PBL, Social Progress and Sustainability

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United Nations Educational, Scientific and Cultural Organization

AALBORG UNIVERSITY
Aalborg Centre for Problem Based Learning in Engineering Science and Sustainability under the auspices of UNESCO

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Foreword

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"[…] *If I am not in the world simply to adapt to it, but rather transform it, and if it is not possible to change the world without a certain dream or vision for it, I must make use of every possibility there is not only to speak about my utopia, but also to engage in practices consistent with it.*"

— Paulo Freire, in *Pedagogy of Indignation*

Reflection on education is also reflection on to which kind of future and society we are preparing our students for. Today's students will perform and operate in a volatile and ever changing society where the knowledge, skills and competencies built during academic years might have to be re-built and adapted to address challenges posed. See for example sustainable development problems, fast technological development and innovation, globalization and economic crises, etc. These challenges call for competences such as self-directed learning, teamwork, communication, critical thinking and interdisciplinary knowledge. Consequently, it is needed to re-think the education environments, the curricula constructions, learning outcomes and experiences capable of preparing future generation to change and transform the world by acting and learning within and from it.

Having this in mind and Paulo Freire's vision represented by the above quote, the 6th International Research Symposium on PBL (IRSPBL' 2017) theme is *PBL, Social Progress and Sustainability* and Universidad Nacional de Colombia hosts it. The overall goal is to reflect how PBL can educate future generations envisioning social progress and sustainability. The symposium is organized around several activities such as workshops, panel sessions, paper presentations and presentation of open access resources with aim is to promote discussion and active learning in all levels of education. Similar to other editions, this sixth edition constitutes a meeting place researchers, practitioners, educational managers and industrial partners contributing to the PBL landscape.

The IRSPBL has collected 53 contributions from 19 different countries, all compiled in this book. The contributions cover a number of relevant PBL topics such as assessment, learning outcomes, students' engagement, management of change, curriculum and course design, PBL models, PBL application, ICT, professional development. This book represents some of the newest results from research on PBL in these different areas.

We hope that you will find the book useful and inspirational for your further work.

Aida Guerra
Fernando José Rodriguez
Anette Kolmos
Ismael Peña Reyes

"Problem-Based Learning, Engineering and Technology for Sustainable Human Development"

Tony Marjoram[1]

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Abstract

There are shortages of engineers in many countries, especially in some fields of engineering, un- and underemployed engineers in others. In these situations it is important that engineering education attracts and retains young people, and gives them skills and competencies that promote employability, enterprise and entrepreneurship. As people learn best when they are enjoying the learning process, engineering education should include fun as well as fundamentals, and learning how to learn for continued professional development, in line with professional attributes and competencies such as those of the Washington Accord. The optimal pedagogical approach for the problem- and project-based profession of engineering is problem and project-based learning. Given the present and future need for sustainable environmental, social, economic and humanitarian development, climate change mitigation and adaptation, and engineers with competencies in these fields, engineering education will need to focus increasingly on technology that is appropriate to these contexts and needs. Young people are attracted to action to address such global issues, and are attracted to engineering when they see its relevance in sustainable and humanitarian development, in an educational approach based on problem and project based learning. This paper discusses these issues, with particular reference to required attributes and competencies and examples of problems and projects in sustainable and humanitarian development that have been proposed to address them in such activities as the Daimler-UNESCO Mondialogo Engineering Award, an award-winning activity that ran from 2003-2010, involving over 10,000 young engineers from over 100 countries, and groups such as Engineers Without Borders around the world.

Keywords: Engineering education, transformation, PBL, sustainability, human development

Type of contribution: Conceptual/ position paper

1 Introduction

In engineering and engineering education a recent interest in many countries has been on addressing reported shortages of engineers, and how to get more young people into engineering, especially young women. This has focused on the promotion of women and inclusion of minorities that are under-represented in engineering, and other 'STEM' subjects. It is becoming clearer that an overall shortage of engineers is part of the picture at the bigger, aggregate level, with more detailed analysis indicating that this perception related mainly to some fields and levels of engineering, and in some locations, wheras there was an increasing awareness of underemployment and unemployment in other fields, levels and locations. This is possibly as a result of over-supply in trying to address overall shortages over the last decade, possibly also resulting from changes following the Global Financial Crisis of 2007-8, from globalisation (for example, increasingly global companies outsourcing services such as design and relocating whole factories overseas),

wider technological innovation and change and, in Australia for example, the mining industry boom and its current decline (the mining boom itself caused economic distortions that lead to the demise of other industry, for example automobile manufacturing). In Australia, an increasing proportion of graduate engineers have difficulty finding appropriate employment, caught in the catch-22 of having little experience that employers prefer. They are consequently obliged to accept lower positions than hoped for, and may be encouraged to identify opportunities and create start-up consultancies and companies. This relates particularly, for example, to areas of civil engineering (affected by lower infrastructure investment, and globalisation), mechanical engineering (industrial relocation and outsourcing) and electrical/electronics engineering – where young engineers have created renewable energy start-ups in an atmosphere of government policy paucity and climate change scepticism. It is also linked to Department of Employment data showing little skill shortage in engineering since 2012-13, although engineers continue to be included on the Department list for approved professional migration (for which Engineers Australia, the national institution for engineers, receives an assessment fee – also creating conflict of interest issues), and also to the contentious policy of issuing skilled temporary visas for overseas engineers. This situation also reflects the need for better statistics and indicators on engineering education, resources and needs in most countries, as part of the need for better numbers in science and engineering (Marjoram, 2015/2).

Apart from the Australian mining boom and its decline, the challenges facing engineering education are common to many countries, rich and poor. For example, in Timor Leste, a developing country to Australia's north recovering from the aftermath of 25 years of Indonesian occupation from 1975- 1999, graduate engineers find difficulty getting jobs because of limited employment and an employer perception that they are too theoretical and hands-off, with little practical or teamwork experience. This reflects an approach to engineering education based on the Indonesian traditional theory- and teacher-lead model at the University of Timor Lorosa'e, which was established as an offshoot of Gajah Mada University to train secondary school teachers, administration and agricultural extension workers - where research, analytical and critical thinking was not supported. As a Timorese Master's student of engineering in Sydney has observed, "There is a huge difference between studying in Australia and studying back home in Timor Leste, because in Australia students are independent and encouraged to be active, whereas in Timor students are expected to just listen to the teacher. We also have a lack of facilities in East Timor and so students find it hard to achieve what they want" (Da Silva, 2013).

2 Engineering and engineering education

Engineering and engineering education today are as they are due to a mixture of technical, cognitive-educational and socio-professional factors – prior engineering and technological innovation and change, prior approaches to engineering education, and the changing role of engineering and engineers in society.

Engineering has developed through the successive waves of technological innovation, from the first wave technological change in the Industrial Revolution of 1785-1845 – 60 years of development, particularly of iron, water power and mechanization. The second wave of technological innovation from 1845-1900 saw the rise of steel, steam power and the railways, over around 55 years. The third wave of technological innovation from 1900-1950 witnessed the development of electricity, chemicals and the oil industry, heavy engineering and the internal combustion engine over a period of 50 years. The fourth wave of technological innovation from 1950-1985 saw the development of automobiles, petrochemicals, electronics and aerospace over 35 years. The fifth wave of technological innovation from 1985-2005 saw the growth of computers, ICT, information societies and economies over around 20 years – in increasingly shorter periods,

from what was a lifetime to less than a generation. The sixth wave of technological innovation (2005-25?) is seeing the further development of new knowledge and applications in the areas of ICTs, biotechnology, nanotechnology, materials technology, robotics and sustainability. The increasing emphasis on sustainable development, climate change mitigation and adaptation will continue into a seventh wave of cleaner/greener engineering and technology, albeit against some populist feelings of climate change and knowledge skepticism. These Kondratiev waves of technological innovation and revolution have seen new modes of knowledge generation, dissemination and application in increasingly knowledge- and information-based societies and economies. These changes have primarily been from "Mode 1" disciplinary knowledge systems to "Mode 2" interdisciplinary knowledge systems (Gibbons et al, 1994; Nowotny et al, 2001). New areas of knowledge such as ICTs and biotec are typified by innovation and interdisciplinary cross-fertilisation and fusion, with the rise of new areas and decline of old disciplines. Kondratiev waves of innovation are presented below (Von Weizsäcker et al, 2009).

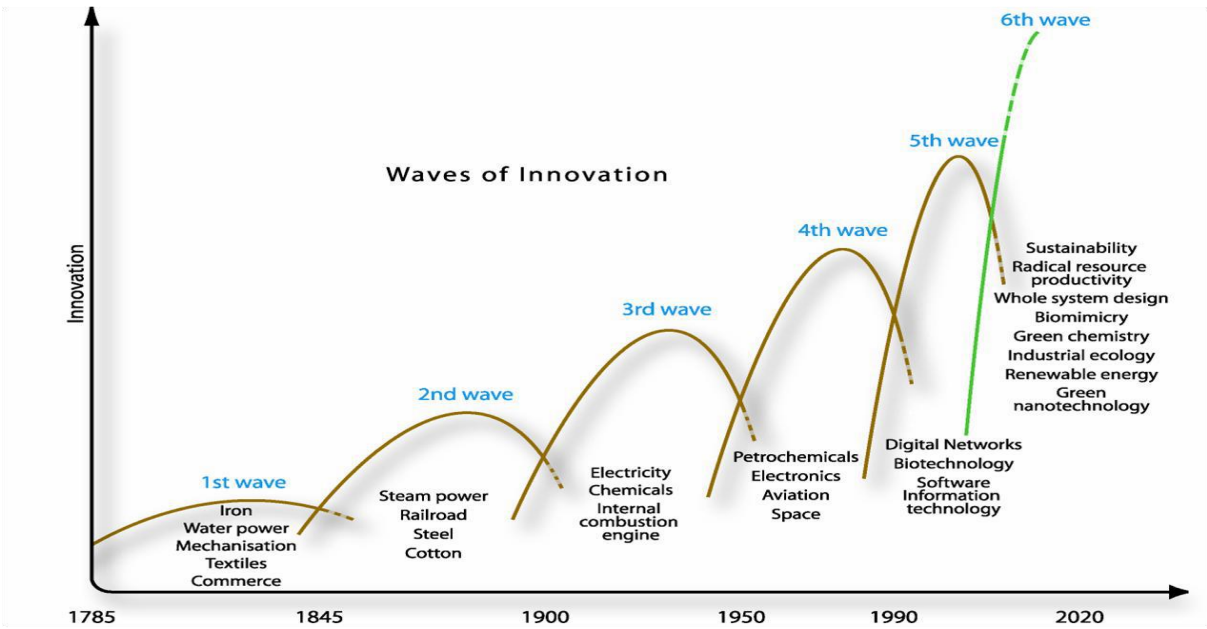

Figure 1: Waves of innovation - Kondratiev waves

3 Engineering education

New modes of knowledge production and application see new needs and new modes of learning (Beanland and Hadgraft, 2014). Engineering education has itself evolved from craft-based learning in the early industrial revolution, with an activity-based, hands-on learning approach, following a Pre- Renaissance separation of knowledge/science and practice/technology. This was succeeded into the second wave of industrial innovation and change by more formal apprenticeships, trade and skills- based, again with an activity-based, hands-on learning approach, coupled with the development of analysis and theory in the post-Renaissance growth of classical science and increasing science-base to engineering. This development continued with the growth of formal schools, colleges and universities, following the establishment of the University of Berlin, the 'Mother of modern universities' by Wilhelm von Humboldt in 1810, creating the "Humboldt model" of engineering education based on theory and practice. As schools, colleges and universities of engineering and technology developed into the 20th Century, so did 'engineering science' and the development of professionalization and disciplinary formation within engineering and of

engineering education and accreditation, with an increasingly science-based, theoretical and a hands-off learning approach – with the decline of the practical element of the Humboldt model. The development of 21st century, post-industrial science and engineering has seen the further erosion of separation between science and engineering, with the growth of interdisciplinary cooperation, integration, networking, systems approach and fusion of science and engineering, with an increasing focus on synthesis, applications and problem-solving.

This has created the need for new educational approaches for the present and next generation of engineers, of education for real world practice and application, based on real world issues and challenges such as climate change, sustainable development, poverty reduction and enhancing the quality of life in developing countries. New educational approaches overturning the traditional teacher-centred approach based on student centred learning combining theory and practice, blended learning, teamwork, continued and lifelong learning. Many focus on problem-solving through project and problem-based learning, following such exemplars as the Aalborg model of PBL, the Conceive Design Implement Operate (CDIO) approach and, most recently, flipped classrooms - reversing traditional learning with online instruction and classroom exercises (not unlike aspects of PBL).

4 Appropriate engineering education – Problem-Based Learning

Core principles of problem-based learning are based around problem orientation, project organisation, integration of theory and practice, participant direction, team-based approach, cooperation and feedback, and can be summarised as follows:

- Problem orientation

  Guided problem analysis/solving - basis for learning Project organisation
- Projects guide problem analysis to reach educational objectives Integration of theory and practice

  Students see link between theory and practical knowledge Participant direction
- Students define problem and make decisions on project work Team-based approach

  Most problem/project work is in groups of 3 or more students Cooperation and feedback
- Peer and supervisor feedback and reflection important in PBL

Problem-Based Leaning is a learning approach that is essentially student-centred, as opposed to teacher-centred in traditional pedagogy, focusing on student learning needs in terms of maintaining the balance and link between theory and practice of the Humboldt model, based on real-life problems. PBL is also project-organised education, with project work supported by lectures and courses, in the context of group or team work in groups of 4-6 students, with staff playing a mentoring supervisory role. PBL may also combine interdisciplinary studies, further integrating theory and practice and a focus on learning to learn and methodological skills, and may be a faculty or university-wide model (as is the case at Aalborg, with faculty variations).

The theoretical background to PBL is that PBL focuses on learning rather than teaching, active learning rather than passive, which is fun, as opposed to traditional teaching, which involves listening and memorising, which is not fun, assessed on the ability to produce and use knowledge.

Knowledge development takes place in collaborative student groups, with staff support, and focuses on learning to develop knowledge. Interest in PBL began in the 1960s-70s, with the development of new universities in around the world and interest in new ways of learning (Kolmos, Krogh and Fink, 2004; de Graaff and Kolmos, 2007; Du, de Graaff and Kolmos, 2009; Barge, 2010).

5 Engineering accreditation - Professional attributes and competencies

A focus of interest in engineering education and accreditation has moved away from engineering curricula to professional attributes and competencies. This is reflected in the work of the International Engineering Alliance – a global group from 30 developed countries with agreements covering the recognition of engineering educational qualifications and professional competence. The IEA includes the Washington Accord - an international accreditation agreement between national accreditation bodies. Interest includes the need for new educational approaches for the present and next generation of engineers - what engineers do we need, will we need? This in turn includes the need for cleaner and greener engineers with background attributes and competencies to deal with problems of climate change mitigation and adaptation and broader issues of sustainable development, new areas of engineering and technology such as robotics and the fact that change has become a constant rather than an exception. In this context there is a need for engineers, and engineering education to respond to rapid change in knowledge, learning how to learn for lifelong and distance learning, continued professional development in a cognitive, knowledge-based approach, which will require adaptability, flexibility and intercultural interdisciplinarity for multiple career paths, requiring experience and competence in terms of understanding, insight, awareness, analysis, synthesis, ethics and social responsibility for practical applications and problem-solving.

These needs and qualities are reflected in the twelve key graduate attributes and professional competencies identified by the Washington Accord (Washington Accord):

1. Engineering knowledge
2. Problem analysis
3. Design and development of solutions
4. Investigation
5. Modern tool usage
6. The engineer and society
7. Environment and society
8. Ethics
9. Individual and team member
10. Communications
11. Project management and finance
12. Life-long learning

As is evident, less than half of these criteria relate to the "old" engineering curricula, with the majority relating to contemporary and emerging needs of professional practice. All are ideally suited to problem- and

project-based learning, as originally outlined by Wilhelm von Humboldt, combining theory and practice.

