Undergraduate survey.

Exactly 100 responses were received from students of various engineering degrees. 68% were male and 32% female which over-represents the female proportion of the actual cohort. 90% of respondents were domiciled in the UK. Almost 80% of the respondents were studying either Mechanical Engineering (47%) or Product Design Engineering (32%) with the remainder being distributed in small numbers across a number of other disciplines such as electronic and electrical engineering, manufacturing, systems and sports engineering.

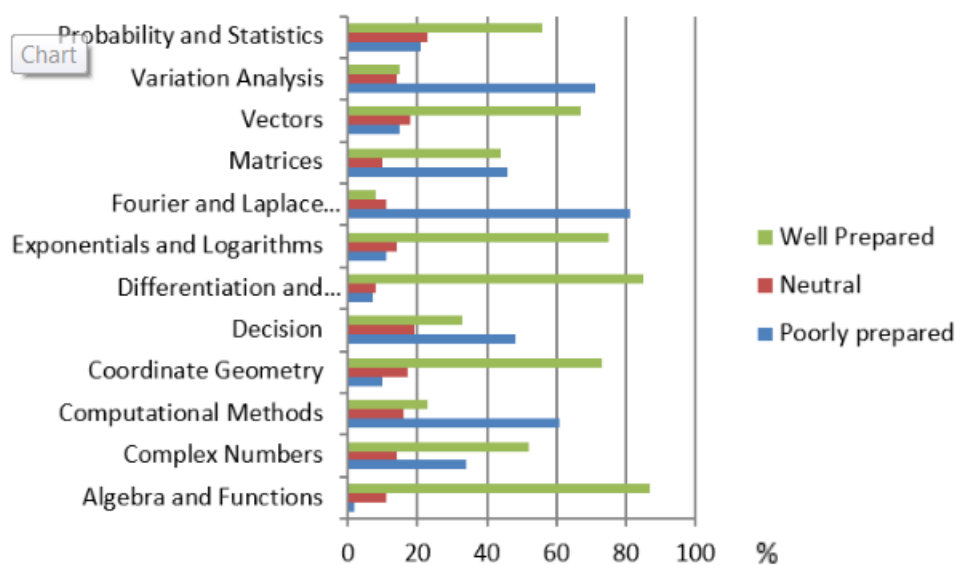


Fig. 1. Initial preparedness of students for studying key mathematics topics.

The respondents were quite evenly distributed across the four years of the degree and more than half already had at least 10 weeks of experience working in industry, mainly through longer placements or internships. 80% had entered the university with an A-level qualification in mathematics and several offered further mathematics as well. Reflecting on their pre-university studies, figure 1 shows a simplification of the Likert data received in which we have joined together 'well' and 'very well prepared' responses, similarly for the 'under-prepared', to which we have also added those who had not previously studied the topic at all. The main areas where prior knowledge appears lacking were variation analysis, computational methods and transforms. All are topics that few students have previously encountered.

Questioned about their career expectations, they predominantly believed in their need to understand fundamental mathematics but were less positive of their need for high level maths skills, 80% expected that they would be trained in specific mathematics as required. They certainly anticipated that they would be required to do mathematical analysis in their careers with only 7% to the contrary. Interestingly, they were aware of the importance of developing 'soft skills', with 82% rated these as more important than knowing many mathematics topics and only 1% less so, although many were neutral on this.

On a scale of 0 to 10, students were asked to compare the usefulness of theoretical and practical skills for their taught engineering modules and within their project work. On this scale, 0 represented purely theoretical, 5 represented equal usefulness and 10 was purely practical. On average, students scored 3.8 for usefulness in engineering modules and 6.5 for project work. Clearly, theory (such as mathematics) is thought to be more useful for taught university modules than in project work that more accurately simulates the industry environment.

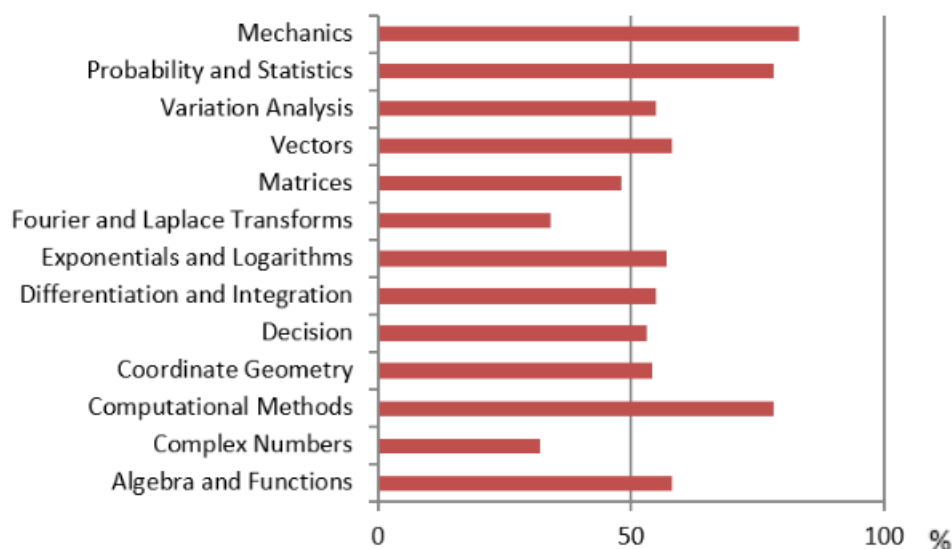


Fig.2, I expect to use these maths topics in industry.

Half the respondents generally believe they have a good understanding of the mathematics that will be required of them in industry and it is interesting to note that this figure approximately coincides with the number that had spent time there, which begs the question about the many students who do not undertake placements etc. 65% of the sample also believed they were well prepared for industry. Figure 2 shows the students' expectations of how they will use their mathematics in their later engineering career. However, the placement students were asked how often they had actually used maths while in industry and the majority (54%) said less than once a month with only 9% needing maths every day.

Figure 3 shows the maths topics that students actually used while on placement which appears to support the need to shift towards computational tools. Students certainly expect to use the maths they had been taught. 95% agreed they would need to know the fundamentals, even though 10% expected to be working outside the engineering field upon graduation.

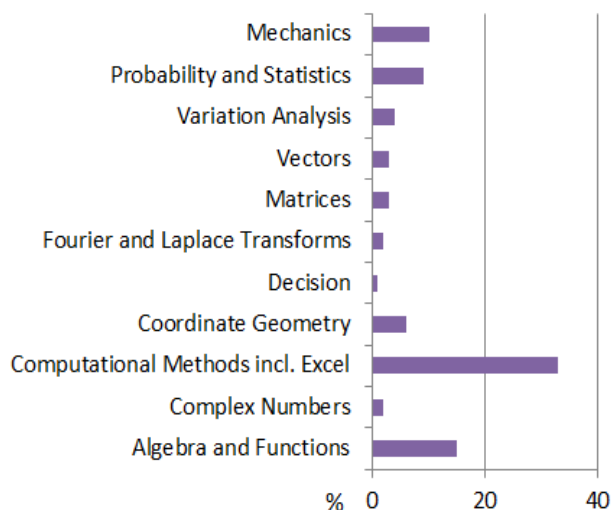


Fig. 3 Topics used on placement in industry.

The survey revealed the wide range of reactions to year-1 mathematics teaching. Quite a large proportion of this group had arrived with 'A' grades in maths and/or 'Further Maths'. As all the freshers are taught together, it is not surprising, and somewhat reassuring, therefore that many (51%) had found their maths easy in year-1. This, however, had a demoralising effect on the strong students. A number commented on this in their free text and some suggested teaching at different levels was needed. Around half (49%) agreed that their mathematics was taught well with another 24% neutral about this. 72% believed that the syllabi were appropriate for their engineering modules. They were quite emphatic that they learned more from tutorial sessions than lectures and also gained from feedback given after tests etc.

4.2 The Industry survey.

The authors were delighted to receive 78 completed responses of which 87% were

male and 13% female. 13% had influence or are responsible for the recruitment of graduates and 12% held managerial positions.

When asked about their experience of working with new graduates, 80% confirmed they arrived with adequate mathematical knowledge and few thought there was a need for further training in maths. Virtually all accepted that engineering graduates are expected to know a range of fundamental topics and 70% expected high level mathematical skills because, they claim, “graduates often do mathematical analysis”. Emphatically, 90% thought graduates must be able to interpret the results of computational analyses with only 3% not needing this.

Company engineers were asked about the use of computational software by ranking on a scale of 0-10 where 0 represented hand calculations only, 5 represents equal usage and 10 represented only using computational software. The average score here was 6.2 showing a leaning towards the use of software. Using a similar scale, respondents were asked to rate the relative usefulness of theoretical and practical skills within the industrial environment. For this question, 0 represented purely theoretical, 5 showed equal usefulness and 10 was purely practical. On average, industrialists scored 5.7 reinforcing the predominant need for practical applications skills.

The industrialists reported a different view about how often mathematics is used. While 54% of placement students had stated their usage was very low at less than once a month, 46% of the responding industrialists used maths every week and only 20% hardly used maths.

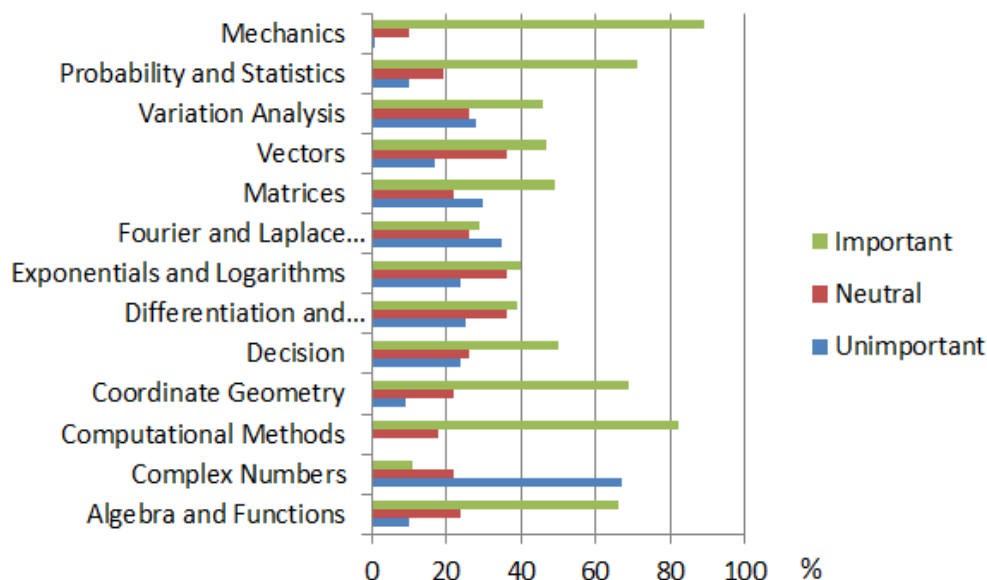


Fig. 4. Perceived importance of mathematical topics for industry.

Industrialists were asked to rate the importance of various maths topics, clearly this is very job dependent but the results, displayed in figure 4 confirm the importance of

fundamental topics such as algebra, geometry and mechanics and the need for familiarity with computational methods. They also reveal that more specialised treatments like transforms and complex numbers have a much lower priority.

The survey also asked if any topics were found lacking. Although this free text question was completed by many, the results were scattered.

Questioned about their experiences of working with new graduates, most found them to be enthusiastic (91%) and generally well prepared (63%), with a good understanding of the maths they need (68%). Around half the respondents had left university within the last 10 years and these people overwhelmingly believed that the mathematics they were taught had been relevant (84%). Despite many anecdotal reports to the contrary, only 27% were critical of graduates' lacking of 'soft' skills.

A number of respondents added comments about how maths education could be improved. A few examples are given here.

"Teach where the maths is used....make (it) more engineering-focused with real world applications, not just theoretical basis..... Associate the mathematics to it's application";

"Subjects such as statistics, computational analysis and programming are becoming ever more important for engineers";

"The course I attended did not cover probability in any great detail which would have been of benefit.";

"What is taught sometimes is out of sync on what the industry is using now. Be it older software/methodology or not used in real world application." "a much deeper focus should be developed on computational methods in later years". ".....more emphasis on graphical mathematical methods".

5 CONCLUSIONS

Both surveys provoked an excellent response rate. Despite this, the data has to be read in the context that the students were drawn from a single School in a single HE institution where the overwhelming majority were studying mechanical engineering. Furthermore, although it was intended to gather data from a wide spectrum of industrialists, the outcome defied this and was heavily skewed towards the aerospace industry so one might expect a higher than average need for high-level mathematical analysis.

This student sample felt generally well prepared for their mathematics studies at university and there is less of a mismatch than originally anticipated between the mathematics taught and the mathematical skills and knowledge required by industry. However, there is an appreciation that more focus needs to be put on statistics, variation analysis and computational methods within engineering education.

There is certainly work to be done regarding the effectiveness of the teaching methods for mathematics currently in use and, this work has specifically highlighted the need to tackle the wide range of entry-level abilities and competencies. Even though the majority of respondents had arrived with high grades from their secondary education, there was a wide range of abilities in the different sub-disciplines. Universities must, therefore teach an inclusive study programme. The danger of this is that topics that are well understood tend to appear easy and cause some students to lose interest. A flexible curriculum is needed to better accommodate the varied needs of a group of students.

Students clearly expect to make use of their mathematics, not just in applied modules at university but throughout their career. By some margin, they perceive the three most important topics as mechanics, statistics and computational methods and these choices were directly confirmed by the industrialists. Interestingly though, few had actually used mathematics other than computational methods while on placement.

Both surveys had few complaints about the teaching methods used or what they were being taught. However, the most commonly recurring theme concerned the need to demonstrate where and how the maths is applied with real examples.

The employers appeared quite satisfied that the graduates they receive were mathematically fluent but emphasised the need for general fundamental understanding of basic mathematics plus a strong appreciation of statistical, graphical and computational methods.