6 Engineering and sustainability

Key elements of sustainability are identified in the UN Global Goals for Sustainable Development, "Transforming our world: the 2030 Agenda for Sustainable Development", following the eight UN Millennium Development Goals 2000-2015. The Sustainable Development Goals (SDGs) consist of seventeen goals, 169 targets and 304 provisional indicators. The seventeen SDGs are for no poverty; end hunger; good health and well-being; quality education; gender equality; clean water and sanitation; affordable and clean energy; decent work and economic growth; industry, innovation and infrastructure; reduced inequalities; sustainable cities and communities; responsible production and consumption; climate action; life below water; life on land; peace and justice, strong institutions; and partnerships for the goals. The SDGs are illustrated in the figure below:

Figure 2: UN Global Goals for Sustainable Development

6.1 The SDGs and Engineering

Engineering is of vital importance in sustainable development and a central factor in directly addressing most of the SDGs, as indicated below.

Poverty:
Engineering and technology are essential in the provision of basic services, infrastructure, income generation and humanitarian development.

Hunger:
Sustainable agriculture, food production, processing depends on engineering.

Health:
Health services, well-being and the quality of life depends increasingly on engineering and medical technology.

Water and sanitation:
Engineering and technology are central in the provision of clean water and sanitation.

Energy:
Affordable, sustainable energy, energy efficiency and renewable energy technologies are developed by engineers.

Employment and economic growth:
Engineering and technology supports economic growth and employment

Industry, Innovation and infrastructure:
Engineering and engineers drive innovation, infrastructure, industry and economic growth

Sustainable cities and communities:
Sustainable cities and communities depend on engineering, construction and infrastructure

Responsible production and consumption:
Engineering and technology underpins sustainable production and consumption.

Climate action:
Climate change mitigation and adaptation, sustainable energy and reduced emissions depend on engineering and technology.

Life below water; Life on land:
All life on Earth will depend increasing on the use of sustainable engineering and technology.

In addition, quality education will be essential if we are to enrol and train the next generation of sustainable engineers, and gender equality is important to ensure that a greater percentage of engineers are women, who also have a greater interest in sustainability. Engineering and technology are also vital in promoting global partnerships for sustainable development and in reducing global inequality. On the other hand, it is unfortunate that engineering is only mentioned specifically twice in the SDG document – in the context of scholarships to developing countries for engineering (SDG Goal 4b), and in relation to global partnerships for sustainable development (SDG Goal 17).

7 Appropriate engineering and technology for humanitarian development

Engineering and technology are also of vital importance in addressing human and social progress and development, and humanitarian activity in the context of post-conflict and post-disaster response, and post crisis transition and development. The SDGs should more widely be considered global goals for sustainability and development, and many of the SDGs listed above relate particularly to social, economic and humanitarian development. These include almost all the seventeen SDGs. Engineering and technology are vital in the reduction of poverty and hunger, in promoting health in such areas as water supply and sanitation and the provision of affordable housing and energy. Engineering and technology also drive industry, innovation and infrastructure, employment and economic growth (Metcalfe, 1995; Stewart, 1977). Engineering and technology underpin sustainable production and consumption and will be an essential part of the solution of climate change mitigation and adaptation and the continuation of life on planet earth.

Engineering and technology play a special role in post-conflict and post-disaster response and reconstruction, in all the areas of social and humanitarian development noted above. Engineers are usually the most immediate post-crisis responders in terms of rescue and making safe, and engineers are at the forefront of reconstruction activities. In Colombia the peace process follows 50 years of armed conflict and

engineering will be vital in post crisis transition and development. East Timor became independent after 25 years of Indonesian occupation, with severely damaged infrastructure and no experience of the understanding, planning, organisation and management of development activities, particularly in rural areas, that had taken place over the same period in similar countries – such as those of the Pacific islands. Engineers with insight into and experience of technology, innovation and social and humanitarian development, and associated institutions, policies, programmes and initiatives, are vital in such situations. Examples of such humanitarian development activities include improved affordable housing building upon local skills and materials. Household water supply using roof-water catchment or slow sand filters and locally made ferro- cement or galvanised rainwater tanks. Improved pit and pour-flush sanitation. Solar PV household energy systems and improved cooking stoves. Food production and processing for household and small business development. Small scale technologies are the basis for many other small business and employment development initiatives, including chicken and livestock raising, bakeries, trades- based and workshop businesses.

The Daimler-UNESCO Mondialogo Engineering Award was an example of an international initiative promoting cooperation between engineering students to address issues of humanitarian development in developing countries, with a particular focus on quality of life improvement and sustainable development. The Mondialogo Engineering Award ran in three series, each concluding with a Symposium and award ceremony, from 2003-2010, organised by Daimler and UNESCO, and involved over 10,000 young engineers from over 100 countries. Students formed international partnerships to cooperate on problem-based, problem-solving project design exercises in humanitarian development. Projects included impressive design solutions to a diversity of humanitarian issues such as affordable water supply and sanitation systems, improved housing and household lighting systems and cooking stoves, low-cost bridges, food production and processing, telemedicine and prosthetic limbs, some of which were successfully commercialised, although this was not a condition of the competition. The Mondialogo Engineering Award was itself a multi award- winning initiative, that sadly concluded with the Global Financial Crisis (UNESCO, 2010).

Low cost bridge building – Rwanda-Germany team

Prosthetic foot – Colombia-USA team

8 Concluding remarks - transforming engineering education

Particular challenges for engineering include the decline of interest and enrolment of young people, especially women, in engineering. This is mainly due to negative perceptions that engineering is boring, nerdy

and uncool, that university courses are difficult, hard work and boring, that engineering jobs are not well paid and that engineering has a negative environmental impact and image. There is also evidence that young people turn away from science at age 10-12, that good science education at primary/secondary level is vital and that teachers can turn young people on/off science. There is an overall need to emphasise engineering as the driver of social/economic development to get engineering on the development agenda, to develop public and policy awareness of engineering, develop information on engineering, highlighting the need for better statistics and indicators on engineering, to promote change in engineering education, curricula and teaching to emphasise relevance and problem-solving, more effectively apply engineering to global issues such as poverty reduction, sustainability and climate change and to develop greener/sustainable engineering and technology and the next wave of innovation. There is a particular need to address negative perceptions that engineering is boring, that engineering education is hard work, that engineering jobs are not well paid and that engineering has negative environmental impact and image. These negative perceptions can be addressed by promoting the public understanding and awareness of engineering, making engineering education more interesting and relevant for problem-solving (eg through problem-based learning), better understand and control the supply and demand for engineers and encouraging small engineering business development and the promotion of engineering as a part of the solution, rather than part of the problem to sustainable development, climate change reduction and mitigation.

Many of these issues, challenges and opportunities are linked in terms of providing positive solutions. When young people, the public and policy-makers see that engineering is a major part of the solution to global issues, their attention and interest is raised and they are attracted to engineering and the relevance of engineering in address global issues humanitarian engineering. There is therefore a need to provide examples of engineering relevance in development and promote transformation and innovation in engineering education – to combine theory and practice as in the original Humboldt model, linking fun and fundamentals and demonstrating that engineering can be cool. Promoting public interest and understanding of engineering will also promote the relevance of engineering to address global issues such as poverty, sustainability and climate change. Promoting the relevance of engineering and humanitarian engineering in addressing such issues has been demonstrated in such initiatives as the Daimler-UNESCO Mondialogo Engineering Award and the many Engineers Without Borders around the world that are very attractive to students (Mondialogo, 2010).

Transformation and innovation in engineering education is important in updating engineering curricula and pedagogy to be less theory and formulae driven, involving more activity, project and problem-based learning, in more just-in-time, hands-on approaches, such as the Aalborg PBL model and related approaches. Other professions have moved in this direction – for example, medical education has moved toward more "patient based" learning. It is beyond time for engineering to do the same. The transformation of engineering education needs to address the need to respond to rapid change in knowledge, learning how to learn in a cognitive, knowledge-based approach with relevance to pressing global issues and challenges

Engineers are innovators and need to innovate in engineering education, based on problem and project-based learning for a problem-solving profession (UNESCO, 2010), linked to issues of relevance such as sustainability and humanitarian engineering and technology. In response to changing knowledge production and application, lifelong learning and continued professional development, there is a need for the increased use of ICT resources for student-centred learning, with limited lectures, where staff act as learning facilitators and mentors. There needs to be greater focus on the development and assessment of graduate attributes and the provision of learning and work space to facilitate student interaction. Transformative

actions are required in the areas of knowledge systems in engineering, science, technology, relating to the social context and ethical issues in engineering and technology, improved data and information on engineering, the development of the engineering profession and organisations, engineering education and educators. The development of engineering policy, planning and decision making is also required, and the promotion of engineering as a separate but related aspect of 'STI' – SETI would be a more accurate descriptor.

Transformation and change does not come easy, however, and barriers may be encountered from people and institutions that do not see the need or rationale for change. Barriers to change in engineering educators and universities relate to the traditional focus on research rather than education that does not reward effective educators, a culture of lecturing rather than learning, space designed for lecturing, conservative attitudes resistant to change and leaders who rarely see the need for transformation. The traditional rhetoric of the need to maintain educational 'quality' is undermined by overloaded academics, declining standards and funding, increasing bureaucracy and focus on revenue, 'efficiency' and university profile, especially university ranking and KPIs (Hill, 2012). Accreditation authorities may also be conservative, slow to change from a traditional approach to one of graduate attributes and professional competencies, but – who can be progressive and drive change, for example the American Accreditation Board for Engineering and Technology (ABET) and the international Washington Accord. The failure to transform engineering education, to address the challenges noted above, will result in insufficient engineers, technologists and technicians around the world, insufficient engineering educators, consequent impact on developing countries and continued brain drain from poorer developing countries - who can ill afford to lose engineers, effectively subsidising richer developed countries, creating borders without engineers!

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Washington Accord - an international agreement established in 1989 recognising equivalencies in accreditation for professional engineering academic degrees between national bodies responsible for accreditation in its signatory countries. Signatories in 2010 included Australia, Canada, Chinese Taipei, Hong Kong China, Ireland, Japan, Korea, Malaysia, New Zealand, Russia, Singapore, South Africa, Turkey, the UK and USA.

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Education for Sustainability: an initial study

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Abstract

The development of sustainability concepts in engineering courses arises as a necessary and complementary discipline in the formation of news professionals. The development of sustainable concepts can be achieved through punctual approaches in short terms, and more effectively through the implementation of sustainability aspects along distinct and integrated disciplines in higher education. The present study intends to discuss the necessity of sustainability conceptualization on engineering courses through the results of an empirical survey undertaken with graduate engineering students. This study will contribute to propose a Sustainability Workshop for the engineering students.

Keywords: sustainability development, engineering courses, survey

Type of contribution: research paper

1 Introduction

Sustainable development is a concept that was first created to integrate economic profit while respecting environmental and social issues during productive activities (Brundtland Commission, 1987). Making products and managing processes with higher efficiency in natural resource use (i.e. fossil fuels, plant biomass, water), properly land use regarding local limits of soil and water conditions, and respect to people's basic needs (i.e. food, water, health) are some of the assumption that must be undertaken to accomplish sustainable development. Nonetheless, the actual application of this concept, since it was proposed up to present, did not always contemplate all of its three pillars.

Such trends have lead our society to over explore planetary resources and witness environmental degradation in the shape of extreme and unexpected environmental events (i.e. landslide, floods, drought) aside from social issues regarding the lack of clean water, sufficient food supply and adequate housing for many people around the globe (WHO, 2017a, b). There may be some explanations to these trends, such as the believe that nature support capability is infinite, or that environmental and social problems are not our own, as long as it does not affect us directly. Additionally, some of these problems may derive from the gaps of sustainability teaching in higher education (Azapagic *et al.*, 2005; McCornick *et al.*, 2015).

It is important to consider that there are different ways of thinking about sustainability beyond the environmental real, the concept considers that deteriorated environments do not contribute to the maintenance of the people's social, environmental, and economic welfare and that every planning must be focused on medium and long term alternatives, alongside political actions (Albano & Senna, 1999). For that matter, possibly, an effective way to deal with the origin of the aforementioned problems is to include these issues during graduate courses, that has not historically debated them. The actions of different

professionals, especially of the Engineering sector, present a high potential to contribute with new processes, products, and technologies that respect the environment and human quality of life.

Currently, discussing sustainability in distinct and integrates disciplines in engineering courses may provide the subsidies to critical thinking and development of sustainable innovations and technology. Silva *et al.*(2008) consider that the purpose of teaching sustainability and social responsibility in engineering courses is to promote the welfare of the different publics affected by the Engineer's actions. Also, they have registered that the offer of disciplines linked to the subject contributed to increase the number of final graduation projects whose themes revolve on sustainability; to increase the number of students of other courses, besides engineering, that are searching for the subject; and to incite the interest for post-graduation courses with this theme.

With that in mind, this paper's purpose is to investigate the level of knowledge and interest of engineering students in the Sustainable Development subject. By doing that we hope to encourage discussions about the knowledge blanks of these future professionals, establishing possible measures to complement engineering course curricula, increasing the future engineers' awareness so they might include sustainable aspects on their projects.

2 Survey

To evaluate the knowledge of engineering students on Sustainable Development, a structured survey was undertaken using a quiz developed by Azapagic *et al.* (2005). The quiz was provided online, in Google Forms, and included a list of subjects linked to sustainability and four answers were available, based on the level of knowledge on each topic: I do not know anything about it, I have heard about it but I cannot explain it, I have some knowledge about it, and I know a lot about it. Students from different disciplines and engineer courses were asked to answer the online quiz within distinct disciplines.

The data registered in the quizzes were organized in the *Excel* software. Charts were generated with the response proportion of each subject and interpreted to identify the level of understanding of the subjects linked to sustainable development.

3 Results and Discussion

The workshop had a total of 210 participants undertaking courses of Aerospace Engineering, Infrastructure Engineering, Railway and Subway Engineering, Naval Engineering, Interdisciplinary Bachelor's Degree in Mobility, and Petroleum Engineering, attending from the first to the fourth year of education.

The first stage of the research consisted in evaluating the knowledge on environmental problems (Fig. 1). More than 50% of the students presented some knowledge on 10 out of 14 topics, especially deforestation, acid rain and air pollution. This means that they most of them have learned about negative impacts and/or important ecological concepts and recognize their occurrence on the planet. Thirty percent of the students know a lot about Water pollution, a great accomplishment, considering the importance of water as a primary resource to sustain life, agriculture and industry activities. This result may be linked to the great advertising of these subjects, which are frequently studied in early school education, are closely witness by students in their neighborhoods; aside from social media, which discuss more and more about the environmental problems that affect our society.

On the other hand, the subjects of which the students presented a lower knowledge level, that is, which they have never heard of, were: photochemical smog, salinity and solid waste (Fig. 1). All of these subjects are highly relevant for our productive activities and our society's quality of life. Salinization and solid waste are linked to changes on the use of the soil, which may hinder several activities and cause diseases and environmental degradation, while the photochemical smog drastically changes the quality of the air that we breathe, causing health problems (Pereira *et al.*, 2014; Pedrotti *et al.*, 2015; ABNT, 2004). The students' unfamiliarity with these subjects reveals an important blank that must be filled in terms of awareness and also of proposal of sustainable technological alternatives.