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DC Educational Development

Improving understanding of DC to DC / DC to AC conversion

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Conference Key Areas: Innovative Teaching and Learning Methods

Keywords: Teaching, Power-Electronics, Experiments

INTRODUCTION

Direct Current appears to be making a comeback, after more than a century. High Voltage DC in Transmission, Electrical Mobility, Electricity Storage with batteries, Sustainable Generation with Photo Voltaic and Solar Home Systems are some of the examples thereof. Next to the usage of DC in applications and appliances, more and

more examples are appearing that combine 'Power Electronics' / Semiconductor technology's with Digital Control to establish the so called 'DC Smart Grids' with active, soft- or firmware controlled components. That is for many quite a different approach to Electrical Engineering. So if DC is really making a comeback, what is done to educate the future generation of Electrical Engineers, to work with these technologies?

The paper proposes a method to teach and instruct the workings of power electronics and electrical drives. This method contains both a theoretical module and a practical module. The basis module is a Full-Bridge inverter, see Fig.1, that can be used to make a single phase inverter. Practical laboratory assignments for students include assembly of a single phase sinusoidal current generator and a low voltage single phase grid-tied inverter. To support the theoretical module, the foundation of the lab assignments is a newly developed Printed Circuit Board [PCB], see Fig. 2, that can be further developed into a broad variety of applications, such as DC-DC converters, DC-AC inverters and motor drives. The PCB contains four half-bridges that can be configured as 4 DC-DC converters, two Full-Bridge inverters or a three phase inverter with an additional DC-DC converter.

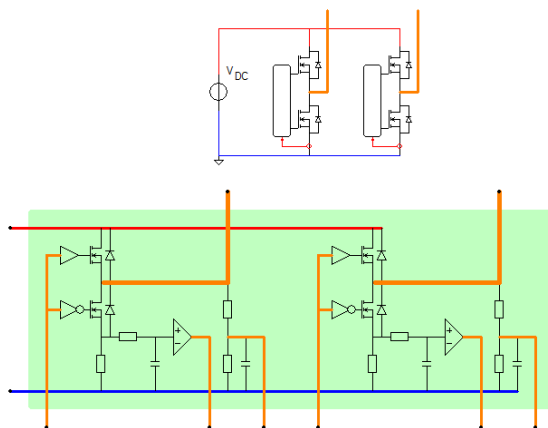


Fig. 1: Full bridge inverter with gate drivers and shunt resistors for current measurement. The schematic is represented by the virtual model within the green shaded area.

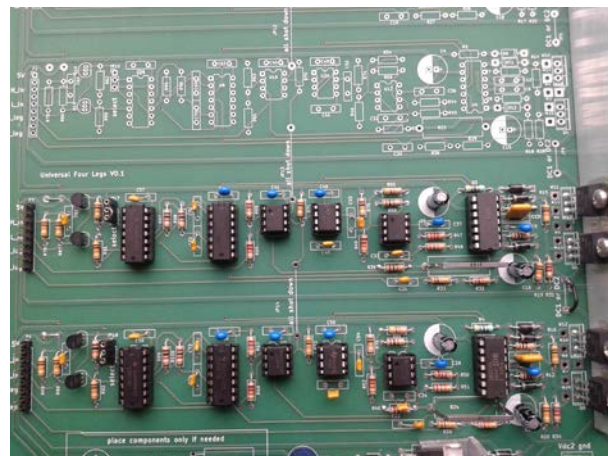


Fig. 2: Inverter PCB (4-half-bridges) with 2 legs with analog current and shoot through protection electronics.

To explain the aims and workings of this new PCB, a set of practical laboratory assignments was developed, with extended functionality compared to what was possible with the single phase Full Bridge inverter from Fig 1. The paper gives an overview of the possibilities of this developed PCB with the help of some typical laboratory examples meant for educational purposes.

1 MODELING DC-DC CONVERTERS

In this section we will outline the method that is used to teach the basics of the theory behind DC-DC converters. This is done by explaining the basics of the switching cell with the help of a synchronous Buck-converter[1]. Students are first learn the basics of the theory behind switched mode power supplies and to experiment with the basics of the Buck converter, a single leg of the PCB can be used.

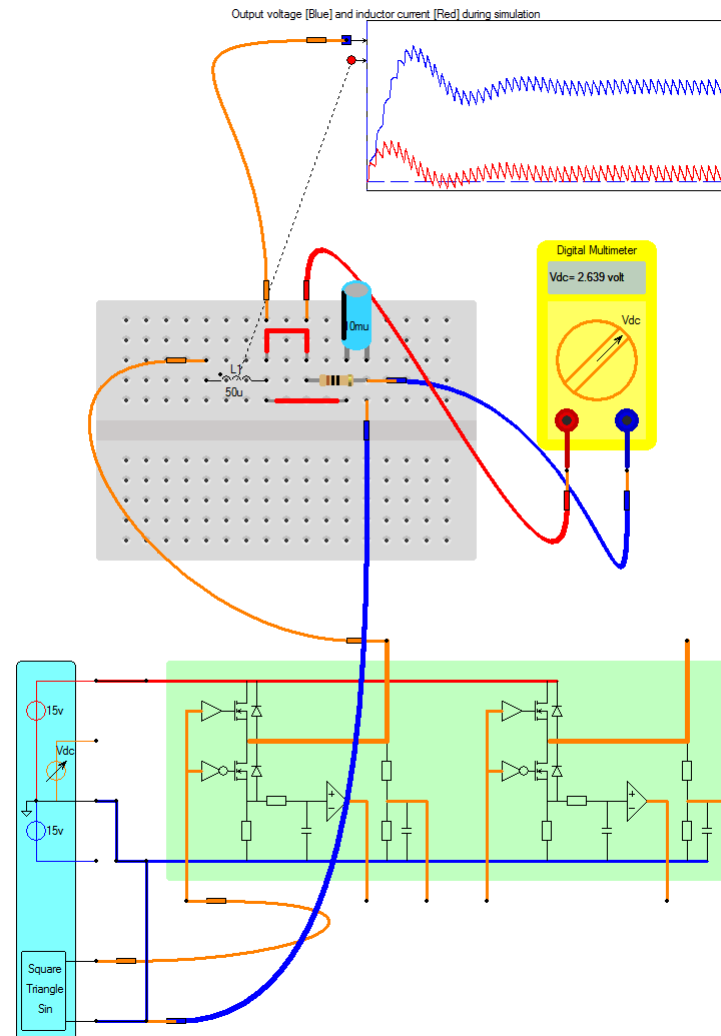


Fig. 3: Simulation of a Synchronous Buck converter with LC filter and load on a virtual breadboard.

The output of the leg is connected to an inductor on a breadboard with output capacitor and resistive load. The control is open loop and simply taken from a signal generator, where frequency and duty cycle of the control signal can be varied. The output voltage is measured using a probe and the inductor current using a current probe and displayed in the scope. The upper trace [blue] is the output voltage, while the lower trace [red] is the inductor current. Using this configuration, students can be

taught of the DC to DC conversion as required when connecting a 20 volt USB line to a 5 volt USB line. As the circuit is built as a synchronous buck, which is analogous to a bidirectional converter, also bidirectional power flow between the input and out output can be studied.

Fig. 3 shows the simulation in Caspoc [2] of the entire setup, where the green shaded component is the PCB. Students first have to study the behaviour during simulation where they have to observe waveforms and study the influence of component parameters on the overall behaviour. Once the assignments in simulation are approved, the student can then build the circuit as firstly done virtually in the simulation in Caspoc and verify the measured actual waveforms on the oscilloscope with results from the simulation.

2 CASE STUDY GRID-TIED INVERTER

The single phase grid-tied inverter [1] is the next assignment. Here the students have to study the behaviour of a single phase inverter with analog PI control to create a sinusoidal current in phase with a sinusoidal voltage from the grid.

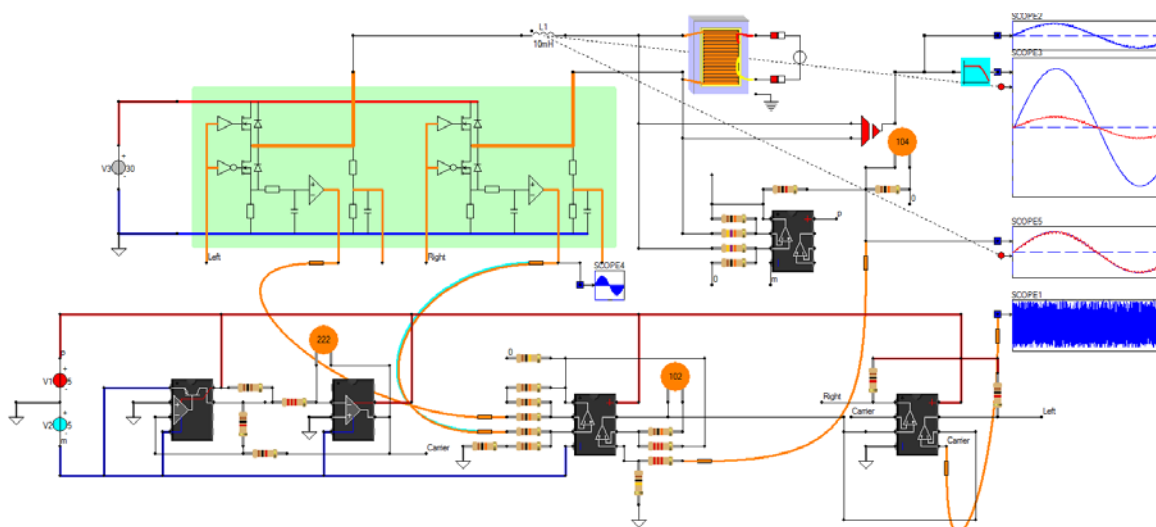


Fig. 4: Single phase grid-tied inverter with analog PI control and carrier oscillator circuit and coupling to the main grid via a mains transformer.

To make this assignment safe and operational for the students a low frequency transformer is used to scale the voltage down from the mains voltage towards a safer low voltage of 12 volts RMS. Here the students learn how Pulse Width Modulation [PWM] can be created using a reference voltage and a high frequency symmetrical carrier signal [1].

Fig.4 shows the simulation of the grid-tied inverter in Caspoc [2]. Besides gaining understanding on power electronics, also the importance of analog circuit design is highlighted by encouraging the students to build an effective analog control circuitry with a minimum of components. The students have to design a triangular waveform

generator using an opamp and comparator, typically an uA741 and LM311 [3]. The PI controller is built around TL082[3] and the generation of the PWM signal is performed by two comparators with pullup resistors. The outputs from the PWM-comparators are input to the gate drivers on the PCB.

From this assignment students will learn how to build a basic analog control, which is based on current measurements through shunt resistors connected between the source of the low-side mosfet and the reference ground, see fig 5.. Important is that the students understand the difficulty in following the sinusoidal voltage waveform using a PI controller. Basic concepts like gain and time constants of a PI controller as well as the current measurement and scaling is done using the two opamps inside the TL082. This simple analog approach is still possible with low frequencies like 50Hz or 60Hz, as the PI controller can track this low frequency easily. When working with three phase inverters and PI controllers for motor drives, the concepts of Field Oriented Control can be taught using a digital controller [4].

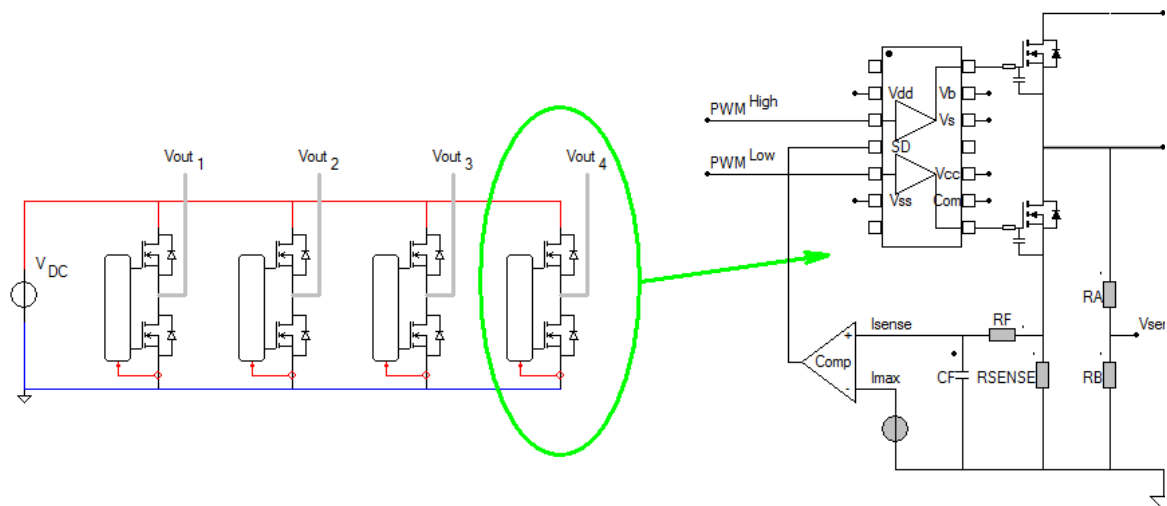


Fig. 5: Current measurement, protection and output voltage measurement of a single leg on the PCB

3 DC MOTOR CONTROLLED

Bipolar and unipolar motor control [4] can be taught using the setup from Fig. 6. Here a bipolar full bridge motor drive is displayed during simulation in Caspoc. The DC motor is connected to a flexible mechanical load. The motor current is monitored using the shunt resistors as shown in Fig. 5 and compared to a constant voltage reference. By adjusting the voltage reference, or taking a voltage reference from a laboratory signal generator, see the voltage source VSQUARE1 in fig. 6, the response of the output current can be observed. Again the students have to understand the working of an analog PI controller and the settings of the gain and time constant of the PI controller using a simple opamp [4].

The simulation in Fig. 6 shows basically the same set up as used for the single phase inverter with current control from fig. 4. The current through the motor windings is measured and compared with a square wave reference voltage. This square wave results in a change of direction in rotation as visible in the scopes in the simulation. The top scope shows the current through the motor windings, while the second scope the angular motor speed shows. The third scope shows the high frequency carrier signal.

As with the other simulation from Fig. 3 and Fig. 4, a virtual breadboard is created where components can be connected using their typical component connections. In this way students can experiment in a virtual way with connecting the components and think about physical placement of components to improve circuit layout.

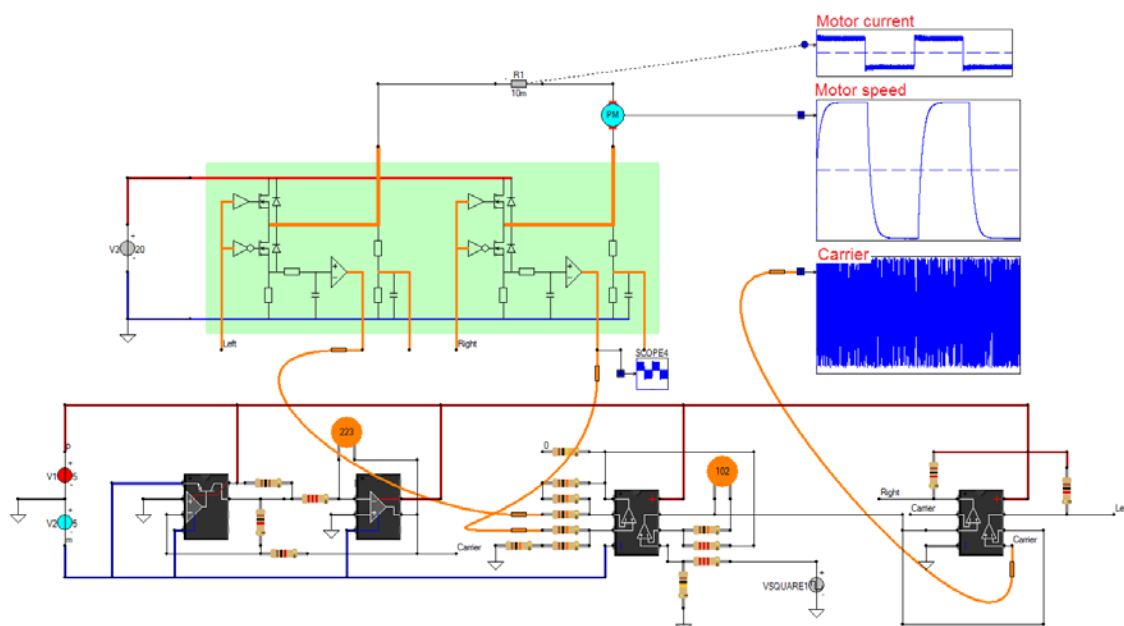


Fig. 6: Permanent Magnet DC motor drive with current control

4 BRUSHLESS MOTOR DRIVE

The principle control of a Brushless motor drive is shown in Fig. 7. During the simulation the hall signals are visible and the rotor turns. Before turning to a virtual breadboard the students firstly have to understand the working of a brushless motor drive with Hall sensors. The simulation includes a basic model of a two-level inverter feeding a brushless motor. Parameters for the brushless motor include winding inductance and resistance as well pole pair and back-emf constant. The output of the brushless motor is connected via a Hall sensor to a mechanical load. The angular speed of the motor drive is displayed in the scope on the right side. Students first have to understand the typical wiring from the Hall sensors towards the control.

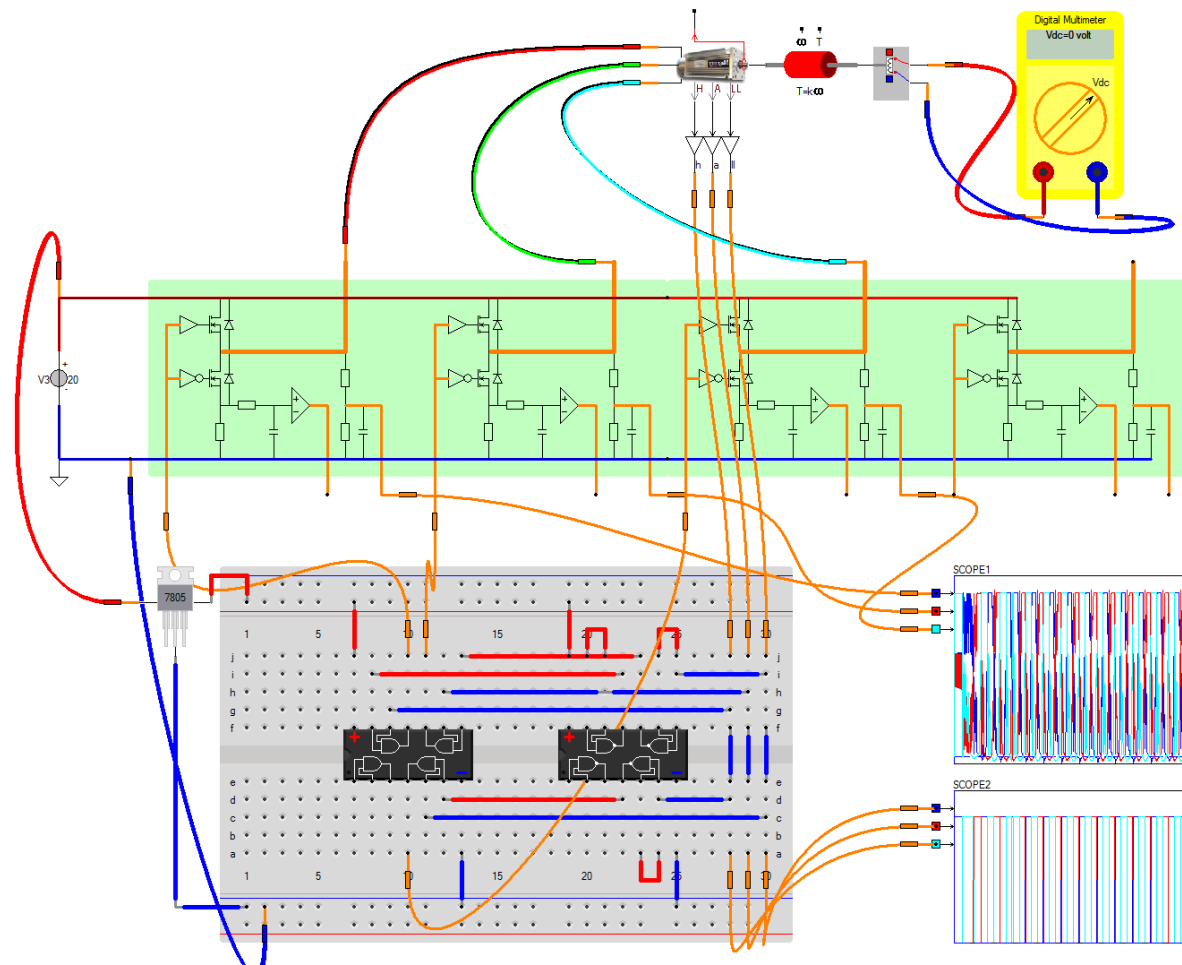


Fig. 8: Brushless motor drive using a virtual breadboard

The cross-section of the brushless motor in Fig.7 is animated during the simulation. The Hall signals coming from the Hall sensor are highlighted, depending on their logical state and the Conducting mosfets as well as the current path are coloured depending on the absolute value of the current. During the animation the rotor in the cross-section will rotate as well as the direction (indicated by the two arrows) of the applied winding flux from the stator. The students can visually inspect the dependency of the rotor position, Hall signals, control signals for the mosfets as well as the currents flowing through the motor windings. The scopes at the bottom left side of Fig 7. show the DC link current and line voltage between the first and second motor terminal. The current shows the typical rectangular blocks, while the line voltage shows the trapezoidal back-emf of the motor and the typical voltage spikes during commutation.

A simulation using a virtual breadboard with logic NAND and AND [3] is shown in Fig. 8. The angular speed of the motor is measured using a Tacho and displayed in

the digital multimeter. The Hall signals from the brushless motor are directly connected to the logic AND and NAND gates, that make the control signals for the mosfets. Since the PCB contains the required gate drivers for the mosfets, the outputs from the AND gates can directly be connected with the gating inputs of the PCB. A linear voltage regulator 7805 is applied to feed the logical gates [3].

The scope on the bottom right side shows the three Hall signals, while the other scope shows the voltage on the motor terminals from the voltage measurement terminals from the PCB.

5 SUMMARY AND ACKNOWLEDGMENTS

This Paper presents a result of the USB-(D)C initiative [5] in which USB type C technology is being developed. This project is funded by the Dutch Ministry of Economic Affairs. This result will also be available via the DCT-REES ERASMUS+ initiative, in which partners from EU and South-Africa work together to (re)develop educational materials towards a future DC-Grid. The pivotal role of Power Electronics for many different types of applications is described. The examples show how this experimental set up can be used to teach typical DC-DC applications, such as conversion and power exchange between two different DC voltages. Also the application of a grid-tied inverter and a PMDC and Brushless motor drive are demonstrated. Other applications that can be created using this PCB are Maximum Power Point trackers for solar cells, as well as battery chargers. In the case of motor drives the applications can be extended towards step motor control, unipolar and bipolar, full step half step and microstepping, bipolar and unipolar permanent magnet DC motor control as well as three phase trapezoidal brushless motor control and permanent magnet synchronous machine control using a digital controller. Analog control is directly connected to the voltage and current measurements terminals on the PCB and can control the mosfets using a natural sampling PWM modulation[4]. Digital control using a microcontroller can be added by connecting the measured signals to the analog inputs of the microcontroller, while the outputs from the microcontroller can drive the inputs of the gate drivers on the PCB.

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Current Situation and Problems of Engineering Ethics Education at Colleges and Universities in China

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Conference Key Areas:

Keywords: engineering ethics, course construction, questionnaire

I. Introduction

As the time evolves, science and technology are playing an ever-increasingly important role in modern economy and society. However, any engineering technology is double-sided in itself and both its positive and negative effects on the human society and natural environment have been bringing more and more attention to the issues of the ethics of engineers. Engineering ethics education should become an indispensable step in the cultivation of high-quality engineers in the future.

At present, China leads the world in engineering education in scale. There are engineering specialties at 2,368 colleges and universities in China, accounting for 93.6% of all regular institutions of higher learning in China; and the current enrollment for engineering education is 10.40 million, accounting for 38.1% of the total. ¹However, as a big country in engineering education, compared with developed countries, China has not formed an organized and

¹ Data source: A speech titled Several Thoughts about the Reform and Development of Engineering Education in China by LIN Huiqing, Deputy Minister of Education of People's Republic of China, at the "2015 International Forum on Engineering Education"

advanced system of ethics education; as a result, the engineering and technological talents we cultivate can not meet the requirements of the "Made in China 2025" development strategy.

The research on engineering education in mainland China started with a 1998 research program called "Research on Engineering Ethics" supported by the National Social Science Fund of China, led by Prof. Xiao Ping at Southwest Jiaotong University. After that, a course called "Engineering Ethics Studies" was offered at Southwest Jiaotong University to fill a gap in courses on engineering ethics among colleges and universities in mainland China. In recent years, a number of universities, such as Tsinghua University, Zhejiang University and Xi'an Jiaotong University, etc., have started to offer related courses on engineering ethics one after another. Given the differences in faculty and in the needs of the target audience of teaching at different universities, there are vast differences in course offering, course construction, teaching content and teaching modes, etc., among different universities. In order to get a full and objective picture of the current situation of courses on engineering ethics at universities in China, Tsinghua University Engineering Ethics Research Program, on the occasion of the "Advanced Workshop on Engineering Ethics Courses for Core Teachers" organized by the National Engineering Professional Degree Education Steering Committee ("Steering Committee" for short hereinafter), conducted related surveys and, in combination with the survey results, tries to understand the current situation of course offering on engineering ethics at universities in China, analyze existing issues and put forward corresponding strategies.

II. Research Process

(1) Questionnaire design

In order to understand the recognition of engineering ethics education by universities, the industry and teachers as well as the current situation of course offering on engineering ethics at universities in China, Tsinghua University Engineering Ethics Research Program has specifically designed a questionnaire. Before the survey, they consulted related material, conducted interviews and panel discussions. In the end, the research program team designed two kinds of questionnaires--one to be filled out by competent authorities for postgraduate education, and the other for teachers.

(2) Survey Procedures

In order to understand the situation of engineering ethics education at universities in China, Tsinghua University Engineering Ethics Research Program conducted two surveys. The two surveys, with valid check, collect 84 questionnaires from postgraduate education authorities and 412 from teachers, are all effective. The two surveys involved 122 colleges and universities in total. The valid questionnaires recovered were statistically analyzed with Excel and SPSS19.0.

III. Survey Results and Analysis

This survey involves 122 colleges and universities, 34 of which have started offering courses on engineering ethics, 80 plans to offer them, and 4 have not started offering them and do not have such plans, either. Nevertheless, many engineering universities and colleges not covered by the survey are also actively exploring and making preparations for such courses. Although the sample universities and colleges account for only nearly one quarter of all units for the cultivation of masters in engineering, they represent all levels of institutions of higher learning in China to certain extents. Therefore, they typically reveal the general situation of colleges and universities in China. Through statistical analysis of the survey questionnaires, we found that the following issues exist in the practices of engineering ethics education at colleges and universities in China:

(1) Issues with the Top-level Design of Engineering Ethics Education.

Survey results indicate that 90% of the teachers believe that it is necessary for engineering specialties at colleges and universities to offer courses on engineering ethics, and 10% believe that it is not necessary to offer such courses or they are dispensable; postgraduate education authorities at 81 colleges and universities believe that it is necessary and those at 3 don't believe it is necessary; of the sample enterprises, regarding the question of the necessity for "strengthening the sense of social responsibility of postgraduate students for professional engineering degrees, pushing ahead with engineering ethics course construction", 68 enterprises believe that it is "very necessary", 199 "necessary", 4 "unnecessary" and 5 "neutral".