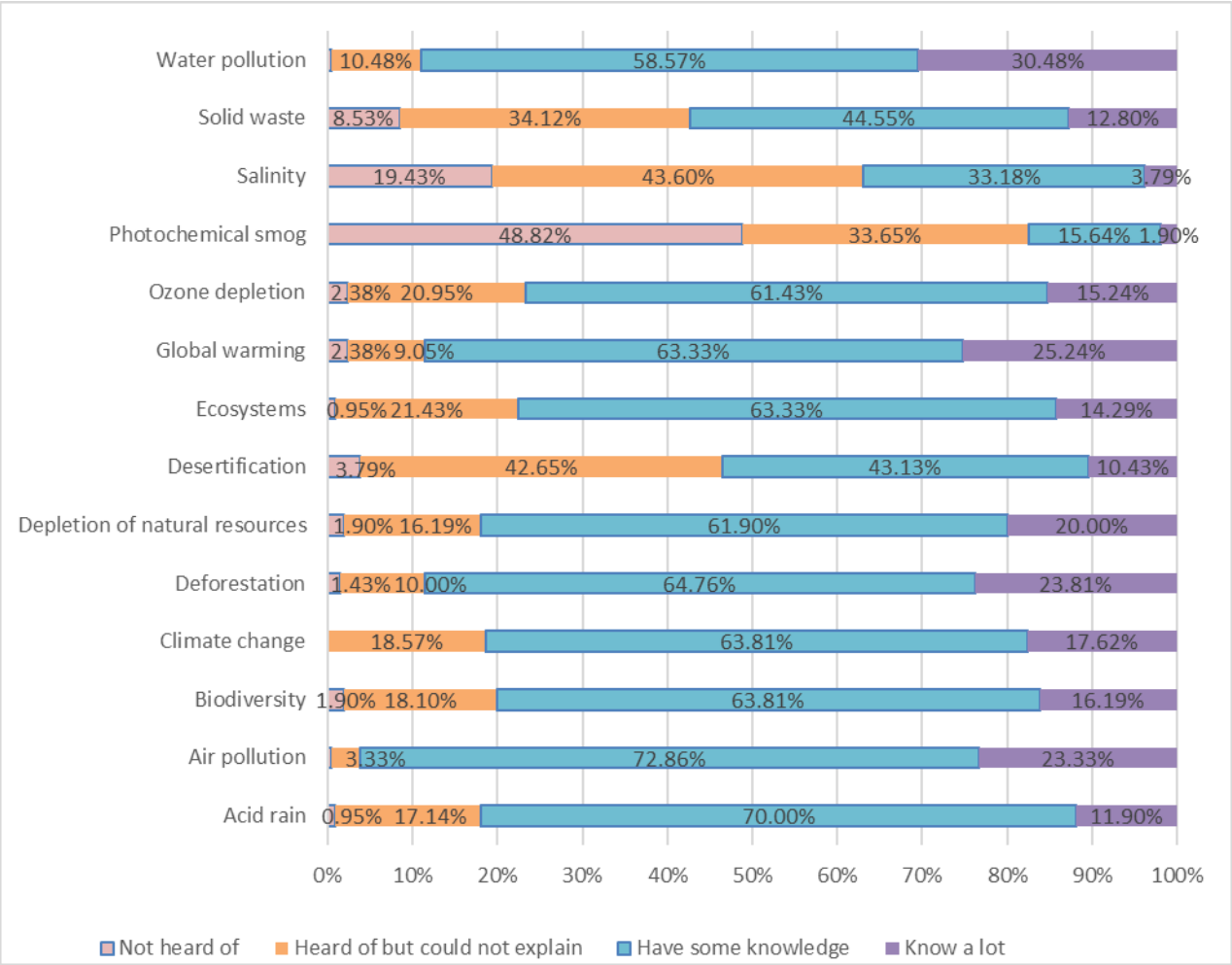

Figure 1: Environmental Issues

Regarding legislation, politics and environmental rules, we noticed that most students are unfamiliar or have little knowledge about the subject (Fig. 2). The subjects in which the students showed greater knowledge— the Kyoto Protocol, and Rio Declaration - are the ones that are more mentioned in media broadcasts, which facilitate the first contact with the subject and the possibility of individual deepening. It should be mentioned that more than 60% of the students have some knowledge or at least heard about Regulation ISO 14001 (Fig. 2). This regulation provides directives to implement Environmental Management Systems on companies, currently in growing expansion and of extreme relevance for the performance of future professionals, which points to another important blank that must be filled during the educational curriculum. Eco-Management and Audit Scheme and Florence Convention (European Landscape

Convention) were two of the topics of which most students had never heard about. Both of them are related to European Environmental Management programs, that deal with land use issues and ecological management of resources, and the absence of knowledge was expected. The third topic students never heard about was IPCC – Intergovernmental Panel on Climate Change. This result in quite preoccupant, since IPCC is a highly active body of assessment on climate change, with the production of several reports discussed by the media.

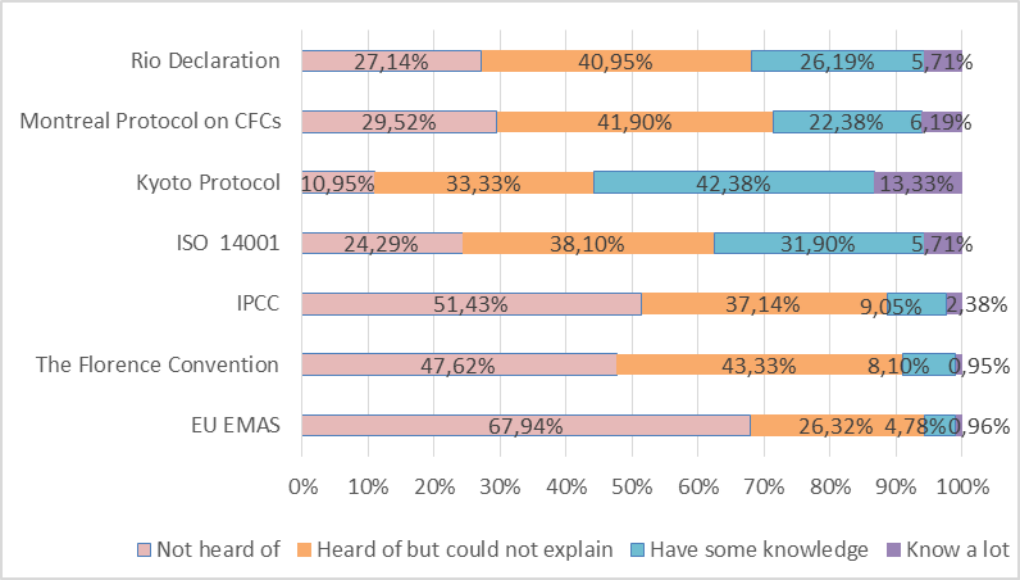

Figure 2: Environmental Legislation, Policy and Standards

Considering that engineers are responsible for creating new technologies and adapting processes and products, their knowledge on tools, technologies, and environmental approaches was analyzed (Fig. 3). In this topic, the students showed a better knowledge level and, although basic, most of them heard about subjects like clean technologies, renewable energy technology and waste minimization. Such subjects attract more attention of future professionals because they are inherently linked to their performance. Therefore, we should contextualize these subjects' implementation in the students' scientific and professional performance, encouraging their deepening and the direct application of such concepts or objectives in the proposal of new alternatives during education. It should be mentioned that new trains of thought and approaches have been advocating that instead of making efforts to deal with the waste that we produce, we should focus on planning industrial processes that do not produce waste at all (EPEA, 2017).

Topics students have never heard about were tradable permits and eco-labelling (Fig. 3). Tradable permits are instruments aimed at reducing pollution. A maximum permissible emission rate is determined by government and permits that allow for the production of a maximum emission are issued to industry players. These permits can subsequently be traded to firms that require more permits in order to continue their activities. Eco-labelling is a voluntary method of environmental performance certification and labelling. An ecolabel identifies products or services proven environmentally preferable overall, within a specific product or service category. These are both important subjects to industries activities and must be better discussed in higher education, since they are directly linked to economic valorisation of products and processes.

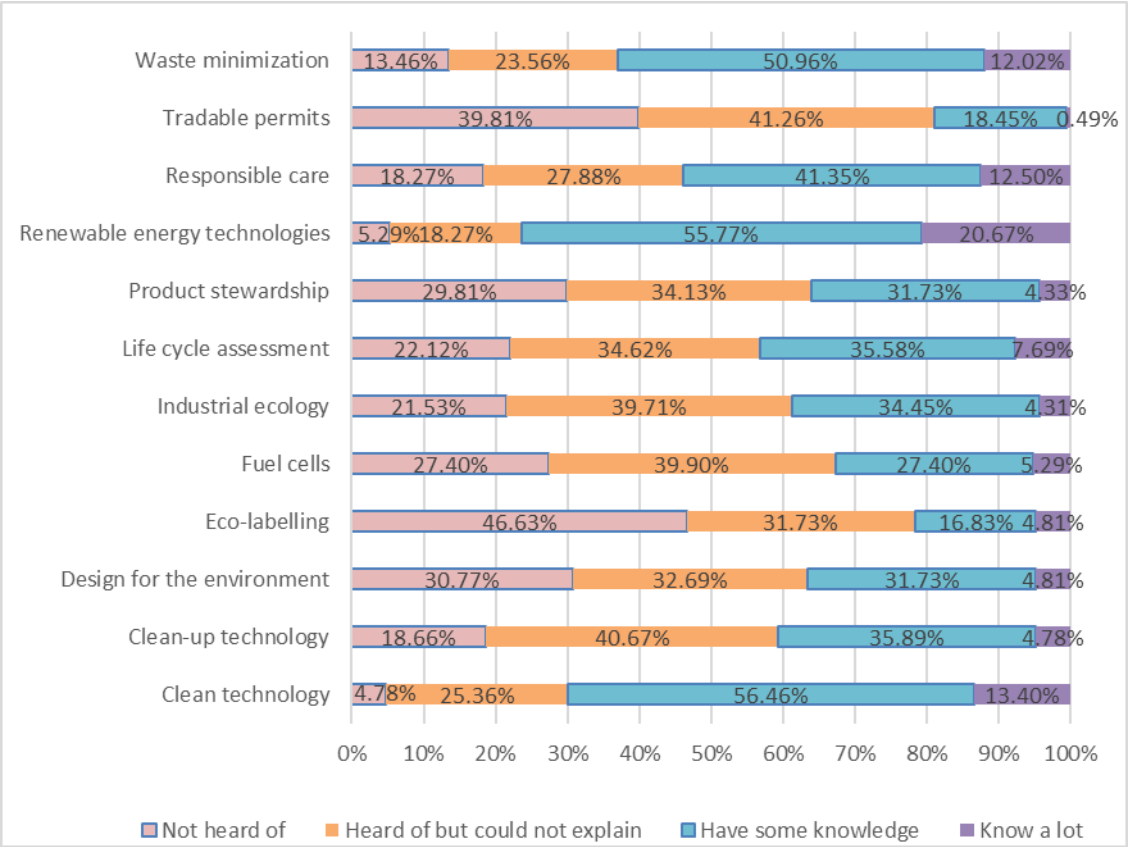

Figure 3: Environmental Tools, Technologies and Approaches

The knowledge analysis on sustainable development revealed that over half of the students never heard about stakeholder participation and precautionary principle (Fig. 4). We must underscore here the unawareness of the human being's importance and the social aspect as a fundamental component for the real promotion of sustainable development. Sustainability is usually linked more conspicuously only to nature. However, keeping a balanced and healthy environment affects the persons' (stakeholders) quality of life and the development of productive activities directly. Also, pollution treating processes are encouraged, although the most coherent and efficient thing to do would be preventing waste production, according to the precautionary principle.

It is important to underscore that the students presented some knowledge on the concept and components of sustainable development—social, environmental, and economic—, on population growth, and the social responsibility, besides actions that can be taken by companies and engineers to promote sustainable development (Fig. 4). Considering that one of the major aggravating factors for the levels of environmental degradation that we witness today is human population growth, which consumes much more resources than the planet can replenish, it is fundamental that the future engineering professionals think on this problem and work to minimize its negative effects (Monteiro, 2010).

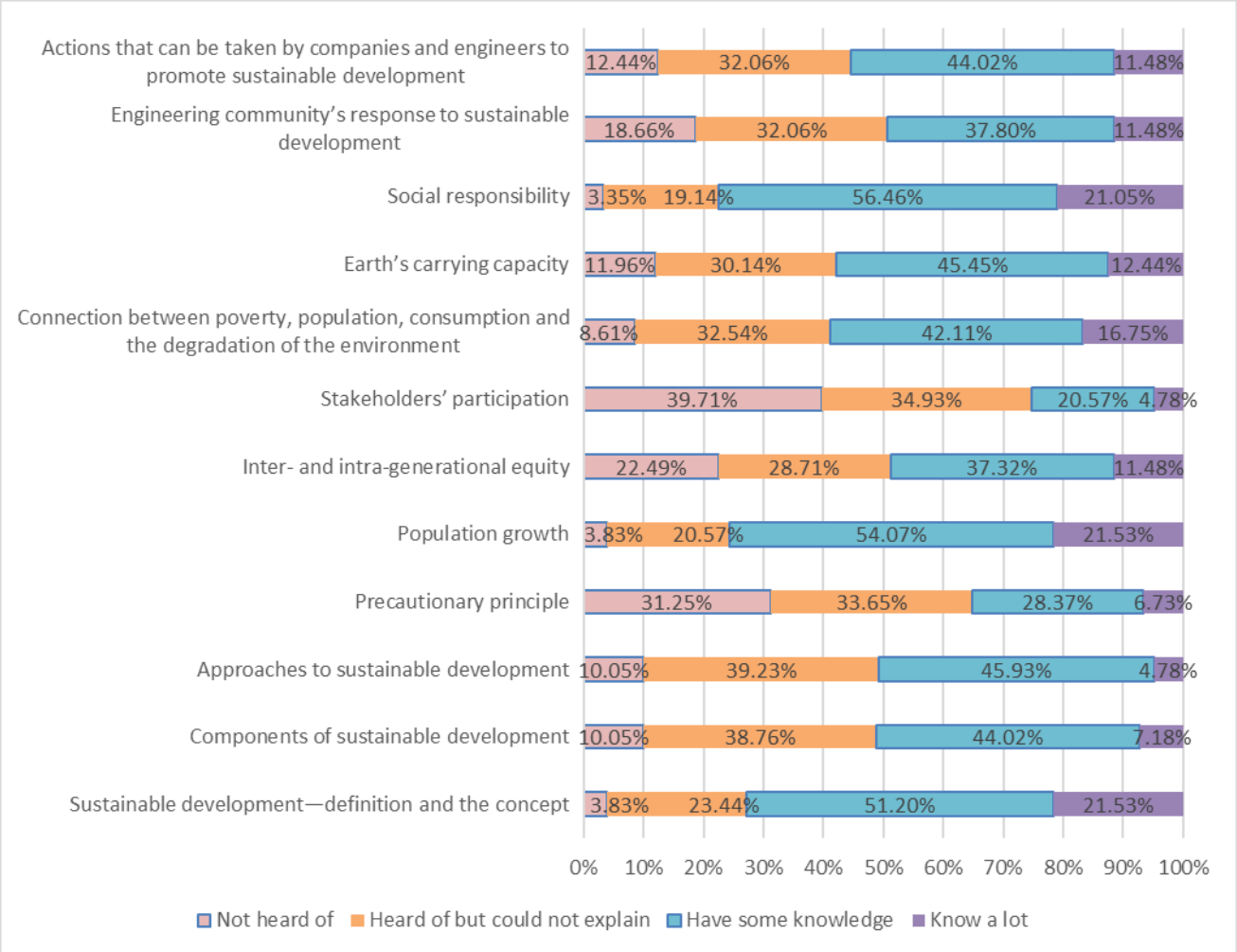

Figure 4: Sustainable Development

Most students (over 60%) considered Sustainable Development very important for the future generations, society, Country, for themselves as engineers and as individuals (Fig. 5). These responses reflect the idea that every person may cooperate to improve everyone's quality of life, and that our society must implement sustainability in their everyday life to remain economically, socially, and environmentally productive. It is important to highlight that a few students considered sustainable development not important the society world-wide and to their country. This result shows that, even though we develop a great amount of discussions and awareness along higher education, some people might still consider it not important. These people must be target to improve some change in sustainable thinking.