The surveys reveal that 68% of the teachers believe that "attention from leaders" is the primary factor influencing the offering of courses on engineering ethics. In addition, 42.3% of the teachers believe that "the lack of directive documents from superiors" is a main influencing factor. In our interviews, some teachers also mentioned that the popularization of courses on engineering ethics would be a little easier with documents from superior education authorities.

The lack of top-level design of engineering ethics education in China has a lot to do with the culture and thinking around higher education in China. For a long time, greater importance has been attached to sciences instead of humanities in the planning and implementation of science and engineering education in China. This attitude has resulted in a general perception that engineering ethics education is dispensable for science and engineering students and that the so-called "engineering spirit" is nothing but accuracy and efficiency, and engineering education is only expected to educate the students to pursue the true, the real and the refined, to do their own jobs well and to develop, design and produce high-quality and beneficial products. As regards how these products function and what their functions are in the society, that's the question for the government, entrepreneurs and users, which is beyond the

responsibility and capacity of engineers.²Therefore, it is a general perception that engineering education has nothing to do with ethics, which has resulted in minimal importance attached to engineering ethics education or simply the absence of it in the top-level design of engineering education at colleges and universities in China.

(2) Shortage of Teachers for Engineering Ethics Education

In the survey, there are 4 questions about the basic issues of faculty and course offering. The results indicate that in "Key Issues for Engineering Ethics Course Construction", 63% of the respondents believe that faculty is a key issue, followed by teaching materials, teaching modes and syllabus, etc.; other issues include the construction of case databases and sharing of teaching resources, etc.

As regards "Factors Influencing the Offering of Courses on Engineering Ethics", 61% of the teachers believe that "faculty strength issue" is a key factor influencing the offering of courses on engineering ethics. As regards the question "Whether the teachers for engineering ethics education at your university can meet actual teaching requirements", survey results indicate that 68% of the teachers don't believe that they can meet the requirements very well or they believe that they simply can't. Only 9% of the teachers believe that the teachers at their universities can meet the requirements of teaching courses on engineering ethics, and 23% believe that they can "basically meet the requirements". Further analysis of the issues with faculty indicates that 62% of the teachers believe that the paramount issue with faculty for courses on engineering ethics at respective universities is "undermanned", 44% believe that the issue is "professional level" and only 8.6% believe that there are no issues with faculty at their universities.

(3) Insufficient Teaching Resources for Engineering Ethics

The issues of insufficient teaching resources for engineering ethics are first reflected in the insufficiency in textbook resources. An overview of the domestically published textbooks on engineering ethics indicates that before 2009, there was only one comprehensive textbook on engineering ethics compiled by Xiao Ping, which is Engineering Ethics Studies. At present, apart from engineering ethics textbooks in professional fields, there are less than 30 comprehensive textbooks and translated works on engineering ethics education. Due to insufficient varieties of textbooks, the teaching needs of different engineering specialties cannot be met.

The second is insufficient case databases and other resources. Teachers who have started offering courses generally reflect that there are not many local cases available, and most cases on engineering ethics come from abroad. Due to differences in social backgrounds, culture and laws and

² Cao Nanyan. Reflections on Engineering Ethics Education at Colleges and Universities in China [J]. Higher Engineering Education. 2004(5).

regulations, etc., the students think that they are a little remote. Meanwhile, the local cases are mostly about medicine, civil engineering, water conservancy, chemical engineering and environment, etc.; there are few cases on ethics in major engineering fields, such as agriculture and foodstuffs, let alone those limited cases and contents about niche industries and fields. Especially with the time rapidly evolving and with Chinese engineering science and technology going global, some cases on Chinese engineering ethics against the backdrop of globalization are also in urgent need.

In recent years, the national education authorities have also attached more importance to engineering ethics education. Since 2004, the Steering Committee, under the leadership of the Ministry of Education, has been fully promoting the construction of courses on engineering ethics at colleges and universities and has introduced a series of measures including publishing textbooks, training teachers, building case databases, creating MOOCs and holding seminars on education, etc.

(4) Featureless Content of Courses on Engineering Ethics

At present, those engaged in teaching and research of engineering ethics are mostly experts and scholars in philosophy and ethics, and the teaching contents of the courses mainly focus on ethical issues that engineers must face, their responsibilities and their professional code of conduct, etc. For instance, for the question "What aspects of contents do you think that the courses on engineering ethics mainly include?", our research program team found that the third option--"ethical issues in engineering"--is highly recognized among the teachers, with 88% of them selecting it. The second option--"basic theories and methods for engineering ethics"--is the least recognized.

Some engineering colleges and universities even replace engineering ethics education with moral education or professional ethics education. However, in-depth development of engineering ethics education cannot be achieved only with the work of experts on philosophy or ethics, and it is also not possible to solve many practical issues of engineering ethics only through moral education.³

Engineering ethics is an emerging discipline. Up to now, there is still no consensus on the main content of courses on engineering ethics as well as its teaching methods and standards within the educational and engineering circles. People are often at a loss before so many different or even conflicting viewpoints and perceptions. Therefore, it is very necessary to establish teaching contents and methods for courses on engineering ethics with both Chinese and global characteristics in combination with practical engineering activities in China.

³ Liu Jing. Constructing a Cultivation System for Engineering Ethics Education Based on System Theory [J]. Higher Engineering Education Research, 2010(6).

(5) Undiversified Method for Engineering Ethics Education

Facing the question “which kind of teaching mode do you think is more appropriate for engineering ethics?”, more than two thirds of the respondents gave the answer of “hybrid teaching” mode. Study results showed that the MOOC-based hybrid learning mode contributes to improving the teaching quality in higher education and developing the students’ collaboration and autonomous learning abilities. But our interviews found that engineering ethics is mainly taught by teachers in colleges and universities which have offered the course now. Currently, the undiversified and simplified teaching methods for engineering ethics have affected the training quality of engineering technology talents and, to a certain extent, have resulted in various problems in the engineering design and management practices in China in the context of deficient supervision system for engineering ethics.

IV. Reflections and Suggestions

Here are some reflections and suggestions based on the issues and analysis in the foregoing Part.

(1) Strengthen the ideological understanding and top-level design

The aforesaid survey shows that the courses of engineering ethics education have been understood ambiguously, and defective in its top-level design. Today’s countries, especially developed ones, attach great importance to engineering ethics education. For international higher engineering education, it has been generally agreed to strengthen engineering ethics education. In the international universal engineering education accreditation, it is generally required to include the contents of engineering ethics education. As China is a full member of the *Washington Accord*, higher engineering education will inevitably require stronger education on ethics when China gears to international conventions. Meanwhile, with the further implementation of national development initiatives such as “Made in China 2025” and the “Belt and Road”, it is undoubtedly a historical mission for China’s engineering education to train well-rounded talents in engineering science and technology.

There is a saying in China that human effort can achieve anything. Whether a thing can be done depends firstly on the degree to which it is understood and implemented, especially the attention from high-level leaders and the top-level design. Universities are a cradle of highly-competent talent in engineering science and technology. In a sense, the ethics and morals of our future engineers serve as a wind vane for ethics and morals in the industry. For this reason, colleges and universities must really pay attention to engineering ethics education for their students. Their discipline construction shall allow the engineering ethics education to be included in the engineering discipline construction requirements. Their education programs shall allow the engineering ethics courses to be included in the compulsory course requirements. Their admission tests shall allow the engineering ethics contents

to be included in the scope of testing. Their teaching assessment shall allow the engineering ethics to be included in the indicator system. These measures are effective tools to attract the attention of colleges and universities to engineering ethics education.

(2) Strengthen the faculty team cultivation

The foregoing analysis indicates that the insufficient quality and quantity of teachers is a main factor influencing the engineering ethics education in China. Therefore, firstly, colleges and universities are recommended to strengthen the training of teachers, especially engineering teachers, because the engineering ethics course will be given mainly by science and engineering teachers in the future. If every science and engineering teacher keeps engineering ethics in mind during education and teaching, it will be greatly helpful for developing the students' awareness of ethics.

Secondly, colleges and universities are recommended to encourage teachers engaged in engineering ethics to take a temporary post and have a part-time job in enterprises and engineering projects. As most young teachers become a teacher immediately after graduating from colleges and universities, they lack practice in the life cycle of a product or an engineering project, let alone get familiar with the engineering ethics issues in each stage.

Thirdly, colleges and universities are recommended to establish an interdisciplinary faculty team. Engineering ethics education involves several disciplines crossing each other and mixing together, and problems always come from different disciplines. Interdisciplinary integration can cover the shortage of engineering ethics teachers on the one hand, and practically promote the multi-disciplinary integrated development of engineering ethics on the other hand.

At last, it is advisable for colleges and universities to engage personnel from enterprises and industry associations to join the team of engineering ethics teachers. As it is impossible to promote engineering ethics exclusively by relying on universities, enterprises in the industry shall assume greater responsibilities for shaping an ecological environment for engineering ethics. From the perspective of market and employer, external experts are hired to make the university and its students realize the important role of engineering ethics in enterprises in the industry.

(3) Boost the construction of teaching resources

Teaching resources are an integral part of the teaching, also a basic guarantee for and an important carrier of teaching, and is crucial to smooth teaching. Teaching resources, if abundant and applicable, will directly affect the extent and level to which the teaching objectives are achieved.

Textbook compilation is a basic construction work in colleges and universities, which can ensure higher teaching quality and highly-competent talent. As categories of academic degree of engineering are changed to 8 categories such as electronic information, machinery, materials and chemical

engineering, textbook compilation has to meet the needs of reform to break down the textbooks on engineering ethics into 8 categories. During the compilation of textbooks, the center shall be put on higher textbook quality and case base.

The quantity and quality of local cases in China is one of the important factors concerning the future development of engineering ethics education in China. Without supporting from good cases of engineering ethics, the theories, standards and methods of engineering ethics are like castle in the air, and are so abstract for students to have a sense of reality in the scenario, which will produce an unsatisfied teaching effect. The availability of resources of profoundly analyzed cases grouped by industry, region and function will effectively boost the education and teaching on engineering ethics. As a result, it is the top priority to build case bases on the engineering ethics course.

(4) Create new education and teaching methods

In the course teaching, whether the teaching method is applied properly will directly affect the effect of teaching, and affect the quality of critical thinking about the engineering ethics issues. The engineering practice issues are always complicated, so are the engineering ethics issues involved. The same issue may not necessarily have the same answer. Consequently, for such a course involving critical thinking, the teaching should be a problem based as much as possible and lead the students to think and debate from the perspective of engineering ethics through scenario simulation, and discuss diversified solutions. In the early stage of engineering ethics course construction in China, colleges and universities are more recommended to introduce engineering ethics education into their teaching in many ways including discussion, case teaching, scenario simulation, role play and online classes based on their respective actual situation of teachers and majors, thus to improve the effectiveness of the engineering ethics course.

In a word, a qualified engineering technology talent must be well developed morally, intellectually and physically. Excellent technical skills and solid professional foundation alone are not enough to ensure the talent to create a first-rate career and make contributions to the human society and the country. Engineering ethics education must be offered for engineering technology talent to develop their awareness of ethics and sense of social responsibility. Based on the current practical issues, it is an important and urgent task to improve the quality of engineering ethics education in China.

Workshops

Creative Ways of Teaching Engineering

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- **WHAT can session participants expect to gain?** (motivation & learning outcomes)

This workshop introduces creative ways of teaching engineering content. Creativity will be regarded as essential for understanding difficult engineering concepts and for motivating the interests of undergraduate college students. The relevance of creativity for engineering education will be discussed; criteria for creative projects/assignments and a creativity teaching framework are presented. Together we will run through creative pedagogies of inclusion and engagement while exploring teaching creatively within content-specific environments. Participants will leave the workshop with steps to design assignments (for example, how to explain a law of thermodynamics in a creative form) that will activate student creativity in design-thinking and demonstrate inclusive teaching practices.

- **WHY is that session relevant?** (rationale of the session)

Based on our own research and the research of others in engineering education and beyond, we know that deep learning in engineering is a desired outcome but not easily achieved. However, students who are invited to present complex concepts in creative ways have demonstrated mastery over those concepts. In addition, our research emphasizes a connection between design-thinking and creativity that can enhance inclusive teaching.

Inclusive teaching is vital in the current classroom, for any subject. But often engineers relegate this idea to “soft-skills” and do not see its potential to reach more students and contribute to deep learning. We offer a model that shows how acknowledging creative ways of knowing shows respect and validates student diversity of cultures, languages, and viewpoints. This leads to more engaged learning and better engineers for the future.

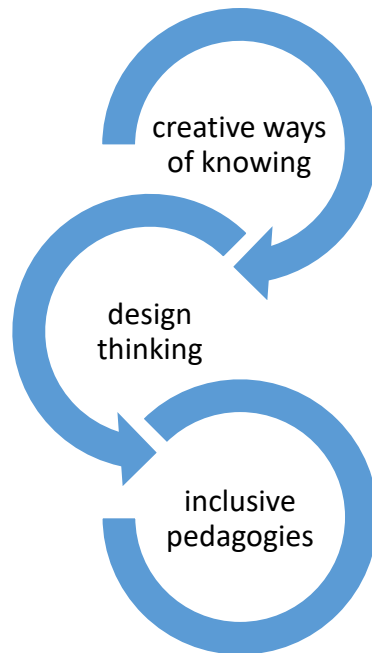


Figure 1. Model of connections needed to build this approach. {Diana Bairaktarova and Michele Eodice}

• **HOW are session participants engaged?** (engagement of and interaction with session participants in alignment with expected learning outcomes)

In this workshop, participants will be engaged in learning how to build a new culture in engineering classrooms that rewards risk-taking; develops and enhances students' ability to think creatively; and ensures student success in designing creative projects. Through interactive activities and dynamic discussion that draw on the latest theories on creativity and design thinking related to engineering practice, participants will be introduced to techniques and strategies they need to successfully teach their students to become adept with diverse peoples and ideas, to collaborate, and to contribute more and better ideas through creative ways of knowing in engineering.

• **HOW will results be summarized?** (take home for session participants)

Each participant will take home (1) detailed handouts to be used during the ideation portion of the workshop; (2) descriptions of the creative teaching technique, creativity criteria, and the underlying theory; (3) an assignment outline for the creative assignment unit that can be introduced in class; (4) an assessment rubric for such assignments; (5) a deeper appreciation for teaching inclusively; (6) ideas, ideas, ideas.

Increase the Impact of Your Journal Publications

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Internet and social media are rapidly changing the context for getting your scholarly publications noticed and read. Even the first few words of your journal article title can influence how early it appears in internet search results! This session is designed for academic researchers in any field to learn about strategies they can use when preparing and disseminating their journal articles and to increase the impact of their work. We will provide examples from the engineering education research context.

In proposing this session, we note that publishing the results of engineering education projects in archival journals is not considered the most impactful practice. However, publishing is a reality of academic life, and this session is designed to help engineering education researchers increase their impact and credibility.

The topics for the session include:

- Search engine optimization through careful selection of your title, abstract and keywords
- Brief review of impact measures including journal impact factor and h-index
- Modern methods for measuring the impact of your article, including Kudos, Altmetric, and citation tracking
- Registration with ORCID and Google Scholar to ensure the accuracy of your author impact scores
- Considerations for open access publishing your work

After attending the session, participants will be able to:

- List best practices for increasing an article's search engine discoverability

- Compare and contrast various measures of journal, article, and author impact
- Locate organizations, websites and other resources for increasing the impact of their journal publications
- Make informed decisions about registering with various author-tracking services and publishing their work in open access journals

We will organize the session to be highly interactive, using games, small group discussions and brief individual exercises to help participants learn and apply the information. Our plan for the 2-hour session is:

10 mins: Introduction and overview

20 mins: Preparing your article (exercises to rewrite titles, opening lines and keywords)

20 mins: Social media strategies for increasing visibility and impact of articles (brainstorming)

20 mins: Impact factor matching game (what data is used in which calculations)

20 mins: Open access publishing myths (true or false game)

20 mins: Review of resources, which will be summarized on a handout

10 mins: Wrap-up and dismissal

The overlooked stakeholder: discovering the cornerstones of future universities through students' opinions

Workshop proposed by BEST (Board of European Students of Technology)

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ABSTRACT

Context

Stakeholders' views on the ideal future university will be tackled, based on the participants of the workshop and European students' opinions expressed during BEST Symposia on Education (BSE)[1][2][3]. Three currently important questions on Engineering Education will be answered: **what students want to learn, how they want to learn and where they want to learn**. Topics such as curriculum development, learning methods and learning spaces will be addressed, respectively. The interactive nature of the workshop will allow participants not only to become aware of differences between stakeholders' opinions, but also to contribute on discussing the BSE outcomes.

For the past 22 years, Board of European Students of Technology (BEST) has involved students in STEM education. BEST works voluntarily to bring forward the perspectives of students as a key element in educational decision making and increase the dissemination of students' input at SEFI AC 2018. The workshop contribution will enhance constructive dialogue between students, universities, and other Higher Education stakeholders.

Organisation

The workshop will facilitate the assessment of different perspectives on the highlighted questions. The groups will brainstorm on which elements are key to improve learning, through a world café facilitation structure: By rotating the working groups, the mentioned elements will be prioritized and compared to data from BSEs [Fig. 1]. The successive analysis conducted by the working groups will reveal similarities and differences between BSE students and workshop participants, which ideally should represent different stakeholders on education.

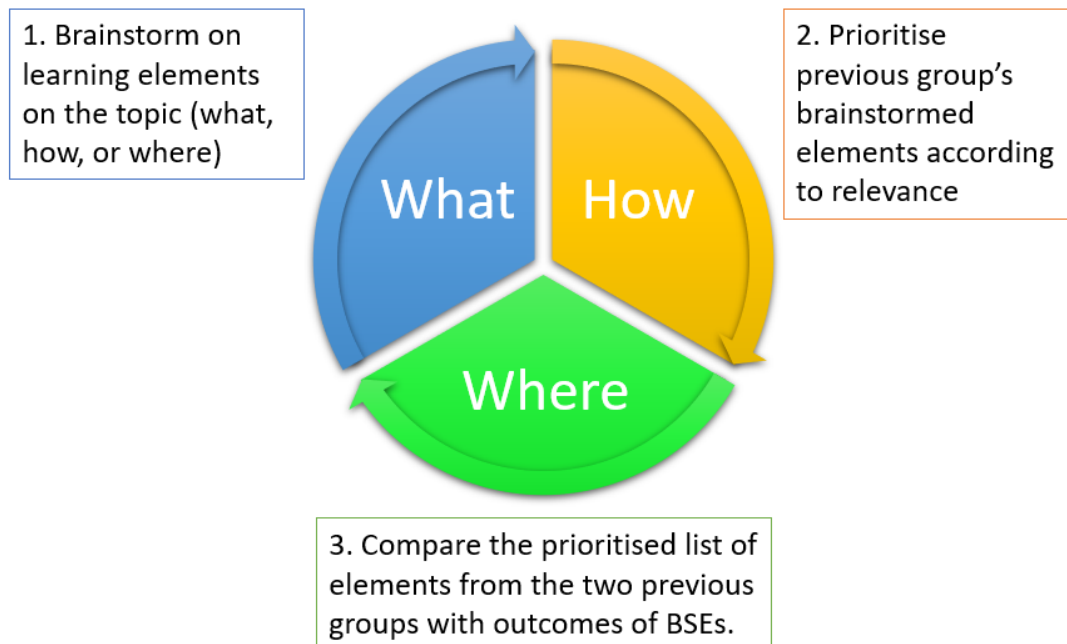


Fig. 1: World café structure for the brainstorming (1), prioritization (2), and comparative process (3) on elements of future universities. Each working group will be assigned to a station (addressing “what”, “how”, and “where” respectively). Every rotation initiates the next phase of the process, from 1 to 3.

The conclusions will be presented by each team, followed by a group discussion. The aim is not to evaluate the quality of ideas by either stakeholder, but to raise awareness to the extent at which students' perspectives are missing in discussions on ideal learning environments.

Successively, discussion groups will share their experiences of bridging the gap by including students. Each group will have the task to create a summarizing poster of their recommendations for best practices in stakeholder inclusion [Fig. 2]. The posters will be presented in a poster fair concluding the workshop.



Fig. 2: Organisation of the discussion groups, which will produce a poster on their outcomes on best practices in stakeholder inclusion.

Expected outcomes

The differences in perspectives on what, how, and where students should learn, will be summarized quantitatively between the stakeholders present at the workshop and the students of past BSEs. Recommendations will emerge from the sharing of best practices in the poster fair for the inclusion of all stakeholders in developing education. The workshop will serve as a rich opportunity for the participants to exchange ideas and learn from different practices. The outcomes will be highly relevant to raise awareness of the educational involvement of students, which is within the scope of the educational involvement department of BEST.

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Learning dashboard for supporting students: from first-year engineering to MOOC students

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Conference Key Areas: Retention of students, Engineering Skills, Recruitment

Keywords: learning analytics, learning dashboards, student success, retention, machine learning, first-year experience

INTRODUCTION

The economic and financial crisis is having an important socio-economic effect in Europe and is threatening Europe's economic growth model. To counter the crisis, Europe should further evolve to a knowledge-driven and technology-based economy. This evolution however causes a rise in the demand for personnel with post-secondary education diploma [1]. In the transition from secondary to higher education a lot of high-potential students drop out [2]. Furthermore, MOOCs experience extremely high non-completion rates [3].

By applying **learning analytics** on indicators that are predictive for a successful transition and online course completion, students can be provided with feedback on in

order to improve their self-regulation, hereby providing support during the first-year and in online courses.

MOTIVATION

Within the Erasmus+ project STELA “Successful Transition from secondary to higher Education using Learning Analytics”, three European engineering bachelor programs have been exploring the use of learning analytics and learning dashboards to support both first-year and MOOC students. The focus of the project has been on actionable feedback using a scalable approach that allows for institution-wide deployments.

Thanks to deployments of five student-facing dashboards more than 5.000 first-year students and 3.000 MOOC students were reached.

RATIONALE OF THE SESSION

The goal of the workshop is fourfold:

1. Familiarize the attendants with the learning dashboards developed in the project;
2. Share the project results, and especially the measured impact;
3. Challenge the scalability of the dashboards; and
4. Obtain feedback on the 11 main project recommendations.

PARTICIPANT ENGAGEMENT

We will use around 15 minutes of the workshop for plenary presentation. The remainder is dedicated to group work. Here we detail the activities according to the four workshop goals:

1. Within a group, each attendee explores one of the developed dashboards using an on-line live demo dashboard, and the obtained results (made available in a presentation format). Next, each group member presents the dashboard to the other group members and summarizes the results. Each group discusses the obtained results and selects one that is most striking to them.
2. The different groups present their “most striking” result to each other. Next, a small plenary discussion is done.
3. Regarding the transferability, each attendee reflects about one opportunity and one challenge for transferring the dashboards to their institute. The opportunities and challenges are shared in a “live” wordcloud that is subject of plenary discussion.
4. The project findings are provided to the different groups. Groups discuss the usability, clarity, and quality of these recommendations. Feedback is written down on a shared document. As a closure, the groups share one point of feedback with all attendees.

If participants bring their own device, they can get a live experience of the dashboards.

WORKSHOP OUTCOMES

For the attendees the outcomes are the following:

1. access to the demo learning dashboards of the projects;

2. results of the project's learning dashboards;
3. list of opportunities and challenges for transfer of learning dashboards to other institutes;
4. project recommendations.

For the project the outcomes are the following:

1. Opportunities and challenges for transferability will be processed and shared on the project webpage.
2. Feedback on the project recommendations are processed in the final project months, and will contribute to the project quality.

ACKNOWLEDGMENT

We gratefully acknowledge the support of the Erasmus+ program; STELA Project with number 562167-EPP-1-2015-1-BE-EPPKA3-PI-FORWARD.

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Reviewers, reviewers, reviewers!

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It is an undisputable fact that a journal is only as good as its reviewers. A person who is willing to write thorough, constructive and thoughtful reviews is therefore a valued treasure for a journal and its editors. A journal needs a big enough pool of reviewers to keep the assignment of each person manageable, allowing reviewers to take the full effort required for each manuscript and respond promptly. While the invitations from editors never seem to arrive when the time is quite right, there are also some rewards for the reviewer. Regular reviewing is a good way to

stay in tune with the field, and acquire insights that can improve one's own writing. It is also considered to be a merit for promotion and tenure, and as part of one's professional practice. To some extent a reviewer is an ambassador of the journal and of the relevant field of scholarship.

The purpose of this workshop is to discuss the art of reviewing manuscripts, and to provide participants with advice on best practices when reviewing education research manuscripts. Participants will also gain insights into the state of engineering education journals, and see the editorial process from the inside. We welcome experienced reviewers as well as those who are eager to start taking on review assignments.

The workshop leaders are editors of the journals:

- European Journal of Engineering Education
- Journal of Engineering Education
- IEEE Transactions on Education
- Nordic Journal of STEM Education

Expected outcomes

After the workshop, we will all be able to:

- Describe the role of peer review for a journal and a scholarly field
- Explain different quality criteria for scholarship in engineering education, and how they can be applied in peer review
- Discuss various aspects of reviewing, for instance:
 - particular aspects of a manuscript that a review could consider
 - how to help authors improve their manuscripts
 - how to help editors make fair decisions
 - how to spend one's time wisely

Workshop Outline

INTRODUCTIONS

- Participants and workshop leaders [10 minutes]
- About the Journals (where we stand today, aims and scope, review criteria and review process) [30 minutes]

GROUP EXERCISE

- Make teams of four. On the tables are sample reviews (anonymised).
Make a poster: "Characteristics of helpful reviews" [45 minutes]
- Vernissage (hanging the posters)

PLENARY DISCUSSIONS

- Results from group exercise [30 minutes]

FINISH

- Photographing the posters and signing up as reviewers [5 minutes]

Graduate Engineering Skills: Have we cracked this nut?

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1. WHAT shall be discussed?

How do students, educators and employers develop a deep understanding of what a graduate engineer's skills entail?

There are numerous skillset articulations from several professional bodies and institutions. Are they universal and transferrable across borders? How do you develop the required literacy level amongst the stakeholders to ensure a shared understanding of each skill?

How does an institution's culture influence its engineering curricula?

Every university claims to equip its graduates with generic skills and attributes that distinguish it from other institutions and frequently draws upon its rich cultural heritage and reputation to justify its claim. How different are these claims? Are they measureable? Do they manifest in the engineering curriculum in any meaningful manner?

In which contexts are a graduate engineer's skills best embedded into curricula?

Should all skills be taught in an engineering context? How do we design appropriate learning outcomes and assessment methods to demonstrate this embedding? As engineering education researchers, how do we best evaluate successful skills embedding?

1. WHY is that discussion relevant within EE? (rationale of the topic) There is an ongoing debate at national, European and global level about engineering skills. Educators are asked on a regular basis, whether they are equipping graduates with the 'right' skills. This workshop provides an opportunity to reflect on the current position and for the SEFI community to develop a greater understanding of the issues. This will also help drive the work of the SEFI Engineering Skills working group into the future.

1. WHAT can session participants expect to gain? (motivation & learning outcomes)

Participants will gain from the discussion that arises between educators and industrialist from different countries and types of institution, bringing their own perspectives to enrich the discussion.

1. HOW can session participants prepare? (preparation material)

Participants are requested to bring material that articulates the current status and debate on engineering graduate's skills from their own institutions both at School and university level, national professional bodies and there relevant sources. We request participants to bring a list of agreed skills in their School/Department, if possible.