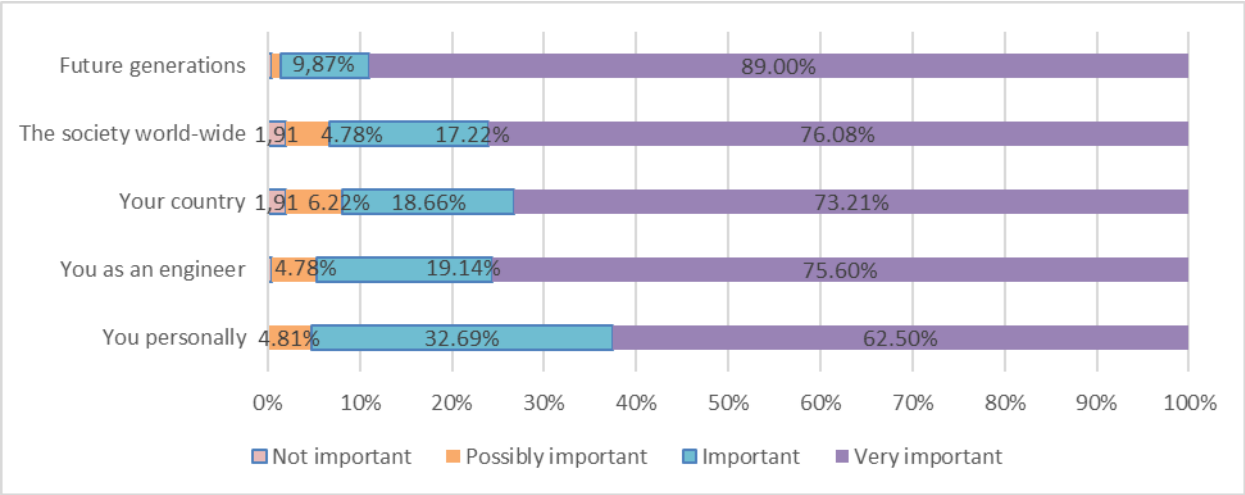

Figure 5: How would you rate the importance of sustainable development

The last question revolved on the level of environment education in formal education. A student said that he never had environmental education classes in school, while half of the participants, students that are attending engineering classes for 1 or 2 years, said that they still have not attended a class on the subject in the university. Such results also reflect deficiencies on the courses curricula, not only due to the lack of specific disciplines, but also due to the inefficiency in approaching the subject in correlated disciplines. For example, Fisher and McAdams (2015) tried to establish the levels of divergence in the understanding of sustainability based on the classes taken by engineering students. The kind and not the number of classes taken by the students reflected on how the concept of sustainability was conceived. Students that took the Natural Sciences course, for example, had a better understanding of the environmental aspects, while those who took Business, Economics, and Politics had a better understanding of eco-efficiency concepts. Therefore, different sustainability aspects, when dealt by different disciplines, result in different and complementary understandings by each individual.

Overall, most students showed some (but not a lot) knowledge on environmental issues, environmental tools and technologies, and sustainable development, while legislation was the most outdated subject. These results, along with literature review showed that sustainable development concepts are not well explored in engineering education, both in Brazil and in other countries, showing that the courses are more focused on the technical aspects rather than approaching environmental issues along the way. Conducting this kind of research may contribute to discover knowledge gaps and direct some efforts into changes in engineering curricula, by discussing sustainable development in and integrated matter within higher education.

The next action of this research is to propose a Sustainability Workshop for the engineering students, based on the results of this initial study carried out.

4 Acknowledgment

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International student outcomes of problem-based sustainability projects

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Abstract

This case study examines the strengths and weaknesses of a Problem-based learning project conducted at a New Zealand Institute of Technology by international students researching the process and effects of converting a petrol-powered three-wheeled motorised vehicle (Tuk-Tuk) into a battery-powered electric vehicle. Such unmodified vehicles are a significant cause of air pollution and allied social issues in third-world countries. Students were divided into two groups according to their study areas - the first group (two automotive students from Tanzania and Fiji) focused mainly on mechanical aspects of the conversion. The second group (three electrotechnology students from Saudi Arabia) designed the power system and explored the practicality of using solar energy to assist battery recharging. Both groups had specialist supervisors and were expected to collaborate with one another, but all students were asked to develop their own research questions and methodology, focussing on the wider rationale for sustainability within their discipline. The purpose of the current study is to examine the learning experiences of these international students who had participated in this collaborative, interdisciplinary, sustainable transport project. They were expected to undertake all aspects and challenges of a real-world project - theoretical research, design choices, purchasing decisions, dealing with components suppliers, as well as communicating with supervisors and industry bodies. In this process students demonstrated different levels of independence in learning and problem solving skills and the project had a significantly different impact on each student. At the end of the project feedback was sought from all the students on their learning, and the extent to which they thought it might influence their insights into sustainability and their career opportunities upon returning home. Their reflections, together with the responses from the two supervisors, have led to recommendations for future improvements in this form of pedagogy.

Keywords: Sustainability, Real-world project, International students, Scaffolding

Type of contribution: best practice paper

1 Introduction

This paper describes an investigation using PBL methods for facilitating sustainability with final year degree students many of whom are international.

The Bachelor of Applied Technology at Unitec Institute of Technology has been offered to students since 2004 and although it has been much re-constructed over the intervening years, it has always included the graduate capability of Sustainability in its professional outcomes. In other words, students emerging with this qualification are not only expected to be industry ready, they should also be aware of the significance of Sustainability as it relates to their profession, whether that is in electrotechnology, automotive engineering or marine design.

In a compulsory second-year course, Sustainable Technologies, students have previously been exposed to a range of innovative technologies connected to transport, pollution and energy generation, and have come to see that many technological developments, designed to benefit individuals or communities have frequently been accompanied by a range of negative effects. For a large proportion of our international students this is the first time they have encountered such ideas and for a few of them, this has made a significant impression (Panko & Sharma, 2014).

Out of this background came the concept of inviting two groups of international students to undertake Problem-based Sustainability learning for their final year project. With initial input from the automotive students, this developed into an investigation of the process and effects of converting a petrol-powered three-wheeled motorised vehicle (a Tuk-Tuk) into a batterypowered electric vehicle. Unmodified vehicles of this type are a significant cause of air pollution and allied social issues in third-world countries, especially in Tanzania where they are a widespread form of transport. It was anticipated that converting these vehicles from fossil fuel to electric power and enabling them to recharge efficiently in rural areas could introduce sustainability benefits to local communities, particularly in terms of health and economics.

2 Theoretical underpinning

Literature indicates that vocational students frequently have dismissive attitudes towards sustainability (Shephard, 2008; Torbjörnsson, Molin & Karlberg, 2011). Nevertheless, the United Nations Millennium Declaration (2000) emphasises that changing the values of people, especially from the technological sector, is vital if sustainable development is to be achieved and this can only happen through a process of transformative learning (Sterling, 2001). Sterling explains this as a paradigm shift, "which values, sustains and realises human potential *in relation to* the need to attain and sustain social, economic and ecological well-being, recognising that they must be part of the same dynamic" (Sterling, 2001:22). It is therefore hoped that substantial elements of this attribute have become more than mere knowledge of sustainability practices for our students, applicable to their varying industries. By examining examples from their home countries as well as undertaking practical investigations, a change in their affective domains – their values, attitudes and behaviours (Shephard, 2008) is sought through their programme of study. Obviously, the extent to which this is successful would be expected to vary from student to student.

Much has been written about the finer points of PBL and although there is no unanimous position about its precise characteristics, a number of basic principles of this learning process can be seen as constant (Table 1). Likewise, a number of different models have been promulgated, such as Hybrid PBL (Bessant et all, 2013) which Bessant and her colleagues have found effective in sustainability education. Some of the most generally accepted features have been identified by Nelson (2010) and are indicated briefly on Table 1. Similarly, features which demonstrate effective learning about sustainability, primarily through active engagement, have been analysed by Burns (2011) amongst others, and show many overlapping features with those highlighted by Nelson. In both cases these are designed to bring about transformative learning which Burns emphasises cannot be achieved through teacher-centred, transmissive models of education.

While our Industry Project case study relates to the main elements of PBL and transformative sustainability education, it does not fit neatly into the proposed formats. This is because it is a practical model and as such is an eclectic mix, varying in accordance with the context of discipline, learner and supervisor. However, within the Savin-Baden schema (2000) our project comes closest to her Model II – PBL for Professional Action, which is particularly relevant when we consider the role of the facilitator later in this paper.

Using these models, we have drawn links between the three elements of PBL, Sustainability and our Industry Project model, as indicated in Table 1. Nevertheless, as our course relied heavily on the students' abilities to work independently, solving a number of ill-structured contextualised problems and then to see practical applications in their professional fields (Burns, 2011), a potential weakness became apparent. This weakness, earlier identified by Savin-Baden (2003), is the possibility of the development of a narrow set of skills which may not include cognitive content or professional judgement. This aspect is relevant to this study as Savin-Baden highlights that the role of the facilitator/supervisor is critical and that in order to develop increasing learner independence, scaffolding has to provide room for this to take place. This issue becomes increasingly significant when students come from a variety of international backgrounds, many unused to taking responsibility for their own learning. This was the prime motivation in the development of this case study as it is anticipated that improvements will be made to the delivery of our project as a result of our findings.

Table 1: A comparison between the principles of PBL, Sustainability teaching and the Industry Project course.

PBL principles (Nelson, 2010)	**Sustainability learning principles (Burns, 2011)**	**Industry Project**
Student-centred	Empowering learners to solve complex problems to sustain places and communities	Supervisors facilitate learners to solve problems & relate to home country
Ill-structured contextualised problems	Content: Sustainability themes	Trial technical solutions – with a sustainability focus
A multi-disciplinary focus	Context: Place and crossdiscipline based	Discipline knowledge combined across groups
Self-regulation and collaboration	Process: Participatory and experiential	Experiential and collaborative
Reflection and evaluation	Perspectives: Diverse critical questioning	Reflect on learning and seek affective learning outcomes.
Closing analyses	Transformational learning	Future translation of sustainability project experience into action in an international context.

Making this process effective, in the eyes of both students and supervisors, for a diverse range of students has been analysed in detail by Kim and Hannafin (2011) who have identified five stages in the process of scaffolding practical PBL. These can be summed up as Problem: identification, exploration, reconstruction, presentation and reflection and when considered in detail, these stages allow supervisors to respond flexibly to the needs of different learners.

3 Project design

Students were divided into two groups according to their discipline areas – the first group (two automotive students from Tanzania and Fiji) focused mainly on the mechanical aspects of the conversion. The second group (three electrotechnology students from Saudi Arabia) designed the power system and explored the practicality of using solar panels attached to the roof of the Tuk-Tuk to assist battery recharging. The Industry Project was allocated one semester to complete, following a preliminary research proposal had been undertaken by the students in the previous semester.

This paper was initially intended to focus on the overall strengths and weaknesses of the Industry Project as an application of PBL, particularly in respect to Sustainability. However, the information gained caused us also to consider the diverse scaffolding requirements of the students as it became a significant issue in the study.

The approach we took comprised participant evaluation of the PBL project from the points of view of both supervisors as well as the five students involved. An observation record was also kept of the project as it unfolded and how students responded to the challenges of a real-world project – involving a combination of theoretical research, design choices, purchasing decisions, dealing with components suppliers, as well as communicating with supervisors and industry bodies. The primary motivation for the main part of the study is to improve the PBL experience, in particular for international students who are likely to be unaccustomed to this form of independent learning, as well as increasing the likelihood of subsequent sustainability uptake in their professional lives. Ellis, Cummings & Turner (2009) highlighted the increased engagement of international students when highly interactive PBL techniques were applied and revealed that their students subsequently produced high quality reports.

Once the practical work was completed, the reports completed and awarded a grade, semistructured interviews were carried out with each group separately, both students and their supervisors, in order to encourage open discussion. It is planned to attempt to continue this communication with the students once they have returned to their homes, via brief phone calls, to discover whether any long-term sustainability effects can be identified. After an initial flurry of meetings, the students settled down to meet with their supervisors approximately once a week, sometimes in small groups within their own study areas but frequently as a group of five with one or both supervisors.

Practical workshops with theoretical discussions (started at the second half of the semester) were the first real opportunity for the two groups to meet and get to know each other. At an early stage they also visited an industry group of electric vehicle enthusiasts where they saw a variety of somewhat eccentric forms of transport such as a single-wheeled motorbike and a car propelled by electricity produced from a wood-burning stove. Having seen examples of what could be achieved and the enthusiasm these projects generated, they collectively agreed to order a new petrol-powered Tuk-Tuk. Initially it was anticipated this could be obtained through Institute connections in India and several weeks passed without progress being made before the students took the initiative and placed an order with a Chinese supplier. At that point they decided to delay their purchase of a conversion kit until they had examined the vehicle and knew what would be suitable. They also postponed obtaining the solar panels for the same reason. These items eventually arrived a few weeks before the conclusion of the project.

Such extensive delays impacted the practical aspects of their project, particularly for the Saudi Arabian students exploring the alternative energy systems. In principle this required them to rely heavily on the theoretical aspects of their studies, with time to investigate in more depth the potential effects of transport

sustainability and pollution as well as energy supplies in their own countries. In practice they became highly concerned about obtaining a successful outcome and began to doubt whether they would pass the course – their ultimate goal. This unsurprising response reinforces Savin-Baden's (2003) findings that learners were likely to react to difficulties in at least four distinct ways: retreat, temporising, avoidance or finally engagement, the first three being forms of resistance. To limit resistance and encourage engagement, a recent handbook supporting PBL facilitators (Fraser, 2015) stresses that instructors need to be most active in the early stage of development in order to facilitate a SMART project (Specific, Measurable, Achievable, Realistic and are able to fit the Timeframe).

Once the Tuk-Tuk was delivered, the students and the automotive supervisor met regularly at weekends, spending a full day each week collaborating on a series of mechanical and electrical tests – the results of which strongly reinforced the pollution effects of the Tuk-Tuk. They were encouraged to keep writing up their research and the electrotechnology students joined their class colleagues in arranging a demonstration of their project as part of their assessed work.

4 Findings

The findings described here were obtained primarily from four data sources: semi-structured interviews, observations (made by the first two authors during the study); students' reports, and lastly, the results summary of the grades obtained by each of the five students. In addition to gaining participants overall responses to their experiences, we also concentrated on aspects of their learning processes such as collaboration, content learning and sustainability concepts.

4.1 Interviews

Three separate interviews took place, one with both supervisors, the second with the automotive students and the third with the electrotechnology students.

Firstly, the two supervisors considered that the projects had ultimately been successful but that the individual and cultural characteristics of the two groups caused the students to respond in different ways to their experiences. They largely agreed with each other's evaluation of the students' performance: that overall the projects had been challenging, engaging and had increased the capabilities of the undergraduates. Both supervisors explained that in this study, as in other classes they had facilitated, they had found Saudi Arabian learners to be pragmatic, non-risk takers focussing strongly on obtaining a good grade which they believed will lead them into satisfactory employment. One of this paper's authors said, "*My students enjoyed the challenges of a real-life project while for some of the other students, obstacles, such as time and resources, were very frustrating… they [the automotive students] come here with shiny eyes*." On the other hand, the other supervisor said, *"The electrotechnology students were looking for the answer, rather than for the experience"*.

They agreed that the automotive students appeared to be motivated by curiosity and ready to accept the challenges that real-world situations caused. All students remained on-task and kept returning to the workshop sessions. One of the supervisors emphasised that it was vital that all students should feel engaged with their particular topic and for this reason that it was important that topic choice be provided to enable this to occur.

Both supervisors noted that one of the automotive students had driven the project, had led the communication with the others and had developed a deep appreciation of both the sustainable and technical aspects of his work. Although this had been one of the reasons why the project had been successful, it also meant that some of the other team members were put into the position of 'followers' and therefore had less of an opportunity to initiate their own research.

In relation to assessment, the electrotechnology supervisor explained that his colleagues used a cross-moderation process where all grades were jointly considered. At that meeting the faculty had been impressed by the fact that the students were continuing to work on their project even after the reports had been handed in. Collaborative practical work, clearly of great significance in the Industry Project, was positively recognised during the assessment process but was not explicit in the marking schedule.

Supervisors confirmed that the students were aware that their projects were underpinned by Sustainability concepts and had focussed on aspects which related to their industries within their own countries. For example, although there are no Tuk-Tuks operating in Saudi Arabia, the students had seen opportunities for small electric vehicles of this type to be of great potential value during religious celebrations when many thousands of people required flexible pollutionfree transportation. One supervisor recommended that supervisors should always have a Plan B, such as the development of a small bench-top proof of concept. This could not only be a fallback strategy but at an earlier stage could help to conceptualise the sub-sections of the major project and provide confidence to the learners.

Secondly, when the two automotive students were interviewed, they emphasised the significance they gained by tangibly 'doing' the project. They stressed the value they discovered in team work and the benefits of working with a cross cultural group, "*Knowing how everyone behaves and how different cultures work. Because the marketplace today is not like the traditional workplace where you have your own people there only."* They explained that they had learnt how to enhance their communication skills to deal with industry suppliers, colleagues and supervisors. They had also developed an awareness of time management skills, coming to recognise that each person in a team works differently and for this to be successful, patience is often required. However, above everything else they kept returning to the depth of understanding they gained though their practical studies, "*you talk about electric cars – it's just a word but when you actually do it, you see how simplistic it is … and how much you could do with it*."