Responsible Leadership Development in Engineering Education

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Motivation for attending and learning outcomes of the session:

Engineering is a key force in the achievement of well-being, health and quality of life. However, leadership development with focus on sustainability, self-reflection, and (personal) responsibility usually plays a minor role in engineering education. The question arises how the aspects of responsibility and sustainability can be fostered in engineering education.

The workshop is primarily targeted for professors and lecturers. However students are also welcome to reach a more thorough understanding of the discussed subject.

The goal is to build a more holistic competence spectrum with high relevance on the job market – likewise it raises awareness for the 17 SDGs (sustainable development goals developed by UN). The graduates should display a higher capability to create an impact on a world of growing complexity and dynamics.

Background and rationale of the session / concept/program:

In order to create a mindset of sustainability and responsibility, a so called “Responsible Leadership Certificate” program for industrial engineering master students was developed. The concept is based on the six “PRiME” principles (Principles of Responsible Management Education) initiated by the UN. Key aspects of the of the program are:

- Four semester certificate for Master students
- Foundation: “PRiME-principles” and “UN Global Compact”
- Min. 8 ECTS courses linked to PRiME being part of base master curriculum
- Optional 4 ECTS electives (e.g. business talks/ ethics winter school/ others)
- Deliverables: → e-portfolio (reflective paper) developed over 4 semester

Engaging session design:

Key questions guiding the workshop are the following:

- How are the responsibility aspects implemented in engineering curricula?
- What can we learn from good/ best practice examples?
- How do integrate these aspects without compromising the “basic engineering skills”?

Depending on the number of attendees, there are basically three options/settings how the workshop sessions will be designed.

- **Setting 1:** Brainstorming sessions on questions above using small cards and a pin board. Subsequent clustering and discussion of key findings in the whole group.
- **Setting 2:** Traditional small groups elaborating specific questions on flip charts. Each participant decides for one topic/ principle according to personal preferences.
- **Setting 3:** "World Cafe setting". The participants rotate between the tables. Each table group elaborates a specific question. The participants write on "table cloth" (flip chart paper on the table).

In each case the small groups will address key aspects of the topic and practical means to foster the learning outcomes. The workshop will develop best practice approaches that have the potential to be rolled out in other higher education institutions.

Rationale for the work/ implications & benefits:

The „Responsible Leadership“ program strengthens motivated people in their own personal & professional development. It is an important pillar in the qualification of engineers on master level and is considered as an essential building block for the development of responsible behavior.

Significance for Engineering Education:

The presentation of the concept in the conference workshop will be used to discuss further ideas on how to improve the awareness for responsibility aspects and also the transfer of the 17 SDGs in engineering education programs.

Learning Assistants Quick Start Program

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Extended Abstract

WHAT can session participants expect to gain? (motivation & learning outcomes) Some colleges and universities have established sophisticated Learning Assistant (LA) programs that include weekly preparation sessions and a pedagogy course to teach learning assistants how to effectively facilitate discussions among groups of students in a variety of classroom settings (<https://www.learningassistantalliance.org/>). However, many instructors who wish to incorporate LAs into their courses do not have the time or resources to develop a college-wide or department-wide LA program. In this workshop, participants will explore, first-hand, an online Learning Assistant Quick Start Program (LAQSP) designed to supplement instructors' efforts to prepare LAs for their role as mentors and peer instructors. The LAQSP is a one-week online mini-course that provides an opportunity for LAs to learn from local and national experts about evidence-based teaching and learning strategies and to collaborate with other LAs, both new and experienced, to explore the strategies that work best. While learning about the LAQSP, workshop participants will discuss the benefits and challenges of using Learning Assistants.

WHY is that session relevant? (rationale of the session)

Teaching approaches that use evidenced-based, active learning and student-centered instruction have been shown to improve student learning in STEM fields (Freeman, 2014; PNAS). Studies also show that Learning Assistants (LAs) can significantly enhance student learning and reduce failure rates in STEM education (Pollock, 2009; Otero, 2015). While LAs have been widely used in science courses at many colleges and universities, use of LAs in engineering courses is much less prevalent. The LAQSP has been offered for four consecutive semesters at the workshop facilitator's institution which is a large US Research I university. The typical enrollment has been 50-75 LAs. More than 80% of Learning Assistants who participated in the initial offering of the program recommended that instructors who use Learning Assistants enroll their LAs in the Quick Start Program. Likewise, faculty who required their LAs to complete the program indicated that it was beneficial.

HOW are session participants engaged? (engagement of and interaction with session participants in alignment with expected learning outcomes)

To fully benefit from the Workshop, participants should bring a laptop or tablet since Workshop participants will complete an abridged version of the Desire-2-Learn (D2L) LAQSP. The Workshop will begin with small-group discussions about the benefits of Learning Assistants and the various strategies that can be used for recruiting and engaging Learning Assistants. Next, participants will investigate the online portion of the program, including many of the activities designed to prepare LAs for their duties. For example, they will watch short videos of actual Learning Assistants who address some of the challenges that LAs face and will engage in discussions about these challenges. Participants will also discuss the merits of the recommended face-to-face component of the program which provides an opportunity for LAs and faculty to practice using the skills they have learned. While time will not allow participants to complete all of the activities in the LAQSP, they will gain a good sense of the program to consider whether they wish to adopt the program for use at their institution.

HOW will results be summarized? (take home for session participants)

The workshop participant will have the opportunity to import the LAQSP components from an IMSCP-compliant zip file, a standard file format, to any learning management system that supports this format. The Learning Assistants Quick Start Program website (<http://academicaffairs.arizona.edu/learning-assistants-quick-start-program>) provides additional information. There is no fee to adopt the program, however, acknowledgement of the source is appreciated.

Let us play T-mind to reflect upon teaching and learning

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Professional knowledge is to a high degree based on tacit knowledge [1]. For university teachers, tacit knowledge includes knowledge about what works – and what does not work - when teaching a specific class of students a specific subject in a specific context. However, it is important to make tacit knowledge explicit for at least two reasons: Firstly, for the individual teacher it may support a more conscious linking of experiences from own teaching practice to general principles of teaching and learning, which could enable a systematic analysis and development of own teaching to improve student learning [2]. Secondly, it is also beneficial to make one's tacit knowledge explicit in order to discuss teaching and learning with other persons, e.g. during peer coaching of less experienced colleagues, or collaboration on teaching development with colleagues leading to creation of a community of practice [3].

We have developed the *T-mind game* (Teachers' mind about teaching and learning) for university teachers to articulate and share their reflections on teaching and learning in a collective process. The game consists of a board and a deck of cards. Each card contains a statement related to teaching and/or learning, e.g. "Of course, an engineer must be able to calculate" and "Chalk is a dusty but effective media. Use it more!" The idea with card having pre-printed statements is that it will make it easier for university teachers to join the game. No player will have to stand by a personally formulated statement. During the game each player selects cards that he or she finds important in relation to his or hers good teaching experiences. The cards are then ranked and discussed in groups to explore if common approaches can be identified and see if consensus can be reached.

In the workshop we will introduce the ideas and intentions of T-mind and guide the participants through a game session. T-mind is intended to establish a guided, yet informal and amusing, framework for considering and discussing what you find important in your task and role as university teachers. During the game, the participants get a chance to externalize their reflections regarding teaching and learning and to explore their colleagues'. Although no award will be given and no winners will be appointed, you will gain insight into your own and your colleagues' values and attitudes regarding teaching and learning. At the end of the workshop, we will invite to a discussion of possible applications and use scenarios, and to suggestions of improvement of the game.

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Skills and competencies for the Engineer of 2030 to meet sustainability challenges

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Conference Key Areas: Sustainable Development Goals in EE, Engineering Skills, Gender and Diversity in EE

Keywords: Engineering Skills, Sustainable Development, Diversity, Attractiveness of Engineering

INTRODUCTION

Industry 4.0 is upon us and it will have a profound impact on the employment landscape in the coming years. Society needs engineers who are adequately trained with the knowledge and skills to provide a secure, sustainable and successful Europe. To meet future societal challenges, Engineers need new skills and ways of working. In this workshop we would like to answer the question; “What are the skills and competencies required of Engineers to enhance the sustainable development of our society?”

The main objective of this workshop is to explore this question in an international and multicultural setting and to confront the different points of views of the participants, aiming, through contrasts and comparisons, to attain an overview of skills requirements of the Engineer in 2030. We will start with an introductory short case study which will generate discussion in order to identify the required skills and competencies of the future Engineer, framed around the Sustainable Development Goals. Next, participants will be divided into small groups to work on a practical exercise to prioritise the required skill-set. Participants will be asked to reflect on their choices: why these skills and competencies are valuable and how they will prepare Engineers to achieve sustainable development goals. Finally, we will conclude our workshop with an interactive session to engage and encourage discussion and debate amongst participants.

As a principal outcome of this workshop we hope to improve our understanding and knowledge of the skills and competencies required of the Engineers of the future in the realm of sustainability development. The results will hopefully allow us to identify the key trends and to discover divergences and/or convergences between academics, employers and students participants’ opinions. We expect to obtain a broad overview of the required sustainability skills and competencies at European level from diverse social, cultural, economic and societal perspectives.

This workshop is organised within the framework of the Erasmus+ project “A-STEP 2030 - Attracting diverSe Talent to the Engineering Professions of 2030” initiated by the SEFI Attractiveness WG members. The main purpose of this project is to develop new and innovative teaching approaches relevant to learners’ values and adequate to teach a new set of skills and competencies needed for the future. Our ultimate aim is to create an attractive and fascinating learning environment to encourage young people with diverse backgrounds to engage in engineering studies and the profession as a whole.

The results of this workshop will contribute to development of the first project output “SKILLFOCUS 2030”. This report, when complete, will be issued to all participants of the workshop.

Dare to be Agile

New Forms of Workplace Integrated Learning

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Conference Key Areas: Continuing Engineering Education

Keywords: Adult learners, workspace-integrated, Agile learning, competence development

ABSTRACT

The main objective of this workshop is to share and explain the new approach of Agile Learning. It combines elements of Agile Methods (e.g. SCRUM, Design Thinking) with a workplace-based learning setting and project work. Participants will be introduced to the concept and experience it directly.

Background: Shorter innovation cycles require an increasing frequency with which employees need to acquire new skills. Up to now, however, there have been hardly any suitable training formats for this need, since classical forms of qualification (e.g. seminar courses, further training courses) do not fit the individual competence requirements and react too slowly to the dynamics of change in companies.

Thus, there is a need to develop qualification paths and strategies allowing to develop skills and competences within the workplace on an academic level without having to apply for a full study program. The approach of Agile Learning has been developed for this purpose and by now been implemented successfully in several companies.

Agenda:

Problem-Based Learning	Short overview about problem-based and work-integrated learning formats
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Agile Learning Projects	Get to know how agile principles can be applied to work-embedded learning projects. Learn about the process, roles and necessary support systems.
Hands-on exercise	Get involved in an agile learning project and experience how working goals and competence development can be interwoven.
Learning experience	Interactive reflection of the learning experience and the learning format.
Practical experience	Results and evaluation of ongoing and former projects
Application and best practices	Question-driven discussion about best practices and possible applications in different companies.

The workshop is organised in the framework of the Erasmus+ project 'ALTEF' – Workplace Integrated Learning for Technical Experts.

Promoting Entrepreneurship and University-Business Cooperation Through Internationalization

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Topics: University-Business cooperation, Engineering Skills, Fostering entrepreneurship

Keywords: Entrepreneurship, Internationalisation, Recruitment, Problem Based Learning

Motivation and learning outcomes

More universities have started to explore the possibilities of having students working on solving real-world problems in groups across disciplines, educational programmes, and even internationally across universities. This has proven to be well received by all stakeholders including companies, universities, professors and students, and all groups appreciate the value created through the international collaboration.

Another added value of international collaboration is the promotion of entrepreneurship. Denmark is seeing quite a large number of international students who end up starting their own businesses. This is interesting as Denmark (and the rest of Europe) is fighting to stimulate more people to become entrepreneurs, and to find better ways of supporting the entrepreneurs in order to develop companies, which are able to grow beyond just a few employees.

This session explores how internationalization can stimulate entrepreneurship and university-business collaboration: We wish to inspire the participants through success stories, but also to uncover unmet needs of students and businesses.

The participants will gain insight into:

- Opportunities and challenges in closer collaboration between students and companies in an international context.
- Opportunities and challenges seen from the perspectives of international entrepreneurs.

The workshop is held in collaboration between the Erasmus+ project EPIC and The Danish Pedagogical Network of Engineering Programmes (IUPN).

Rationale of the session

The session is important for two main reasons:

- to ensure that we learn from the many projects exploring how international collaborations between universities, students and companies can be carried out in a way that is beneficial for all partners and ensure that the students learn what they need according to their learning objectives, while it is also attractive to participate for the companies.
- to understand how we can support excellent international students in Denmark, in particular students who potentially will be starting their own businesses. We will also learn how the collaboration between engineering educational institutions and companies contribute to developing the entrepreneurial mindset.

Engagement of and interaction with participants

The workshop will be organized as an interactive session.

- 60 minutes: The session will begin with six short talks, each for 10 minutes (including changes: Three of them on international student projects in collaboration with companies, and three of them by invited international students who have become entrepreneurs. Each speaker will conclude his/her talk with one question to be discussed among the participants in the workshop (speakers and audience).

- 40 minutes: Discussions in groups based on the questions raised by the presenters. Comments/answers are then collected using Padlet.
- 15 minutes: Discussion of highlights from the groups in plenary.
- 5 minutes for closure and evaluation.

We aim at involving different target groups as participants, including students, university teachers, decision makers, political representatives, Engineering Associations, companies, public bodies etc., as to get many different perspectives on the challenges.

How will results be summarized

The discussions will be supported by Padlets, so the results of the session can be published afterwards – we plan to do this also as a small flyer with recommendations and short descriptions of the companies.

Is Engineering Education Fit for Purpose in the 21st Century?

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**** AUTHORSHIP / PROJECT PARTNERS:** *The Engineering EDGE Project: The Study to which this paper refers is currently being undertaken by the UK & Ireland Engineering Education Research Network. A number of colleagues from the Network have thus far made a significant contribution to the development of the Research Tools and have also equally participated in data collection. In alphabetical order, these colleagues are: Dr Esat Alpay: Dr Jane Andrews: Dr Jude Breton: Professor Robin Clark: Professor John Davies: Manish Malik: Dr Anne Nortcliffe: Ahn Tran: Dr Roger Penlington: Dr Peter Wilmott.*

1. BACKGROUND AND RATIONALE

Defined in the Economist as “A *third great wave of invention and economic disruption, set off by advances in computing and information and communication technology (ICT) in the late 20th century*” [1], we are living through what is increasingly referred to either as the “Third Industrial Revolution” or, perhaps more accurately, the “Digital Revolution”. Driven by rapid technological advances and the omnipotent world-wide-web, it is perhaps not unreasonable to suggest that humanity is on the verge of a global paradigm shift; whereby the need for ‘human contact’ is increasingly being

replaced by 'virtual communication' in every area of life including education, health and social care and industry.

Ironically, whilst mobile technologies seem to be negating the need for 'face to face' 'teaching contact', more students than ever are actually attending university [2]. Indeed, enrolling on a full time University Programme has for many become a 'rite of passage' from adolescence to adulthood. With some suggestion that it takes new Engineering Faculty up to five years to become competent teachers [3] and others arguing that teaching is increasingly viewed as of lower importance than research [4]; there is little disagreement that colleagues working in Higher Education are facing unprecedented pressure to meet the often diametrically opposing demands and requirements of students, management, industry and government [5, 6].

Within this context the question "***Is Engineering Education Fit for Purpose in the 21st Century?***" is one that few dare to ask. In seeking to 'buck the trend' it is this question that will form the central tenet of the discussions and debate in this Workshop

2. AIM OF THE SESSION

The aim of the session is to gain an insight into colleagues' perceptions of the answer to the above question. In order to achieve this aim, three sub-research questions will form the basis of discussion:

- I. Is Engineering Education sufficiently linked to Engineering Industry and Practice?*
- II. Are today's 'Digital Generation' of learners capable of acquiring the high level of practical and theoretical skills and competencies required to become a Professional Engineer?*
- III. Is Active Learning the only way forward in Engineering Education?*

In advance of the Conference, colleagues will be supplied with an Executive Summary of the emerging findings of the Engineering EDGE Study, a work-in-progress that is sponsored by the Royal Academy of Engineering, London, and which seeks to answer the research question '*Are Engineering Educators fit for purpose?*'

The workshop will break through the controversy and 'hype' surrounding Engineering Education and in doing so will encourage colleagues to critically question both their own practice and the wider socio-economic and political drivers that underpin Engineering Higher Education irrespective of country.

3. SESSION OUTPUTS / OUTCOMES / CONTRIBUTION TO ENGINEERING EDUCATION

The Workshop discussions will be recorded contemporaneously, capturing the Engineering Education Research Community's perspective of the challenges and enablers which underpin our lived experiences in the Engineering classroom and laboratory. As such, the Workshop outputs will form part of the Study Findings reported back to the RAEng. Additionally, the Workshop Findings will form the basis of a future academic publication which it is anticipated will be widely disseminated and which it is hoped will be in a position so as to influence policy and practice across European and global Engineering Education

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PREFER Project: Testing professional skills

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Topics: University-Business cooperation, Engineering Skills

Keywords: University-business cooperation, industry relations

One of the main objectives of the PREFER project is to develop a tool that enables engineering students to explore their strengths and weakness regarding a number of professional skills. Based on a threefold Professional Roles Model (Operational Excellence, Product Leadership and Customer Intimacy), the tool provides engineering students insight in their future professional role based on their strengths and weaknesses. This will help students to become more aware of their skills and expectations when entering the labour market.

In this workshop, the participants will get a hands-on experience with the competence test of the tool. More specifically, the participants will be able to explore different items of the Situational Judgement Test (SJT) that are designed to map students' fit with the different professional competences and future roles. Each SJT item targets a particular professional competence and consists of two major components: (1) a realistic case reflecting the engineering reality and (2) four possible behavioral responses.

In smaller groups, the participants will be invited to work on specific assignments regarding the relevance of the case, the link between a case and a competence and the adequacy of the different response categories. As such, the participants are introduced to engaging ways on how abstract professional competences (e.g., 'team player'; 'clear communication'; 'positive critical attitude';...) can be translated into realistic engineering examples that are recognizable for engineering students and young graduates. This workshop will familiarize the participants with fresh insights on how student reflection can be triggered in a light-weight and engaging manner.

In a final plenary part of the workshop, we will jointly reflect on how this tool can be embedded in the engineering curriculum and how students can be engaged to reflect on (1) their future career and (2) the competences they would like to develop further.

Diamonds are formed under pressure

Creating microlearning nuggets

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Conference Key Areas: How learning spaces support innovative teaching and learning, Innovative teaching and learning methods, Teaching creativity and innovation

Keywords: online learning, microlearning

WORKSHOP DESCRIPTION

Today's busy and information-filled world requires us to modify our on-line materials. Most of us use some type of Learning Management System (LMS) where we store our teaching materials, session slides, and other such documents. We may even have thought of ways to make those materials more inviting to students so that they would actually visit the LMS more often. One approach to more inviting, easily digestible materials is producing microlearning nuggets.

The aim of this workshop is to discuss the theories behind microlearning and to provide the participants time to collaborate and at least start planning their own microlearning nuggets. In an ideal situation, the participants, through their collaboration with each other, will provide ideas and help to enable the planning of the microlearning sessions, which can be produced easily after the SEFI 2018 Conference using the plan and information gained at the workshop.

In general, microlearning nuggets are short, focused bits of information available online for learners [1, 2, 3]. These nuggets can be one specific, focused learning session on a topic, or – as is quite common – a series of short sessions linked to

each other. Microlearning sessions can be used to allow learners easy access repetition on explanations of potentially difficult concepts, as well as to review ideas discussed during a lecture or other teaching event. Most often, the microlearning sessions are distributed through an LMS, but other types of distribution channels are also possible.

Workshop (max 30 participants) structure	Minutes
Meet and greet	15
Microlearning – what and why	20
Group (3-5 persons/group) work & discussion	
Note: each group chooses one topic to work on	40
Gallery walk to view group productions	30
Listing of ideas, tools, and other ideas	15
Total	120

Bring along:

an open, collaborative mindset and teachable ideas on what you would like to develop into a microlearning session.

The times are approximate depending on the number of participants. At the end, the collected ideas on how to create a microlearning session, what tool(s) to use, and what issues to keep in mind while developing a microlearning session are listed collaboratively.

Although microlearning has been researched over ten years, it has gained significant popularity only fairly recently [1, 2, 3]. The aim of of this workshop is provide its participants with an overall picture of developing microlearning nuggets, what tools are available, and how to begin the process of creating these short, focused sessions, the intention of which is to activate learners and to provide variety to on-line materials.

Looking forward to seeing you there!

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Organisational readiness for learning analytics: aligning ambitions with available infrastructure and stakeholders management

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Topics: Open and Online Engineering Education, Innovation as the context for Engineering Education, Educational and Organizational Development

Keywords: learning analytics, stakeholder management, student success, data-analysis

INTRODUCTION

The increasing availability of learner data from online learning environments provides opportunities for data analysis, which can be used to improve and support learning and learning design in engineering education. Many institutions start their initial forays into this field by building on existing organisational structures and ICT support infrastructure. In the past years, several supportive frameworks for the implementation of learning analytics at an institution have been developed (Greller & Drachsler, 2012; Paini, 2015; Tsai et al, 2018). As the introduction of learning analytics will not only affect students, but also campus staff, stakeholder management is an important part of these frameworks.

MOTIVATION

The increased digitisation of educational processes and the advent of online education drive the increase of 'big data' in education. This provides all higher engineering education institutions with the opportunity to make use of this data to increase the quality of education and provide better support for student learning processes.

Rationale of the session

The workshop's goals are twofold:

1. Familiarize participants with approaches to the implementation of learning analytics at an institution and the role that existing infrastructure and stakeholder management play in this.
2. Allow participants to reflect on their own organisation and draft an initial approach to start the implementation of learning analytics given the unique characteristics of their own institution.

Participant engagement

The workshop will employ the following structure to engage participants:

1. About 15 minutes will be used for a plenary presentation on the implementation of learning analytics in both online and campus education at a particular higher engineering education institute, in order to provide participants with a shared context for the workshop, and also to provide an example of a particular way of introducing the use of learning analytics at an institute.
2. Next several frameworks for learning analytics implementation with a focus on organisational and stakeholders will be introduced. Their uses and usability will then be discussed with the participants.
3. Participants will then be split into groups of 2-4 and be asked to discuss the following questions:
 1. What is currently present at your institution that enables the implementation of learning analytics?
 2. What kind of existing organisational structure at your institution can support implementation of learning analytics?
 3. Which level of ambition for the implementation of learning analytics would be appropriate for your institution?
 4. Which factors currently hinder the implementation of learning analytics at your institution?
4. Participants will be provided with templates they can use to structure their answers to these questions, to aid in the discussion. Afterwards, the participants can take these home.

Workshop outcomes

The workshop will have the following outcomes:

1. Insights into the ins and outs of a particular learning analytics implementation at an HEE institution.
2. An understanding of several frameworks for learning analytics implementation.
3. An initial design for starting the learning analytics implementation at the participant's own institution



aalto-yliopiston ylioppilaskunta
aalto-universitetets studentkår
aalto university student union

Educating empowered citizens – students as partners

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Abstract:

How are students involved in planning and executing their own education and what can be learned from other universities? How can educators support the societal aspirations of their students and encourage them to make a change and having an impact?

This student-run workshop focuses on developing higher education from a student perspective. Approaching education from the everyday life and questions of the student is crucial in developing future university education: what can I do with my education? How can I have an impact? This workshop is all about sharing best practices on how to benefit from students in order to create better education and environments for learning.

Supporting the ambitions and societal aspirations of current university students is needed if we are to solve the systemic problems that the globe is increasingly facing. The students should not only be educated to become the influencers of tomorrow, but should also feel empowered to make a difference today. As a learning outcome for the workshop, the participants get tools for approaching education and the global future from a student perspective and for developing studies that can empower students to become active members of the society. Including students is so much more than just collecting feedback!

The workshop includes four parts:

- awakening of thoughts through provoking initiatives
- an introduction to developing university education with students as partners (as experienced in Finland and Aalto University Student Union)
- an engaging world cafe session with case examples for sharing best practices in how universities can support the ambitions and societal aspirations of its students
- concluding discussions on creating platforms for students to act as partners in developing their education

The presenters of this workshop come from Finland, where the role of students is defined in the law of the universities. Decision-making is based on the idea of co-decision and considering all the different groups within the university community: the students, the staff and the professors. This tripartite decision-making model is in place cross-cuttingly in universities from the administrative department level committees all the way to the management level academic bodies. Students have an active voice in decision-making, policy formulation and bringing development wishes to various working groups. Student unions work as a bridge between the students and the university, providing research and ideas for development and maintaining close connections to the student body.

EBCC Model: Engineering Skills for Innovative Product Design Based on Regional Needs

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Conference Key Areas: Engineering Skills; Innovation as the Context for Engineering Education; Sustainable Development Goals in Engineering Education.

Keywords: engineering skills, general skills, skill levels, engineering curriculum.

Abstract

The workshop is organized in the framework of the Erasmus+ strategic partnership project No 2017-1-LV01-KA203-035426 “Education, Business and Community Cooperation Model for a Creative European Engineering Education” (EBCC Model). There are five partners in this project: Riga Technical University, Latvia (RTU), Institut Supérieur de Mécanique de Paris, France (SUPMECA), Aristotle University of Thessaloniki, Greece (AUTH), Établissement public territorial Plaine Commune, France (PLAINE

COMMUNE), and the European Society for Engineering Education, Belgium (SEFI). The workshop is facilitated by 7 experienced faculty and administrative staff members from these organizations. They have experience in development and implementation of the curriculum for project-based engineering education.

The objective of the workshop is to share knowledge and best praxis for improvement of the study curriculum and syllabus integrating the skills that are essential for engineering education taking into account the convergence of project/problem-based learning, mechanical engineering, product design using rapid prototyping and computer-aided design methods.

The workshop has length 120 minutes and includes keynote presentations, discussions and practical case in working groups of 5-7 persons. Participants will receive a workshop booklet containing all presentations and reference materials.

Agenda

10 min.: Introduction. Moderated by RTU.

10 min.: The presentation of the survey results on the relevance of the 14 selected skills for engineering education that are based on the convergence of project/problem-based learning, engineering, product design using rapid prototyping and computer-aided design methods. Moderated by RTU.

20 min.: The participants will take part in the survey and express your opinion about essential skills that a contemporary engineer should possess. Moderated by RTU.

5 min.: Creation of working groups of 5-7 persons.

20 min.: The groups will discuss, nominate and present skills that are essential, but are not included in the list of the 14 selected skills. Each group will offer 1-2 additional skills for further evaluation according to the methodology used in EBCC Model. Moderated by RTU.

10 min.: The presentation of guidelines for integration of the selected skills into the curriculum and syllabus. Moderated by SUPMECA.

30 min.: The case study where the working groups assess what skills can be developed in study courses of the provided case curriculum and to what level. Moderated by SUPMECA and assisted by RTU, AUTH and PLAINE COMMUNE.

15 min.: Feedback by each group and the final remarks. Moderated by RTU.

The participants will learn to what extent students should acquire the selected skills keeping in mind the research, technology and labor market development tendencies and needs of local community. There will be discussion about the methodology and results of the survey and the list of the selected skills. The

participants will take part in practical exercise where they will create an updated version of the case curriculum using in the EBCC Model developed guidelines for integration of the selected skills into the curriculum and syllabus.