They agreed that they had developed a different perception of the importance of sustainability and how and why they should struggle to achieve this in their day-to-day lives, especially where this is not happening in their home countries. One saw hope for Tanzania with the growing awareness of youth and he believed that the new generation of educated people would start to put sustainability concepts '*into the system'*. The other considered that the fields of energy and transport would be the ones to benefit most from sustainability innovation in Fiji. He explained that the government of Fiji supported this step and had already reduced import tax on electric vehicles from 15% to 0%. They recommended that all students taking the Bachelor of Applied Technology should have the opportunity to focus more on practical projects rather than producing reports with a mainly theoretical basis. They suggested the use of some form of 3-D modelling to develop scaled down prototypes relevant to their disciplines.

Thirdly, the three electrotechnology students focussed largely on the technical side of their project and the difficulties they experienced. They spoke about being advised at the start to read widely but that would be too confusing as it "*brings to our minds too many ideas*." They commented on the delays they experienced and said that if they had realised the extent of the problems, they would have requested a different topic. "*The main focus for us as students is to gain marks*." However, they agreed that even the difficulties enabled them to gain experiences that would help them in their professions – namely time management and ordering equipment "*This is what huge companies and even countries face – delays and payment problems can be big issues*."

They spoke enthusiastically of the collaborative nature of the project, the value they found in working together as a group and with the automotive students. "*On your own it would take more time and be more difficult*." "*Within our own group some individuals may know more or be motivators – 'don't worry, I've got the solution*." They also said that some aspects of supervision had greatly helped them. For example, making the measurements they needed so that they could order the correct conversion kits.

In regard to the concept of sustainability they said that they had started from a position of unfamiliarity, first meeting the concept in their earlier course, 'Sustainable Technologies'.

In our own country, the focus we have is oil and as Saudis we want to change that. We can make solar panels and electric vehicles which can benefit the country and decrease pollution because an electric car makes a friendly environment.

They considered that there were many opportunities for alternative energy in Saudi Arabia, due to that country's high levels of sunshine and explained they were hoping to pursue these prospects once employed in industry.

Their biggest concern concerned the role they saw their supervisor had played. Although they acknowledged he had forced them to think deeply and explain all their decisions they felt he had largely ignored them. They were distressed he had not held regular weekly meetings and had delayed responding to their emails when they sought either answers to their problems or feedback to their work. They concluded by wishing they had been able to have more input into their choice of project and that the assessment scheme could have more accurately acknowledged the effort they had put in.

4.2 Workshop observations

The following observations of learning experiences were made by an automotive lecturer who was initially supposed to supervise the automotive students only in mechanical aspects of the conversion process. After the electrotechnology students expressed their wish to participate in the mechanical part of the conversion, two groups were set to work as a team. The team building meetings failed at the beginning as the automotive students became very sceptical about the knowledge and capabilities of electrotechnology students, one of them even expressing serious doubts about productivity and prospects of such team work. It put the already distressed electrotechnology students in a defensive mood, diminishing the required collaboration.

Initially, the supervisor tried to address this additional challenge in a formal way by reminding that they all (including the supervisor himself) were largely learners in this conversion process. Later, another more efficient approach was found - the supervisor would allocate additional time to initiate and to maintain an informal conversation within the team on seemingly irrelevant but engaging topics: national cuisines and sports, students' hobbies and their home countries lifestyles, traditions, cultural practices, etc. Such conversations (prior to the workshops and during lunch and tea breaks) significantly reduced the initial psychological barrier between two groups. The automotive students even began to provide peer supervision in the mechanical part of the conversion for their less experienced electrotechnology colleagues. Later, when interviewed, the automotive students recognised the challenge and the value of working in a cross-cultural team, admitting also that it helped to enhance their communication skills and to practice their patience.

The electrotechnology students appeared to be diligent, earnest and reliable learners, but reluctant to show their knowledge and to demonstrate capabilities. They were curious and fairly engaged in the practical process, but rather cautious in challenging the status quo of technology - the necessary step in this conversion process. They showed their ability to be reasonably independent learners but it required some additional guidance from the supervisor and efforts in terms of workshop planning and structuring. With these supports the electrotechnology students, for example, were quite successful in evaluating fuel consumption, tailpipe exhaust and noise emissions of the unmodified Tuk-Tuk and were able not only to explore and to reconstruct the problem but also to reflect on their learning experiences.

The automotive students were eager to learn from the conversion process and were highly motivated by prospects to see and to test the final product of such conversion. They came into the project with a good level of theoretical knowledge and considerable practical experience in repairing cars and trucks, also having some initial perception of 'simplicity' for the conversion process. This attitude changed very quickly, as from the very beginning it became obvious that the conversion process, by comparison with vehicle servicing/repair, was not a standardised process defined by the manufacturer in a workshop manual. For example, the ordered conversion kit (the rear axle with an electric motor) did not have the right dimensions, so the students with the supervisor had to manufacture additional components and to revise the installation principles.

It was even more challenging, since all money from the research grant was spent for purchasing/shipping the Tuk-Tuk and the conversion kit. This shortage of funding had also a surprisingly positive effect on learning experiences – instead of ordering expensive components from third party suppliers, they were made in-house by the research team. Many of those components received an elegant, simple yet effective design and were made from scrap metal, thus giving another dimension of sustainability for this project.

The automotive students, as independent learners, responded to those challenges by demonstrating high level of non-standard and creative thinking, problem solving and interpersonal skills. As a result, the first stage of the Tuk-Tuk conversion process (without the installation of the solar recharging system) was completed successfully.

4.3 Results and Reports

All five students produced individual reports and after assessment and moderation all five passed, both automotive students gaining A+ while the electrotechnology students each received B+.

The automotive reports were wide-ranging, examining a number of aspects of sustainable transport in their home countries and provided extensive literature on the nature of problems and their possible solutions. The practical investigation of the Tuk-Tuk, such as its production of environmental pollutants, high noise

emission and ineffective levels of fuel consumption only occupied approximately a quarter of the completed reports. The conversion of the fossil-fuelled Tuk-Tuk to a vehicle with an electric motor served primarily as a practical example of energy conservation. The value of encouraging solar power to be used as a mechanism to charge these vehicles was considered from the standpoint of how it could improve the lives of rural populations.

On the other hand, the electrotechnology students concentrated on the data achieved from the Tuk-Tuk investigation and provided detailed descriptions of the technology involved in such a conversion. Although brief mention was made of electric vehicles in relation to sustainability, this was not examined in any depth.

5 Discussion and Recommendations

For all students, regardless of nationality, the Industry Project successfully encouraged the PBL values of student centeredness, multi-disciplinary focus, self-regulation and collaboration highlighted by Nelson (2010). This empowered them to tackle complex problems with a sustainability theme and potentially provided a transformative learning experience.

All students worked enthusiastically to solve complex cross-disciplinary issues and attempted to consider them in the light of sustainability, to a greater or lesser extent. Where this aspect was weak, further guidance from supervisors could have been a remediating factor. This leads to the question of the extent of assistance that might be needed, when the demands of supporting inexperienced international students might conflict with the need to let them develop their own solutions. This issue has been discussed by Kim and Hannafin (2011) within the concept of scaffolding and appears to be particularly appropriate when responding to the needs of international learners. These authors demonstrate that it is totally legitimate to provide additional guidance at any stage of the project that may be posing difficulties. Often this will be in the opening stage when project identification and engagement is occurring and also towards the conclusion when the projects are being presented, an especially difficult time for non-English speakers. Additional scaffolding during the identification and explorations stages would allow students to refocus on their sustainability goals, especially about the potential impact of their projects in their home countries.

Although it would be unsafe to generalise from such a small case study, some issues relating to international students and PBL did emerge, which appeared to be corroborated by lecturers' experiences beyond this investigation. These confirmed the expectation that international students are likely to start PBL without prior experience of many of the fundamental principles of independent learning and the 'what if?' mode of creative thinking. This relates to Burn's (2011) concepts of encouraging critical questioning.

A number of enhancements to this course have emerged during this case study which might help to improve its outcomes can be summarised as follows:

- Support diverse needs of international learners by selective scaffolding (Kim and Hannafin, 2011).
- Provide active guidance in the early stages (Fraser, 2015).
- Clarify the assessment process so that learners are motivated to develop wide cognitive competency (Savin-Baden, 2003).
- Encourage the development of a 'back-up' plan to increase confidence and to ensure that lack of resources does not inhibit project success.

6 Conclusion

It is hard to conceive of any PBL model that could support the needs of every learner, considering the distinctions that are introduced through the diversity of international students and supervisors' different methods of stimulating learner independence. As Savin-Baden points out, "students' own agenda and their reasons for 'being learners' at a particular point in their lives, can affect to a large extent their expectation of, and response to, the kinds of learning on offer." (2000: 145)

Nevertheless, our observation from this case study show that facilitators do need to recognise that these differences exist and scaffold their support within these parameters.

In order to further this Best Practice study, observations could be extended with a larger number of students and information could be sought about the impact such PBL experiences have upon their subsequent professional lives in regard to both the scaffolding they might require to encourage their learning autonomy as well as a deeper awareness of sustainability?

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Introduction of Problem-Based Learning Utilizing Regional Characteristics

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Abstract

Gifu Prefecture, where our college is located, has a wealth of nature such as mountains and rivers, and recently has some high-tech industries including information technology, aerospace, automobiles and robots. It also has environmental and regional characteristics, combining the different features of traditional cultures and the latest technology industries. This paper describes the following challenges of PBL including fieldwork by some faculty members of our college in collaboration with the community: (1) Architecture education working closely with local community renovation activities, and taking advantage of traditional culture based on the general features of this prefecture, (2) A challenge to propose students' solutions to the problems of local communities, reassessing and taking advantage of architecture resources of a local community, (3) A challenge among Japanese and foreign students with different academic disciplines with an aim to seek new research challenges.

Keywords: Problem-Based Learning, regional characteristics, fieldwork, different academic, disciplines

Type of contribution: Research paper

1 Introduction

In Japan, National Institute of Technology (NIT) colleges (KOSEN; National Institute of Technology, 2009) are unique higher education institutions, where junior high school graduates start to learn specialized engineering subjects in the first year and can obtain a bachelor's degree after completing the two-year advanced courses followed by the five-year departments. Both the departments and the advanced courses have curriculum characterized by actual experience-based education through problem-based learning (PBL) and active learning (Ogawa, 2016).

NIT, Gifu College is located in Gifu Prefecture (Gifu Prefectural Government, 2017), in the center of Japan. The prefecture is famous for the historic Villages of Shirakawa-go (Shirakawa-go, 2014). The district is registered in the UNESCO World Heritage sites. On the other hand, industries such as information technology, aerospace and automobile robots are flourishing there.

This paper describes the following three challenges as fieldwork PBL closely related to such a unique region:

(1) Architecture education working closely with local community renovation activities, (2) A challenge to propose students' solutions to the problems of local communities, (3) A challenge among Japanese and foreign students with different academic disciplines with an aim to seek new research challenges.

Specifically, (1) Since 2002, research laboratory students, along with local residents, have been engaged in an effort to put empty houses to practical use in conjunction with community renovation in downtown locations of Hachimancho (Hachimancho, 2017), Gujo City (Imada, 2015). The PBL activity can be divided

into two terms: In the first term various kinds of events were prepared in downtown locations, and in the second term the strategies to put empty houses to practical use were developed. (2) As a PBL challenge, taking up an abolished school located in Neo district, Motosu City (Motosu City, 2010) , which local residents as well as the local government are facing difficulty in dealing with, some students at the Department of Architecture of our college made a concrete, attractive proposal to take full advantage of the building. After conducting field investigations, they wrapped up their revival plan (draft), and made technical architecture drawings. (3) As a PBL trial practice of an effort regarding a scientific exchange among students with different academic disciplines, three master's students of a German university and five final-year students of our college sought research challenges which include something remarkable of each other's studies, hoping that the challenges will become new innovative seeds.

2 Architecture education working closely with local community renovation activities

Focusing on the increasing number of empty houses in downtown locations of Hachimancho, Gujo City, Gifu Prefecture, some students in the laboratory and local residents have been making a PBL challenge toward their utilization.

A) Phase1：PBL with the community renewal council

The PBL challenge to utilize empty houses start with participation in the “Hachiman Project” launched by the community renewal council of Hachimancho in 2002.

B) Phase 2：PBL for preparing various kinds of events

Houses of common people in town are referred to as “machiya”. Our involvement in utilizing empty machiya in Hachimancho, Gujo City as a PBL challenge restarted in 2009, when an employee of Gujo municipal government, one of the leading members of the community renewal council, asked us to work with the organization at the stage of Phase 1. We made a shining chair “Akariza” and used it as lighting and as a chair in a club with live music. (Figure 1).

Figure 1: Space with live music built in the PBL challenge where shining chairs “Akariza” are placed.

Also, the PBL challenge encouraged local voluntary residents to perform kabuki (Kabuki, 2017), a type of traditional performance art, in collaboration with students' performance with live music. (Figure 2) The kabuki performance by local residents has continued until now as an annual event.

Figure 2: Kabuki performed by local voluntary residents.

C) Phase3 : PBL to start actual utilization of empty houses

In April, 2015, Gujo municipal government started the "machiya utilization project", and it set the movement of the PBL challenge for utilizing empty machiya in Hachimancho off the ground on a full scale. In 2015, our research laboratory realized the use of machiya as a library called "MachiyaBibrioteca". (Figure 3) Also, the students are engaged in the PBL challenge to make a renovation plan and put it into action. (Figure 4).

Figure 3: Space built in the PBL challenge utilizing a machiya as a library.

Figure 4: Renovation in the PBL challenge.

By being involved in the community renewal on an ongoing basis, the students' skills and their fresh ideas will promote this renewal, which can be a key element for local residents to proceed with community planning. The students' ongoing engagement with a regional community will make them feel that they are needed there and that they can play a role in transforming it, which can surely be a starting point of their relationship with the real world.

3 An effort to propose students' solutions to the problems of local communities

In the mountainous region in the north of Motosu City, Gifu Prefecture was the former Neo village, which is known for being the seismic center of the 8.0 Nobi Earthquake in 1891, where the population has been increasingly on the decline in recent years (Shimizu, 2015). In May, 2011, some teachers at the Department of Architecture had an opportunity to exchange information with some employees of Motosu municipal government. On that occasion, the teachers obtained much real-time local information, such as the charm of life surrounded by nature in Neo district, Motosu City and uses of a closed elementary school made of wood. Therefore, targeting the closed school, some students of NIT, Gifu College set a PBL challenge to make a practical and attractive proposal with the view to use the architecture. In order to consider a real-time PBL problem more realistically, they planned the following practical activities.

A) Direction of solutions and proposals by the PBL challenge

With a vision that an idea leading to a problem resolution will be created by combining architectural domain knowledge which our college has (teachers) and young, flexible power of ideas (students) with execution which residents and public administration have, students, first of all, suggested their idea in the PBL challenge.

B) Outline of the PBL challenge

Table 1: Activity plan of the PBL challenge.

Schedule	Content of implementation
June, 2011	Explanation of problems, fieldwork (Neo district, Motosu City)
	Considering problems 1 (functions to be combined: what are needed for the region)
July, 2011	Considering problems 2 (a renewal plan of a closed schoolhouse)
	Considering problems 3 (what are needed and what are not needed: what to make)
August, 2011	Considering problems 4 (consideration using a study model)
September, 2011	Engaging problems
October, 2011	Submitting work
November, 2011	Presentation
December, 2011	Distributing printed copies

Table 1 shows the PBL activity plan. In June, 2011, we considered problems and inspected the closed elementary school made of wood. (Figures 5, 6) On September 27, 2011, we held a "Design Idea Competition". (Figure 7)

Unlike the competitions they had participated in before, the students had a chance to hear, in their own words, what ordinary citizens thought of their work and proposals, giving a fresh impetus to the students for further development. It is most important to listen to what both a client and a user want and try hard to meet them in the process of designing an architectural structure and executing construction work. Through the PBL challenge the students, who will become architects or work controllers in future, shared a really meaningful experience. Also, the adoption of a competition style was effective in strengthening the students' motivation to address the challenge.

Figure 5: The targeted abolished school (left) and the school made of wood (right).