EBCC Model: Idea Creation for Project/Problem-Based Learning in Engineering Education

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Conference Key Areas: Engineering Skills; Innovation as the Context for Engineering Education; Sustainable Development Goals in Engineering Education.

Keywords: sustainable partnership, real life cases, engineering education, community, local government.

Abstract

The workshop is organized in the framework of the Erasmus+ strategic partnership project No 2017-1-LV01-KA203-035426 “Education, Business and Community Cooperation Model for a Creative European Engineering Education” (EBCC Model). There are five partners in this project: Riga Technical University, Latvia (RTU), Institut Supérieur de Mécanique de Paris, France (SUPMECA), Aristotle University of Thessaloniki, Greece (AUTH), Établissement public territorial Plaine Commune, France (PLAINE COMMUNE), and the European Society for Engineering Education, Belgium (SEFI). The workshop is facilitated by 7 experienced faculty and administrative

staff members from these organizations. They have experience in development and implementation of the curriculum for project-based engineering education.

The objective of the workshop is to share knowledge and best praxis in cooperation of local governments and communities with higher education institutions to use real life cases in engineering education.

The selection of the topics for project/problem-based learning (PPBL) is essential for academic success. It should ensure multidisciplinary approach and emphasize the involvement of different levels (for example Master and Bachelor) in order that students from different levels / with different backgrounds could work and learn together.

The workshop has length 120 minutes and includes keynote presentations, discussions and the role-play exercise in working groups of 5-7 persons. Participants will receive a workshop booklet containing all presentations and reference materials.

Agenda

10 min.: Introduction. Moderated by SUPMECA.

10 min.: The presentation and discussions on cooperation praxis and tendencies of local government and community with higher education institutions. Moderated by PLAINE COMMUNE.

10 min.: The presentation and discussions on the proposed case and/or innovative project idea creation model. Moderated by RTU.

15 min.: Presentation about rapid prototyping and kind of projects in which it is more adapted / efficient. Moderated by AUTH.

10 min.: The presentation and discussions on recommendations for student team building in PPBL to achieve academic targets at the same time contributing in the solution of real life problems. Moderated by SUPMECA.

15 min.: Case description for the role-play exercise: information (including pictures, short videos) on community demographic, economic and social situation, main development targets of the local government and other additional information. Creation of working groups of 5-7 persons. Moderated by PLAINE COMMUNE.

30 min.: The role-play exercise to find innovative ideas for PPBL analyzing economic processes and issues in community. The participants will play roles of teachers and students, but RTU, SUPMECA, AUTH and PLAINE COMMUNE representatives will play roles of local government and community members. Moderated by SUPMECA.

15 min.: Presentation of the exercise results by working groups. Feedback and the final remarks. Moderated by SUPMECA.

15 min.: Final remarks. Moderated by RTU

The participants will learn how to redefine problems outside boundaries of one study course, as well as will share knowledge and best praxis for facilitating use of 3D printing technologies to allow students to acquire practical skills in product design engineering. They will try to combine academic targets with the development of innovative products, the industry needs and the contribution to the regional development.

Key References in Engineering Education Research

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Conference Key Areas: Engineering Education Research

Keywords: engineering education research, key publications

1 RATIONALE

Although engineering education research (EER) has been evolving and expanding significantly in recent years, it is still a relatively new field in the European context. As a result, those with an interest in EER and particularly those entering the field, frequently report challenges in gaining an overall sense of existing EER scholarship. The workshop aims to broaden participants' knowledge of important publications within the area by analyzing and discussing a small number of publications selected by members SEFI Working Group on Engineering Education Research (see author list) as being canonical studies in the field.

2 PARTICIPANT ENGAGEMENT

The session will take a hands-on approach with individual, small group and plenary activities. In addition to analyzing specific publications, participants will have opportunities to discuss with Working Group members and the other participants the selection of these particular publications as key works.

3 TAKEAWAY

The attendees will have gained insight into existing Engineering Education scholarship, and its key publications in particular. Not only do they obtain a list of key references, but also practical suggestions as to how to identify important works in the field. Participant conclusions will be made available online after the session. In addition, participants will gain access to a larger list of important publications that is being prepared by the Working Group.

Round Table Discussions

The structural coherence of problem-based projects

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Background

The *problem-based project* is a much-applied method for facilitating learning experiences that mirror engineering practice. Problem-based projects have many names. Examples are problem-based learning, challenge-based learning, design-implement experience, and capstone design project. Using problem-based projects as learning method supports active learning where students construct internal knowledge about a topic throughout the project.

In problem-based projects, teams of students design solutions to problems. These problems often reside with an 'industrial partner', i.e. a firm with which the student team cooperates. Examples of industrial partners are manufacturers, public utilities, software developers, contractors, and entrepreneurs.

In engineering, problem-solving projects usually either improve an existing entity or design a new entity from scratch. Improving an existing entity is e.g. lengthening a machine's durability. The project team develops a solution, which might be a combination of a new material and an improved machine maintenance policy. Designing a new entity is e.g. a project that designs a building. In this project, the solution is constituted by the drawings of the building and perhaps a small-scale building model.

The perhaps most prevalent and yet most vaguely defined terms for a great problem-based project is 'structural coherence'. Synonyms for the concept are 'project flow', 'red line' or 'red thread', and 'inherent logic'. In the spoken language, an often used *antonym* for structural coherence is "apples and oranges".

The structural coherence of a project refers to how the elements of the project fit together. These elements are often (1) problem statement, (2) methodology, (3) analysis, (4) solution design, and (5) implementation.

Purpose of roundtable discussion

The purpose of this roundtable discussion is *to operationalize the term structural coherence*. The objective is to reach a set of criteria that students and lecturers can use to evaluate a project's structural coherence. Operational criteria are easier to understand for students than the abstract term itself, and discussing an explicit set of criteria decreases the term's vagueness.

Roundtable discussion procedure

The roundtable discussion will deal with the relationships between the structural elements of a project following the sequence below:

1. The relationship between problem statement and methodology
2. The relationship between methodology and analysis
3. The relationship between analysis and solution design
4. The relationship between solution design and implementation

For each of the discussion's points, the roundtable hosts will prepare questions and tentative statements about a relationship between two elements. These questions and tentative statements will (hopefully) inspire discussions about (1) the generic relationships between structural elements, (2) differences across engineering fields, and (3) differences between projects that improve existing entities and projects that design new entities.

Outcome

Participants can expect to gain an increased understanding of the concept of structural coherence in problem-based projects.

Relevant participant preparation

For a fruitful discussion, participants are encouraged to bring with them their recent experience of supervising and evaluating problem-based projects. The discussion will benefit from the inclusion of specific project examples.

Favoring deep learning approaches by switching from journal club to invention club

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In line with contemporary good teaching practices and in response to the increased uptake of a broader range of students, educations at the university level are transitioning from teaching and learning activities that favor 'surface learning' to activities that favor deep learning approaches. Additionally, in many Western European countries, innovation and entrepreneurship has become an integral part of many university programs and courses. The ambition is that this may not only train students in value creation and company building, but that it may also improve student motivation, encourage creative thought processes, and favor deep learning. However, on the PhD education level, it is interesting to note that one of the common activities encountered by students in a research lab is the traditional journal club. The traditional journal club has the goal of introducing creativity and new ideas into a research group, but ironically does so via an approach that is almost as far from deep learning as possible.

To ensure that deep learning approaches are encouraged and to bring in new ideas to my group, I introduced the concept of 'invention club'. Similar to a journal club, students have to present a scientific concept/idea to the rest of the group every second week. But instead of parroting other researchers' ideas, they are forced to think creatively about how science can be exploited in an innovative way, as their presentation is qualitatively evaluated by the colloquium as to whether their idea is novel, relevant, and feasible. Based on 12 sessions in my own group, I found that this switch from a journal club to an invention club strengthened motivation and facilitated creative thought processes among the students. Several good ideas were presented, and it is noteworthy that out of 12 students participating in the invention club, five of them are now engaged outside of the university in innovation and entrepreneurship activities inspired by ideas presented in the invention club. Among others, a small biotech company is in the making.

The intention with this roundtable discussion is for participants to share experiences and insight into practical methods that can foster deep learning and creativity outside of the traditional course environment, such as in research groups or at the PhD program level. The intended outcome is to provide participants with reflections and ideas for how to establish a creative and motivating research environment. To achieve this, I will spend 5 minutes setting the stage by sharing my own experiences and asking open questions on how deep learning is fostered at the highest educational level (PhD studies). Thereafter, each participant will share his/her experiences, while common themes are noted down. Finally, the session will conclude with the preparation of a list of 10 key points for an educator to keep in mind to foster deep learning and creativity in a research group.

Keywords: Deep learning approaches, entrepreneurship, innovation, journal club, invention club, student motivation.

Protecting the Space for Large Scale Innovation

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- WHAT shall be discussed? (highly focused topic)

Engineering education conferences are full of small scale innovations that are able to have a strong impact at the classroom level; however it is difficult to scale innovation to a larger scale. As the project moves from the control of an individual academic to include more colleagues, more collaborators and more administrators - and requires more resources and involves more risk - it becomes increasingly challenging to maintain the momentum.

This workshop brings together leaders from three recognised world-leading innovative programs to discuss how they managed to engage colleagues, protect their vision and to create a space for their innovations to flourish - and how these lessons can transfer to your context at your institution.

- WHY is that discussion relevant within EE? (rationale of the topic)

The move from classroom innovation to large-scale innovation is difficult, and requires additional skills beyond just personal expertise. Successful innovations are expensive; failed innovations even more so. Understanding how to deal with the non-engineers and even non-academics involved, what motivates (and scares) them, and how to address these concerns, makes innovation in engineering education more sustainable.

- WHAT can session participants expect to gain? (motivation & learning outcomes)

Participants will gain a range of actionable advice on how they can implement innovations at their own institution. Further, they will also get an overarching sense of the common themes involved in large-scale change, so that they are able to adapt these principles to their own context.

Participants will also gain insights into the mindsets of senior academics and administrators, and the perspectives that they bring to supporting and evaluating change within their universities.

- HOW can session participants prepare? (preparation material)

Participants who are presently engaged in or planning large scale change would benefit by reflecting upon the barriers they have already encountered or anticipate in their change.

Participants' own examples of successfully protecting innovation would also be useful to the group.

Intended Session Timeline:

(Noting this has been cut from a 90 minute workshop to 60 minute roundtable):

0-5 mins Introduction – who the presenters are, the innovations that we led in our institutions, and the #1 problem we faced doing it

5-20 mins Activity: Participants identify their key challenges, placing post-it notes around the walls, looking to identify emergent clusters such as People, Places, Programs etc

20-30 mins Whole group review of what are the dominant clusters, facilitators identifying the most common themes that challenge innovation, with reference to their own experiences

30-45 mins Activity: Participants identify how they have experienced these themes, and provide potential solutions by placing (different coloured) post-it notes around the problem clusters on the wall

45-55 mins Whole group debrief – facilitators identify the most common themes in the solutions, again with reference to their own experiences

56-60 mins Takeaway: participants use a provided “postcard” to write down the two actionable pieces of advice that are most useful to their context to take back to their own institution

Adapting the training and assessment of competences in engineering curricula to the 2020-context

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1. Background and rationale

The Faculty of Engineering Science at KU Leuven has a longstanding tradition in engineering education. A wide variety of different engineering programmes are offered at the Bachelor's level (2), at the Master's level (23) and at the Advanced Master's level (6).

For more than 15 years already, the Faculty has invested in learning pathways for the development of competences: problem solving and design, reporting skills, information skills, entrepreneurial skills,... The Faculty has chosen to integrate these pathways in several already existing courses and/or in the in 2004 newly created series of Problem Solving & Design courses (PS&D). In these courses the development of competences and skills is one of the main objectives.

As more learning pathways were implemented over the years [1-4], several challenges popped up:

- Proper and qualitative guidance of the students;
- Providing proper, enough and timely feedback on competences and not only on (technical) content;
- Making students aware of the competences they obtain or need to develop further;
- Meaningful integration in the courses.

Besides these challenges, there is also the need for aligning the curricula to the skillset alumni need to keep pace in contemporary and future (engineering) work field. [5] As a result, updating and renewing the existing PS&D-courses, with specific attention for entrepreneurial skills has become inevitable.

The Faculty decided to invest in an innovative project 'AEGenZS' (Assessment of Engineering GenerationZ-skills) that will focus on the following aspects:

- Problem analysis including a study of similar initiatives at other institutions abroad by surveys of didactic teams and students and literature study;
- To underpin and develop (new) learning pathways, modules, information sessions,...
- Creating support for innovation;

- Pilot projects on implementation and evaluation of advises formulated;
- International benchmarking.

The project will start in summer 2018 and the SEFI2018-conference offers an excellent opportunity to gain inspiration from international colleagues and to share experiences, challenges and ideas with them. Also for the international colleagues the approach of the project and its challenges as well as the discussions and exchanges of experiences, can be an inspiration and a learning experience.

2. Session design

- A short introduction to the background and rationale of 'AEGenZS' and its objectives.
- Discussion1:
 - Objective: exchange of experiences, identification of common challenges
 - Questions:
 - How does your HEI integrate the education of competences in its curricula?
 - Are the described challenges recognizable?
 - Have similar projects been running at your HEI?
 - ...
- A short overview based on the study of recent literature and new insights on the training and assessment of competences in current engineering curricula.
- Discussion2:
 - Objective: linking results of discussion 1 to recent literature and insights
 - Questions:
 - Does your HEI already anticipate the recent developments?
 - What tools are available to tackle challenges recognized in discussion1?
 - ...
- Summary of both previous discussions. One or two main (common) challenges are selected to discuss in detail. As a conclusion, ideas and guidelines to deal with these challenges are formulated as an inspiration for the participants to take home to their HEIs.
- A report of the round table will be sent to all participants.

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ANNUAL CONFERENCE 17-21 SEPTEMBER 2018
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