Figure 6: A nearby shrine with big trees (left) and a field survey conducted by the students (right).

Figure 7: Exhibiting proposed work in Neo district (left) and a presentation (right).

C) Vision

The PBL challenge brought 39 kinds of attractive proposals created by young students. (Figure 8) However, they are not working plans, but only ideas (futuristic views). In order to promote effective utilization of regional architectural resources on a full scale, the residents themselves are expected to consider, for example, what is needed to activate local community and how to use a closed schoolhouse, and think over such matters with autonomous bodies, government and experts. We will be happy if our PBL challenge triggers the flow.

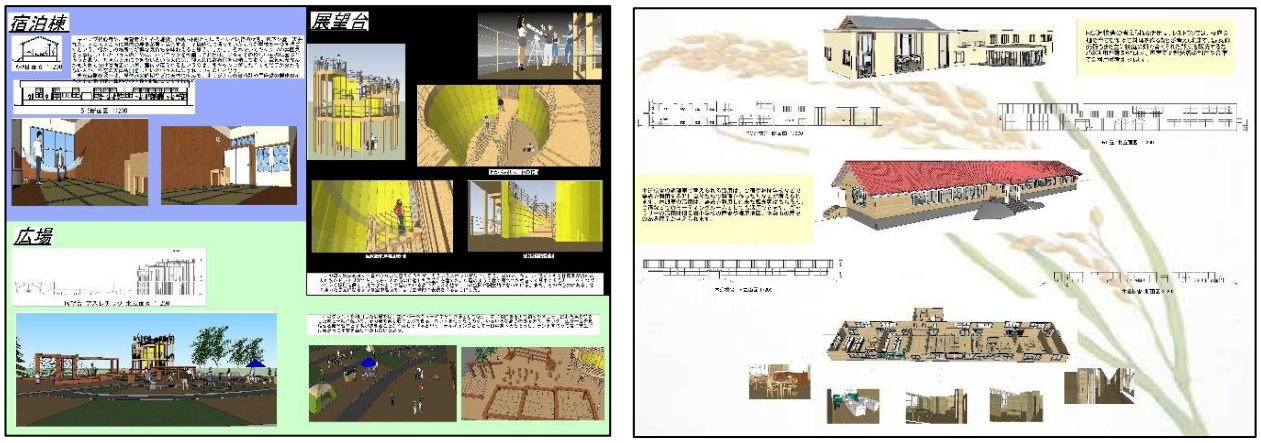

Figure 8: Examples of renovation proposed by the students (left and right).

4 A PBL challenge among Japanese and foreign students with different academic disciplines with an aim to seek new research challenges

In recent years, with the globalization of industry, Japanese higher education institutions of science and technology are placing more emphasis on developing students' technical English skills than before. On the other hand, the number of students who learn Chinese as a second language is increasing in the institutions. Also, National Institute of Technology (NIT), Japan and our college have active exchanges with colleges and universities in Germany, Malaysia, Thailand and other countries at various levels. In consideration of these facts, we are collecting and analyzing study-related communicating data performed by concerned persons in technical situations such as experiments in laboratories.

With regard to positive effects of exchanges among people who have different specialized academic disciplines (Abbott, A., 2001, Ausburg, T. 2006, Barry, A., Born et al., 2008, Hall, E.F. & Sanders, T., 2015, Jacobs, J.A. & Frickel, S., 2009, Oleson, A. & Voss, J., 1979), it is known that associating with people of different backgrounds will often produce the creation of value and innovative thinking. For example, we understand that there are some cases where a thing which is recognized as a "huge barrier" seen in one perspective would be a "trivial affair" seen in another perspective. This way of thinking is true of students' research work as well. Based on study-related communicating among research students of different specialized academic disciplines, we are conducting a research on the process of how fresh ideas are produced there. The following sections describe the details of a scientific exchange between German and Japanese students.

4.1 Communicating between German and Japanese Students on the Research Outline

Self-introduction among the Students with Different Specialized Academic Disciplines

First, German and Japanese students introduced themselves. Three German students, whose age ranges 23 to 25, are studying in the master's course of Gottfried Wilhelm Leibniz Universität Hannover (Gottfried Wilhelm Leibniz Universität Hannover, 1998). All of them are researching the meteorological environment. On the other hand, five Japanese students, whose age ranges 19 to 21, are studying at a department of NIT, Gifu College (KOSEN, National Institute of Technology. 2009). Four of them are engaged in graduation research on architectural acoustics, and one of them, on educational technology.

Introduction of the Research Outline by German Students

Student A: (Research Theme) Flight simulations in near-surface turbulent wind fields as generated by LES

(Content) Flight simulators should have the ability to prepare pilots for the air traffic and the flight characteristics as realistic as possible. Thereby, one of the most important parameters which have to be taken into account is the wind field with its turbulent fluctuations. Currently, the wind field itself is considered by specifying the average wind speeds and directions in different heights. In addition, the turbulence is described using statistical models. Pilots, however, confirm that particularly the near-ground turbulence caused by the surrounding orography, vegetation or building is not reproduced realistically. One possibility for improving this state is the usage of more realistic wind conditions, which also consider the characteristics of individual airports. Thus, turbulent wind fields shall be generated by using the LES model PALM in order to feed them into the Open Source flight simulator FlightGear. The objective of this method is to examine the impact on the flight behavior of a landing passenger plane over those using the previously in FlightGear implemented approach of a Dryden turbulence spectrum.

Student B: (Research Theme) The implementation of pure vertical nesting into the LES model PALM

(Content) The simulation of phenomena like dust devils and nocturnal radiation fog need a high resolution inside the model domain, especially near the ground and in the vertical direction. This demand leads to high computational and therefore financial costs. In the current version of PALM it is only possible to stretch the model domain in a certain height, causing a non-uniform grid spacing, or to use the horizontal nesting technique which does not allow cyclic boundary conditions. To overcome this problems the so called pure vertical nesting shall be implemented to expand the existing of nesting method. Using this, it is possible to define multiple surface-bound domains with the same horizontal extent as the initial model domain, having limited heights and finer resolutions, working as parallel instances of the model. Hence this is leading to a better resolution of the turbulence in the relevant areas, resulting in a better representation of the specific phenomena. After the implementation the method shall be tested for different numbers of domains, resolution ratios and load balancing. Ultimately it is intended to use the pure vertical nesting for the simulation of dust devils and compare the results, the representation and computational cost with that in non-nested cases.

Student C: (Research Theme) The investigation of roll convection above artic leads with LES

(Content) In polar sea-ice regions channels either open or with thin ice cover arise from divergent flows in the atmosphere or in the water. These so called leads have a great impact on the polar climate since much heat is transported from the sea to the atmospheric boundary layer through the leads, especially during winter. In presence of a background wind often sea smoke is observed above the lead, which arranges band like in the direction of the wind. This suggests a roll-like flow above the lead. The cause of these flow structures and their impact on the exchange of heat, moisture and momentum between ocean and atmosphere was neither investigated numerically nor experimentally up to now. A numerical investigation shall be carried out within the context of this master thesis with the LES Model PALM.

Introduction of the Research Outline by Japanese Students

Student D: (Research Theme) Study on the analysis of the sound environment in a place with live music

Study on the changes in the acoustic properties based on the difference in the shape of a room and an acoustic insulating material -

(Content) The noise problem in the modern residential environment has been emphasized, and the sound leaking to the outside of buildings must be minimized. However, most of the places with live music are actually leaking noise out of the facilities, though sufficient soundproofing measures seem to have been taken. Then, what measure should be taken for developing an ideal soundproof environment? There seems to be room for improvement in soundproofing technique. First, we will compare the differences of acoustic properties of each place with live music of different shapes by running a simulation and conducting an experiment, and examine the change of the sound by such as the type of room shape and soundproofing materials using an acoustic analysis.

Student E: (Research Theme) Wave simulation of classroom space by building acoustics - Analysis based on the difference of the pulse response waveform in the influence of the pillars

(Content) We intend to verify the correctness of the program by comparing the exact solution with the program simulation and do the research of the sound environment of a classroom space.

By the technique of architectural acoustic analysis, the positions and number of pillars, size and shape are changed, the experimental results are compared with the wave simulation, a wave simulation by the pulse

response is conducted, and the effect of the pillars of a classroom space is studied.

Student F: (Research Theme) Study on the changes in the acoustic properties of various open-type spaces

(Content) This study covers space successively spreading from classrooms and open spaces where no building is standing, and we intend to analyze a sound environment in such various open-type spaces. Furthermore, we will analyze the changes in the acoustic properties through simulations and experiments and consider a comfortable sound environment.

Student G: (Research Theme) Study on the changes in the acoustic characteristics based on the differences of the shape of a room and material of childcare facilities

(Content) We intend to run a simulation, conduct an experiment and make an analysis on acoustic characteristics in a childcare facility where young children with different lifestyles of the same age live. Based on the results, we will consider the shape of a room and materials suitable for a childcare facility.

Student H: (Research Theme & Content) Research on educational materials and a learning environment to learn the knowledge of physical phenomena that can be helpful in the field of architecture, and the development of flexible educational materials and a flexible learning environment using ICT. In other words, to learn mechanics (the basis of some fields such as structural mechanics and material mechanics) not only in class but also outside the classroom/at home for preparing for or reviewing the classwork; and to learn aurally and visually using speech synthesis.

4.1 Exchange among the Students with Different Specialized Academic Disciplines

In this trial practice, although the introduction of the research outline did not develop into a discussion on an integrated new theme, some students remarked that it gave a stimulus for a new perspective. Some exchanges with different academic disciplines will create new value in the very short term, others will not. The exchange meeting offered something useful at the spot; some students acquired some specific research methods such as a simulation algorithm. Although no one has reported that he or she had had a flash of inspiration to elevate his or her research, several future reviews of the discussion made at the meeting would bring innovative ideas. With regard to this exchange meeting, lack of basic knowledge on the research of the other college or university students prevented them from flashing an idea into his or her mind sooner.

After the presentations by Japanese students E, F and H, German student A made a comment as follows: Some of the students compare results of acoustic models with real measurement data. Furthermore, they evaluate the impact of acoustics on certain kinds of land usage and materials with different properties. Finally, one student investigates the insulation of sonic waves. Unfortunately, it was not that easy to follow the student's presentations because of their mediocre English pronunciation.

As pointed out here, the pronunciation of three Japanese students was not so good, partly because of a strong Japanese accent. Due largely to insufficient pronunciation training, German students had difficulty in listening to the presentations made by Japanese students E, F and H. It is a future problem to cope with a meeting which non-native English speakers participate in and use a lot of technical terms with accented English.

After the presentations by German students A, B, and C, Japanese student E, F and G made a comment as follows: The same simulation algorithm is used in different ways. We want to consider the possibility of

applying a similar method to our research. Besides, Japanese students F and H made a comment that they could not catch or make out technical terms. This may be because the two Japanese students are not so good at English. However, it is an issue for the future to create a support system for such cases.

5 Conclusion

We consider it important for students to acquire the ability to assess community problems to solve and work on new community planning with a subjective, autonomous perspective, in order for them to find out their role in a community after graduation and revitalize an exhausted Japanese society. On the basis of these ideas, we are promoting PBL challenges in local communities. Educational output of the activities includes the increasing number of students who have interest in regional communities as well as the emergence of students who have consciousness of their community in choosing a college to attend or getting a job. Also, as shown in this paper, some PBL type challenges of active learning in local communities contribute to community planning in a direct or indirect way.

Toward fostering highly skilled personnel, more and more people suggest that practical education which may conduce to affairs in industry should be started at the higher education stage. Recently, under such circumstances, higher education institutions, such as universities and colleges, are actively implementing practical education through industry-academia collaboration, and PBL is considered to be an effective educational means of realizing practical education. The implementation of PBL is now indispensable for practical education in the field of engineering. In this context, the significance of PBL challenges with fieldwork is mounting. Moreover, with the prospect that the globalization of industry promotes interaction with foreigners as well as exchange among different fields, it is important to introduce educational methods with such viewpoints for future education.

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Environmental Engineering learning process from real situations: The case of "Mariana Disaster" in Brazil

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Abstract

On November 5th, 2015 Fundão tailing-dam, in Mariana, Minas Gerais, Brazil, burst and about 50 million cubic meters of iron ore waste caused flash flood through several towns along Gualaxo do Norte river, reaching the Doce River and finally the ocean 17 days later. This is considered Brazilian's biggest environmental disaster. The impacts include the contamination of Doce River watershed, which covers 230 municipalities that use its bed for subsistence, water collection for public, agricultural and industrial uses. It also contaminated southern Atlantic Ocean, once the mud spread across the Espírito Santo coast, affecting sea life. It will take a long time to recover the Doce River watershed and restore its biodiversity. Environmental Engineers have an important role to play in this disaster, trying to recover the affected areas and managing similar situations to avoid future disasters. They have the challenge of making environmental preservation compatible with economic development. During the course of the discipline Limnology, the students were encouraged to study the disaster and how it is still influencing the environment and the society. A field class took the students to whereabouts of the disaster to make water analysis, and the students had the chance to experience the reality of the affected communities, inclusive by reports of residents. After the field class, the students prepared a personal report with their perspective on how the disaster affected their lives and their academic skills, evidencing the problem and how the Environmental Engineer can act in situations like this. One report follows: "The reality goes beyond the images shown on TV. The disaster was huge and most because human error. We must have in mind that our actions matter and influence the lives of many people. As professional, we should learn from the mistakes made to do not repeat in the future".

***Keywords*:** Bento Rodrigues dam disaster, environmental problems, student's learning process

Type of contribution: Best practice paper.

1 Introduction

The Industrial Revolution boosted the economic development and the generation of new industries, which has led to an increase in the demand for mineral resources to manufacture products and technologies to meet the need for human consumption.

Since then, mining has become an important branch for the economic and technological development of several countries and fundamental for the dynamization of the Brazilian economy. According to data presented by CNI - National Confederation of Industry (2012), mining participates with 3% to 4% of Gross National Product – GNP and 20% of total exports, generating 175,000 direct jobs in mining and 2.2 million in the manufacturing mineral industry.

Despite of the economic benefits, the mining generates many impacts, being able to cite the fauna and flora loss, with the removal of the covering material on mining site; air pollution, with emission of particles resulting from the mining activity; water streams pollution, from discharge of sediments and water table contamination (CPRM – Mineral Resources Research Company, 2002). In order to contain water bodies' pollution, sediments are stored in tailings dams. Dams are structural barriers built mainly for water management (irrigation, hydroelectric power and/or flood control, for example) or the storage of industrial and mineral processing waste. Tailings dams are a type of dam built to store mill and waste tailings from mining activities. Mining tailings are classified according to Brazilian standards (ABNT NBR 10.004/2004), as solids, non-hazardous and non-inert. Their composition is basically, formed by sand and metals, such as iron and manganese (BRAZIL, 2015).

In November 5th, 2015, Fundão dam, one of the tailing dams from Samarco Mining Corporation burst and several millions cubic meters of tailings has been spread into Gualaxo do Norte River, a tributary of the Doce River watershed, one of the most important rivers in southeast Brazil. Nineteen fatalities occurred as consequence of the burst, most of them employees from Samarco (15) or Bento Rodrigues inhabitants (4), a district of Mariana municipality, that was located only about 5 kilometers downstream the dam, totally flooded and destroyed in this event.

Tailings dam failures are result of several causal mechanisms (flooding, piping, overtopping, liquefaction or a combination of more than one), spilling out polluted water and tailings with a variety of textural and physical-chemical properties, which may affect downstream ecosystems and socio-economic activities (Rico, Benito and Díez-Herrero, 2008). According to Agência Minas (2016), in the actual case, the cause of the failure was liquefaction. The amount of tailings released is unsure, from 34 million cubic meters (Agência Minas, 2016) to 50 million cubic meters (Ministry of Environment, 2016). The affected rivers are, from upstream to downstream, Gualaxo do Norte, Carmo and Doce.

The entire Gualaxo do Norte River was severely affected up to his mouth at Carmo River. On its shores are located several districts that were destroyed, totally or partially: Bento Rodrigues and Paracatu de Baixo (Mariana municipality) and Gesteira (Barra Longa municipality). Bento Rodrigues was the most affected, mainly due it was close the dam. Paracatu de Baixo, which has been visited by students in this field class, was flooded about three hours after the burst, time sufficient to allow all the population to be rescued by authorities.

2 Objectives

The aim of this case study field class was to present the real situation and impacts caused by the Fundão dam burst to the Environmental Engineering students, providing them substantial facts and information to:

- Evaluate the impacts over the water streams as part of Limnology course in Environmental Engineering curriculum;
- Evaluate the environmental, social and economic impacts caused by the dam burst on Gualaxo do Norte river, Carmo River and Doce river (the latter up to the municipality of Rio Doce, State of Minas Gerais);
- Evaluate the impact of the dam burst on the municipalities of Mariana, Barra Longa, Rio Doce and Santa Cruz do Escalvado, on high Doce River Watershed;
- Understand that the damages are not limited to the place it happened, but to all the Doce River watershed;

- Understand the role of Environmental Engineer as an agent of change, and the inseparability between environmental and social damage;
- Talk to the residents in some of the affected places, recording their reports in order to obtain a social view of the tragedy;
- Present a real case study as a tool to improve learning for Environmental Engineering students.

3 Theoretical basis and methods

The visited areas are located in the municipalities of Mariana, Barra Longa, Acaiaca, Ponte Nova and Rio Doce, all in Minas Gerais state, in the high Doce River watershed, that includes rivers Gualaxo do Norte (most affected), Gualaxo do Sul and Piranga (not affected), Carmo and Doce (affected after reaching the tributary Gualaxo do Norte). Due to lack of technical and financial support, it was not possible to visit the entire Doce River watershed, the ideal situation. Figure 1 presents the Doce River watershed location in Brazil and the location of the dam burst.

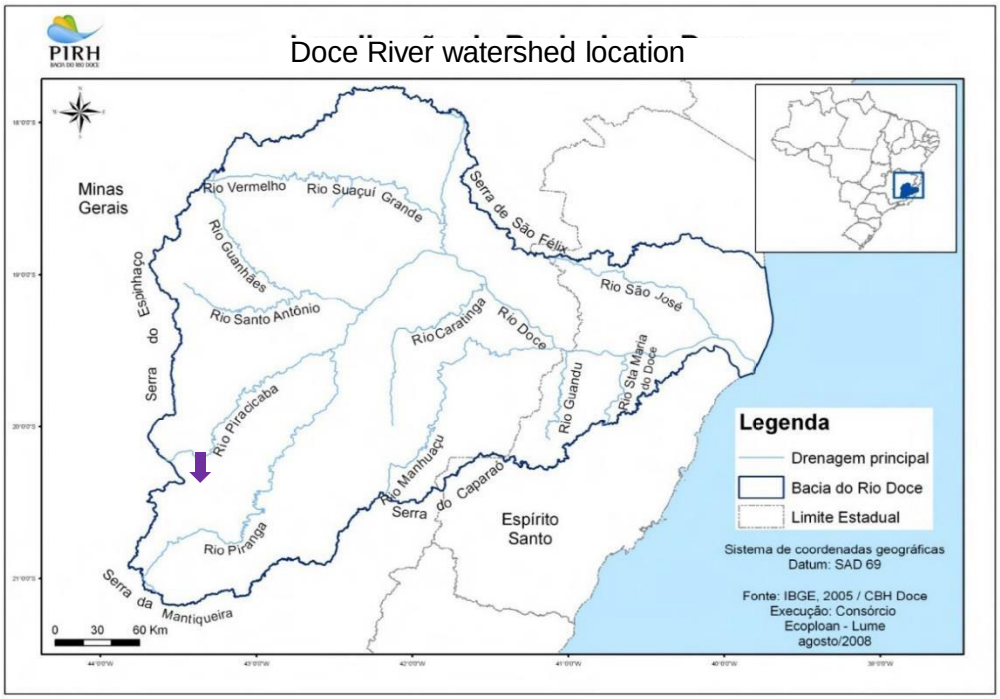

Figure 1. Doce River watershed. Purple arrow indicates the location of Fundão tailing dam. Light blue lines represent Doce River and its main tributaries. Dark blue line represents watershed borders. Source: PIRH DOCE, 2010.

Students were initially asked to see the environmental impacts of the dam burst. As a Limnology course as part of Environmental Engineering curriculum, the main objective of the class was the impacts over the water streams. Therefore, water samples were collected in several points, in affected and not affected areas, to compare the effects over the water streams even one year after the event. Ten points of interest have been chosen and are described in Table 1.

Table 1 - Places visited during the case-study field class.

Location	***Impacted (Yes or No)***	***Objectives***
Samarco facilities (outside)	-	To see the point where the burst occurred.
Carmo River	*NO*	Water quality analysis and visual aspect of the
Gualaxo do Sul River	*NO*	Water quality analysis and visual aspect of the sediments
Piranga River	*NO*	Water quality analysis and visual aspect of the
Gualaxo do Norte River	*YES*	Water quality analysis and visual aspect of the sediments
Carmo River (after reaching Gualaxo do Norte River)	*YES*	Water quality analysis and visual aspect of the sediments
Doce River	*YES*	Water quality analysis and visual aspect of the

The main idea is to allow the learning process by a real situation, which provides an opportunity to students to see and feel, talking to people who were affected, to walk near the wreckage of houses, where the students could use their senses to feel and live the problem. The environmental impacts were also considered, in this case mainly those that affected water streams. For the next years a more interdisciplinary approach is planned, including Environmental Impact Assessment tools in the affected area.

Most of case-study examples in literature are based on theoretical aspects, as in class activities, although this case is on field case study, with an opportunity to see the impacts *in loco*. Case-based learning approach engages students in discussion of specific situations, typically real-world examples. This method is learner-centered and involves intense interaction between the participants. Case-based learning may also focus on the building of knowledge as a group works together to examine the case. The instructor's role is that of a facilitator and the students collaboratively address problems from a perspective that requires analysis. Much of case-based learning involves learners striving to resolve questions that have no single right answer (Pucha and Utschig, 2012).

Students were divided into groups of six. They collected water samples in affected and not affected water streams (Table 1) to compare the results. The parameters taken on field were pH, temperature (°C), dissolved oxygen ($mg.L^{-1}$), oxi-reduction potential (mV), obtained with a Hach® Hydrolab® multiparameter sonde and turbidity (NTU) obtained by a Hach® 2100Q turbidimeter. This aimed to relate this part with the theoretical part of the course, when the goal is to know how to perform and interpret water analysis reports.

As an outcome from the visit, each group had to develop a product as described in Table 2 to be exposed at the university campus during the week from 7 to 11th November, 2016, to remember one year of the disaster. Each group was sorted by place visited, although all the students had experienced all the field aims. The evaluation here was based on the whole process, not only on the final product achieved.

Table 2 - Outcomes of each group after the case study field class.

Group	Product
1	A banner to show the impacts on Paracatu de Baixo District
2	A banner to show the impacts on Barra Longa municipality
3	A banner to show the impacts on Risoleta Neves hydroelectric power-plant
4	A banner comparing the water quality into different streams, some impacted and some do not, as described in Table 1.
5	A video of about 3-4 minutes with pictures showing the story of the visit.

4 Results and Discussion

4.1 Learning outcomes

Group 1 observed at Paracatu de Baixo (Figures 2 to 5) district a huge destruction. Wreckages and an abandoned school shocked them. At one wall of the school's library, a sentence claims: "Here there is a dead library. The people do not want alms! People want its memory alive".

Figure 2 – Wreckages at Paracatu de Baixo.

Figure 3 – Paracatu de Baixo school's library destroyed.

Figure 4 – Catholic church under search for sacre pieces.

Figure 5 - Flower tries to survive surrounded by wreckages.

Group 2 observed at Barra Longa municipality (Figures 6 and 7) that after the disaster, local inhabitants have to live with dust and dirt water that flows in Carmo River. Hospitals observed five times increase in respiratory threats and flu. The Carmo river flooded Barra Longa's main square and at least forty houses. Aquatic wildlife death and about 2,000 cattle death was remembered by inhabitants too.

Figure 6 - Main square under reconstruction in Barra Longa.

Figure 7 - Carmo River at Barra Longa. It is possible to see tailings deposits along the river.

Group 3 observed that Risoleta Neves Hidroelectrical power plant (Figures 8 and 9) opened their floodgates on the day of the disaster as part of its emergency plan and it is inoperative since November 6th, 2015, one day after the disaster. It is still in progress a process of tailings removal because a huge amount of tailings is spread all over its dam area. The municipalities where the dam is located are facing a substantial reduction on taxes due the lack of electrical energy generation.

Figure 8 - Risoleta Neves Hidroelectrical power plant. It is possible to see its floodgates open since the day of the burst. Picture took showing the area of the dam that is empty.

Figure 9 - Trees carried by flash flood at the day of the burst are still laying in the rocks at Risoleta Neves hidroelectrical powerplant dam area.

Group 4 observed the water quality at points described in Table 1. Among all the physical and chemical parameters analyzed, turbidity showed higher values in all samples collected on affected areas, indicating that even one year after the disaster suspended solids are still present and being carried on by rivers, impacting the water quality on the analyzed streams (Figures 10 and 11). Turbidity analysis at no affected streams varied from 2.68 to 28.7 NTU, normal values considering the dry season, and at affected streams varied from 67.2 to 137 NTU, values observed mainly in rainy season before the water streams be affected by Fundão dam burst.

Figure 10 – The turbid Gualaxo do Norte river mouth (left) and Carmo River (right).

Figure 11 - Gualaxo do Norte river near Paracatu de Baixo. Water is abnormally turbid, although the dry season at this time of the year (September, 2016).

Group 5 edited a video of about 3 minutes showing the impacts, with pictures taken at the time of them dam burst and others taken at the field class. The video was exposed at the same site of the banners.

4.2 Students point of view

Brazilian schools do not have disasters, even natural or manmade, on their curricula or transdisciplinary activities, as we can see in developed countries like United States of America (Ray and Hocutt, 2016), Australia (Boon and Pagliano, 2004) or Japan (Kitagawa, 2015). Mutch, 2014 reviewed the role of schools in disaster preparedness, response and recovery, reporting the experiences in Japan, United States and New Zealand. Although the papers cited refers to natural disasters, there is almost no worries about tornadoes, hurricanes or earthquakes in Brazil. Floods are very common in the rainy season, that affects mainly low-income families, but the scenario has much little changes in last decades. It is important to have this approach at schools, preparing children and young adults to face a disaster.

Relating these with the burst case, we could see in Paracatu de Baixo district a war scene. In addition, we could see people saying that they hope to come back to their homes or they expect that the company responsible for the tragedy rebuild the village, hoping that their life could be as close as possible to that they have before the disaster. As said before, Brazilian education system does not have the subject "disasters" on its curricula and to get worse, people feel unsupported by local government.

It is important to highlight that the visual impact brought many feelings in the students, such as anger, sadness, indignation, feeling of powerlessness, desire for change, and hope for a better future. Feelings like that shape the profile of Environmental Engineer.

The knowledge that society and environment are affected by actions taken in the professional activity awaken in today's students the need to be more worried and caring professionals. The attitude of the students after the field class has changed. A wish for justice, for answers, for solutions to current problems was noticed.

Now, follows the point-of-view of some students about their perception after the field class:

> *"During the academic training, we study many disciplines that are often connected to offer a better understanding of the whole situation. The theory often does not seem to apply with real situations, sometimes they are very idealized but when a teacher can apply what is being studied in situations in daily life, in professional life or based on recorded events the understanding and the learning are much deeper, awakening the need to find an answer to the problem. The case of Mariana was deeply studied in the discipline of Limnology by the*

impacts on aquatic life, but we are engineers and the disaster goes far beyond the loss of aquatic biodiversity. It involves many disciplines studied during the 5 years of graduation. The assessment of its environmental impacts we need knowledge of ecology, microbiology, geology and pedology, hydrology, citizenship and social responsibility, economic engineering, fluids, soil mechanics, soil management and conservation for then take decisions about solid waste management, environmental management, and the best approach to recover degraded areas.

Going to the scene of the tragedy and witnessing the event completely changes the way we learn and absorb the theoretical teachings. The reality goes beyond the images shown on TV. The disaster was huge and most because human error. We must have in mind that our actions matter and influence the lives of many people. As professional, we should learn from the mistakes made to do not repeat in the future and how we can change the current situation."

N. BASTOS, Monitor of Limnolgy

"Visiting affected areas is a mix of emotions. You feel love for the people who live there, pity for those who used to live theree, anger for those who have done it and gratitude for all your life. Visiting the region made me reflect on life and rethink the priorities and values that I have and that will make me a better person and professional.

The visit to the site showed how the irresponsibility of some could affect so many lives. Through the sadness seen in the absent-minded eyes of the residents, we reflect on our role as an engineer in society. Perhaps if there were constant inspections or even the correct release of the licenses, the disaster would have been avoided and several people would still have their habits and homes preserved and the ecosystem would not have suffered as it did.

In the field of Engineering, it is possible to deepen into the subject in various fields. It begins with studies that should be done correctly, reviewed and audited. Analyzes of environmental impacts should be considered in the design of the project and during its operation. Monitoring of the tailings dam that burst should be done constantly to avoid surprises. Various studies should have been carried out in detail to ensure the safety of the expansion of the dam. The company should have technologies that would alert the population and its employees in case of disasters.

After the disaster, there is still an immense field of activity of the Engineer, which goes from studies, through decontamination and/or remediation of the affected areas, considering the socioeconomic and environmental aspects. Several measures must be taken in designing the project to its final point to ensure its success and avoid possible disasters already studied. Accidents are predictable and only depend on people able to detect them. Now the challenge is to rebuild the degraded areas and their stories!"

G. VIEIRA, student

"The opportunity to visit the sites hit by the tailings mud in Mariana allowed me to have a better understand of what happened. The news, photos and videos broadcast in the media and social networks creates in us a perspective very close to the reality. But when you can see the place with your own eyes, the old trades, church, school and other establishments covered by the mud, some municipalities isolated and uninhabitable, talking with some affected families ... all of this made me realize that the impact involved in this tragedy is not only environmental, but also social and economic, which gave me a multidisciplinary view of the fact.

In addition, in terms of emotional and psychological sensations, this visit allowed me to have a more human point of view on our actions as engineers. The houses, documents, photos, toys, among other personal objects and sacred objects (previously contained in the church), were spread in that already dried mud. It made me think beyond the technical knowledge acquired in the classroom and engineering labs."

T. SANTOS, student

"A whole day watching what 40 billion liters of mud did to countless families. Pain and sadness, tears on their eyes, at their hearts the routine, the school they attended, the church they prayed are missing... At dusk an incredible sunset illuminating the Doce River and a mix of emotions! Some details stood out in the memory, the smiles of the people I met, the inhabitants' simple way of life, even though their lives were changed from one day to the next, their essences are still there!

Would you expect to learn more than that? Just like the dark night that comes after the sunset, the same sun returns with the hope of the dawn. And the opportunity to try again! A dose of hope in this crazy being called man! A prayer for us to be more supportive, to be kinder to each other, to be more human, to put ourselves in the place of the other, to have more respect and empathy, to be more generous, to be Resilient! Moreover, may we never miss FAITH! "

G. LIMA, student

"Toys, photos, furniture, sadness, an endless anguish. There lived families like mine who lost everything, including life, because of a huge irresponsibility.

The tragedy could have been avoided, since the company knew of the possibility of the dam rupture and that the Risk Card of the same one was outdated. A serious problem facing our country is the absence of efficiently inspection, a tragedy that has led to environmental, social and economic problems. How long will we live in a country that cares about money above anything? How long will they have irresponsible professionals capable of neglecting all the issues involved behind their work?

For me, seeing this tragedy closely, only gave me certainty that my responsibility in the profession I chose is huge. Problems like this or even bigger will arise and they will be in my hands, but I expect to act with responsibility and within the ethics, always aiming at the well being of those who will be affected by my actions."

G. MENDES, student.

"A year ago we saw photos, videos, news. We looked at it all and thought it was unbelievable.

Seeing a little alive and in color is even more incredible and shocking!

To think that almost a year later, when the media remained quiet, nothing more is being said, the situation remains the same and this will continue forever, because it has no money to pay for the recovery a history, a culture, a life (for them the memory will not be short and nothing will erase what was destroyed).

It's not just an Environmental disaster! It is a social crime, committed by the company, by the executive, by the government and by the controller.

What else to say? Yes, there are no words just an appeal.

Future engineers, future executives, future governors ... We are not just going to deal with money, we are going to deal with lives, people, stories! We should be more responsible!! Professionals deals with lives!!!"

L. SILVA, student

5 Conclusions and Recommendations

The contextualization of the whole problem as well as the visualization of the affected areas by the Fundão dam burst shaped students perception of how important it is to connect the social, economic and

technical concepts in their future profession, as Environmental Engineers. Furthermore, the importance in preventing events like this and the knowledge to take care degraded areas.

It is evident that activities beyond classroom as well as different ways of approaching content enhance students performance and interest.

Students must experience the problems caused by big tragedies, which will make them better professionals in the future. This case also can be used to evidence the need for a holistic view in engineering, and how the knowledge from other studied disciplines correlate in the analyzing and problem solving process.

As a teacher, it is important to take other students to these places on the next years if possible, to see the impacts locally and how nature is recovering on the affected places. It is important too that the students' knowledge from other disciplines could be applied, for that is necessary to transform the visit in a more interdisciplinary context, including approaches of Environmental Impact Assessment (EIA).

The constant visit to affect areas can be used as learning tools in the process of teaching local impacts and how nature and society recovers from disasters, mainly in a course as Environmental Engineering.

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Práctica del Aprendizaje Basado en Proyectos de la Universidad Nacional de Colombia en la localidad de SUMAPAZ de la ciudad de Bogotá D.C, Colombia

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Resumen

En el actual contexto colombiano del posible final del conflicto armado, la Universidad Nacional de Colombia, Sede Bogotá, desarrolla un convenio de admisión especial con la Secretaría de Educación del Distrito Capital que apoya el acceso a la educación superior de estudiantes egresados de colegios públicos de la localidad rural de Bogotá, Sumapaz. Esta localidad estuvo en conflicto armado hasta hace pocos años y es parte del mayor complejo de páramos del mundo, de su mismo nombre; el proyecto constituye un buen ejemplo de programa que beneficia a estudiantes provenientes de regiones patrimoniales que han sufrido gravemente los embates del largo conflicto armado colombiano. Para lograr la incorporación exitosa de estos estudiantes a la Universidad, se ha decidido ejecutar un programa académico basado en proyectos interdisciplinarios que permite a los jóvenes avanzar durante cuatro (4) semestres en los currículos de cinco (5) programas: Enfermería, Ingeniería Agrícola, Ingeniería Agronómica, Medicina Veterinaria y Zootecnia. En el presente trabajo describimos la metodología del diseño curricular y algunos resultados parciales de su ejecución. La planeación de los proyectos se inició en el primer semestre de 2016 con un grupo interdisciplinario de profesores voluntarios y ha abarcado hasta ahora objetivos de conocimiento profundo de la región, sus potencialidades y problemáticas, de estudio de contenidos académicos diversos relacionados con el agua y el suelo como componentes básicos del páramo y de exploración de actividades de producción agropecuaria que pueden adaptarse mejor que las que se realizan actualmente a las condiciones y necesidades de preservación de este complejo e importante conjunto de ecosistemas.

Palabras clave: Educación superior, ABP, interdisciplinariedad, diseño curricular, educación para la sustentabilidad

Type of contribution: Best practice paper

1 Introducción

La localidad de Sumapaz es la número 20 del Distrito Capital, la única completamente rural, localizada al sur de la llamada Bogotá urbana. Está ubicada en la Cordillera Oriental, en la región del Macizo de Sumapaz, zona del Alto Sumapaz, entre los 2.600 a 4.320 metros de altura sobre el nivel del mar, y es considerada un ecosistema de montaña insustituible en funciones ecológicas. Abarca una extensión de 75.761 hectáreas que representan el 42% de las 177.944 hectáreas que comprende el Distrito Capital (Zárate, 2012). El Plan Ambiental Local 2013-2016 de la Alcaldía Local de Sumapaz y la Comisión Ambiental Local de Sumapaz (2012, p.11) reconoce la

localidad como parte del Páramo de Sumapaz, el más grande complejo hídrico de Colombia y del mundo (315 mil hectáreas, según la Corporación Autónoma Regional de Cundinamarca, CAR), que integra las cuencas de los ríos Magdalena y Orinoco. El plan resalta que actualmente el Páramo está inscrito en el Sistema de parques naturales como Parque Nacional Natural de Sumapaz y que constituye uno de los más importantes del país por su vegetación, con predominio de frailejones, musgos y pajonales, y por su alta capacidad para condensar y almacenar el agua presente en la atmósfera y en el suelo (Alcaldía Local de Sumapaz & Comisión Ambiental Local de Sumapaz p.18).

En Sumapaz se encuentra la riqueza hídrica más importante del país, pero esa riqueza contrasta con la pobreza de sus habitantes. A comienzos del siglo XX se convirtió en una región ejemplar en Colombia por las luchas de sus campesinos por el derecho a la tierra desde diferentes tipos de organizaciones y sindicatos. También fue escenario de violencia guerrillera a fines del siglo XX y comienzos del siglo XXI. Su población presenta resultados muy bajos en educación, lo que impide que acceda a la educación superior de calidad, razón por la cual la Universidad Nacional de Colombia, Sede Bogotá, y la Secretaría de Educación del Distrito Capital se han asociado para ofrecer un programa de admisión especial para esta población, como contribución para generar condiciones de paz sostenible (Universidad Nacional de Colombia & Secretaría de Educación del Distrito Capital, 2015).

Desde el punto de vista de la política pública del Distrito Capital, en el Plan de Desarrollo Bogotá Humana 2012-2016 de la Alcaldía Mayor de Bogotá (2012) se planteó como meta ampliar la cobertura de la educación superior en los estratos socioeconómicos más bajos. En el mismo plan se proyecta una ciudad que supera la segregación y la discriminación, con el ser humano en el centro de las preocupaciones del desarrollo, sin barreras tangibles o intangibles que les impiden a las personas aumentar sus opciones en la elección de su proyecto de vida; se trata de que todas las personas puedan acceder a las ventajas que les permitan gozar de condiciones de vida superiores a la subsistencia básica. Adicionalmente el plan busca ampliar las capacidades endógenas de la economía bogotana ampliando primero las capacidades de la ciudadanía para la apropiación de saberes, la producción y apropiación social de la ciencia y la tecnología y la creación e innovación para el desarrollo del conocimiento científico (Concejo de Bogotá, 2012).

Por su parte, el Programa Especial de Admisión y Movilidad Académica -PEAMA- de la Universidad Nacional de Colombia se creó con el propósito de facilitar el ingreso a la educación superior a jóvenes que viven en regiones geográficamente distantes, ofreciendo carreras de pregrado en estos lugares. Se inició en las sedes de frontera de la Universidad, Amazonía, Caribe, Orinoquía y Pacífico (Universidad Nacional de Colombia, 2007), para permitir que bachilleres de estas regiones compitieran con sus puntajes en el examen de admisión a la Universidad sólo con aspirantes de su misma región, ampliando sus posibilidades de ingreso. Una vez admitidos, los estudiantes comienzan una fase inicial de sus carreras de cuatro (4) semestres en la región de origen. Finalizada esta etapa se inicia el proceso de movilidad, en el cual los estudiantes continúan sus estudios en alguna de las sedes andinas de la Universidad (Bogotá, Manizales, Medellín o Palmira), donde encuentran ventajas de infraestructura, nivel académico, actualización de programas de estudio y acompañamiento al proceso de cambio desde su zona de origen a la zona de acogida. Luego de terminar la etapa de movilidad en las sedes andinas, los estudiantes favorecidos con el PEAMA deben regresar a sus lugares de origen para desarrollar sus trabajos de grado. En el año 2015 la Universidad Nacional de Colombia extendió el programa PEAMA a regiones de influencia de las sedes andinas, con el fin de fortalecer su proyección en el territorio nacional, su contribución a la unidad nacional y la promoción del desarrollo de la comunidad académica

(Universidad Nacional de Colombia, 2015). El programa PEAMA Sumapaz es el primero que se administra desde la sede Bogotá.

El PEAMA Sumapaz está construyendo un proceso de formación académica basado en proyectos pertinentes a las necesidades, problemas y potencialidades de la región, incluyendo la protección y conservación del páramo. Este proceso de formación, consistente con la tendencia mundial en educación superior hacia el aprendizaje activo de los estudiantes, se ha considerado la mejor alternativa para ayudar a unos estudiantes con baja preparación para la educación superior a iniciar con éxito su avance en las carreras que escojan, al tiempo que adquieren habilidades académicas que les aseguren éxito en su proceso completo en la Universidad. Se busca que los estudiantes construyan verdadero sentido sobre lo que aprenden y sobre las carreras mismas que han escogido, vivan procesos de desarrollo de habilidades académicas y entiendan la necesidad de adquirirlas y se motiven hacia el proceso de formación y el desarrollo de sus intereses en el conocimiento, de manera que disminuya entre ellos la tasa de abandono de los estudios y puedan llegar a compartirlos con los mejores estudiantes del país que van a ser sus compañeros en las sedes de la Universidad a partir del tercer año.

Este artículo presenta el concepto que utilizamos del aprendizaje basado en proyectos (ABP), su planificación y ejecución, la metodología que se viene utilizando para el diseño curricular específico para la región y algunos resultados preliminares al cumplirse el primer año del programa.

2 Aprendizaje basado en proyectos

El ABP es una forma de organizar el aprendizaje en torno a proyectos basados en preguntas o problemas reales que involucran a los estudiantes en actividades de investigación, diseño, análisis y resolución de situaciones problemáticas y toma de decisiones (John, 2000). El ABP tiene sus raíces en la descripción que hace el constructivismo del aprendizaje humano y en la idea de la cognición situada (Brown, Collins & Duguid, 1989), al asumir que los estudiantes aprenden mejor cuando resuelven problemas del contexto próximo, utilizando formas de pensar que se usan en situaciones reales (Duffy & Cunningham, 1997). El ABP se utiliza actualmente en una variedad de niveles educativos, fomentando el aprendizaje por medio de la participación de quienes aprenden en tareas siempre complejas, relacionadas con cada nivel educativo (Ioannou et al., 2016).

El ABP comienza presentando el proyecto a los estudiantes. Los estudiantes en grupos pequeños (generalmente 6-8 participantes) lo analizan, realizan lluvias de ideas para comprenderlo y desarrollar hipótesis basadas en su conocimiento previo e identifican sus propios vacíos de conocimiento (Barrows, 1994). Estos vacíos, es decir lo que los estudiantes necesitan aprender para desarrollar el proyecto, se conocen en ABP como "preguntas de aprendizaje" (Barrows, 1994). El reconocimiento de las preguntas de aprendizaje requiere coordinación de los grupos en tiempo real, mientras que la investigación necesaria para el desarrollo del proyecto suele asignarse a estudiantes individuales (Hmelo-Silver, 2004; Koschmann & Stahl, 1998). Las preguntas de aprendizaje son fundamentales para el aprendizaje auto-dirigido. De hecho es el procesamiento de las preguntas de aprendizaje lo que separa distinta formas de ABP de otras formas de instrucción centrada en el estudiante (Barrett, 2005).

A medida que los estudiantes trabajan en el proyecto, deben reflexionar sobre la información que han recopilado hasta el momento, aclarando sus hipótesis e identificando nuevas preguntas de aprendizaje para desarrollarlo (Hmelo-Silver y Simone, 2013). La reflexión también ocurre en la terminación misma de la tarea,

para extraer lecciones aprendidas. Aquí los estudiantes reflexionan sobre lo que aprendieron al trabajar en el proyecto, consideran críticamente la efectividad de las estrategias que han empleado e identifican áreas donde se autoevalúan y evalúan a sus compañeros con respecto a cómo se comportaron en el aprendizaje autodirigido y en el trabajo colaborativo (Hmelo-Silver & Simone, 2013, Koschmann et al., 1996, Koschmann & Stahl, 1998).

El éxito del ABP depende de una serie de factores, entre los cuales la selección de buenos proyectos y el facilitador experto en ABP son dos principales. El proyecto debe presentar a los estudiantes retos de complejidad adecuados, que no puedan ser enfrentados con su nivel actual de conocimiento o formas de pensar (Barrett, 2005). El papel del facilitador del ABP no es enseñar o dar información sobre el proyecto, sino más bien estimular la profundización del razonamiento y el aprendizaje y facilitar el trabajo colaborativo a lo largo del desarrollo del proyecto (Hmelo-Silver, 2004). Otro factor de éxito es la calidad de la colaboración dentro de los grupos de ABP, ya que ella puede conducir a que los participantes construyan un conocimiento que les permita sustentar hipótesis y desarrollar explicaciones complejas, o no (Hmelo-Silver, 2002).

3 Diseño curricular, metodología y evaluación del conocimiento

Los profesores de la Universidad Nacional, Sede Bogotá, en todas las facultades, trabajan pedagógicamente, en su mayor parte, de forma tradicional. Esto quiere decir que sus objetivos de clase se centran en la transmisión de conocimiento, que consideran necesaria en una primera etapa del aprendizaje para que luego sea posible para los estudiantes aplicar ese conocimiento en actividades especialmente diseñadas para reforzar la adquisición misma. La comprobación es fácil de hacer al observar los currículos de las diferentes carreras y asignaturas, organizados según un ordenamiento de contenidos que deben trabajarse en secuencias determinadas.

Esta práctica, basada en una concepción del conocimiento y de la comprensión en términos de contenidos que se consideran comprendidos a partir de su presentación magistral en clases en las que los estudiantes son receptores del saber dominado por sus profesores, es opuesta a la práctica del ABP y otras que parten de la acción de quienes aprenden. A pesar de que la investigación en educación reconoce hoy en día como necesarias formas de aprender en las que los profesores juegan un papel de guía y soporte de un aprendizaje que los estudiantes logran a partir de su propia acción (e.g. Perrone, 1998; Prensky, 2001; Mora, 2004), la concepción de aprendizaje como cantidad de conocimientos recibidos prevalece en muchos ambientes educativos y dificulta que los profesores se adapten y puedan participar en el diseño y la puesta en práctica de formas de aprender activas para los estudiantes (e.g. García Gómez, 2005; Rodríguez & Kitchen, 2005; Lucarelli, 2008; Blin & Munro, 2008; Monereo Font, 2010; Brownell & Tanner, 2012).

Debido a esto y ante la necesidad de poner en funcionamiento un sistema ABP en Sumapaz con solamente un semestre de planeación y con la participación de profesores de la Universidad que en su mayoría no cuentan con experiencia ni formación en este sistema pedagógico, se inició en el primer semestre de 2016 el trabajo de planeación de lo que se haría con los estudiantes durante los 4 semestres de trabajo. Debía lograrse una forma de trabajar que no solamente resultará eficaz en la formación de los jóvenes sino que fuera aprobada como tránsito efectivo por los currículos tradicionales de las diferentes carreras. El problema curricular básico y muy difícil consistía, pues, en que en un proyecto debía lograrse que los estudiantes manejaran contenidos diversos de aprendizaje de manera eficaz y con excelente comprensión, pero las necesidades de un proyecto impedían

que los contenidos se trabajaran en las mismas secuencias preestablecidas de los currículos tradicionales. Y es que un proyecto conecta contenidos muy diversos y exige emprender su estudio y uso de manera inmediata, en combinaciones que muy a menudo distan de esas secuencias.

El grupo encargado de la coordinación académica del programa comenzó su trabajo estudiando los currículos existentes para las 5 carreras ofrecidas e invitando para la actividad de planeación a los directores curriculares y a profesores de esas carreras y de las ciencias básicas, presentes como núcleo académico común, conocidos en la Universidad por su apertura y a veces por alguna experiencia en formas diferentes de organizar el aprendizaje de sus estudiantes. La invitación, una apelación a la voluntad de los profesores interesados, se justifica porque al emprender un cambio pedagógico tan grande, que afecta no solamente el currículo sino los roles de profesores y estudiantes, debía contarse -por un lado- con las facultades y con quienes administran académicamente los programas y -por otro- con interés por parte de los profesores participantes. Basar este tipo de cambio en la imposición podía llevar al fracaso del proyecto en su inicio. Todo esto se sustentó en la confianza en que lo que se necesita para lograr aprendizaje profundo y efectivo de los estudiantes en el ABP es unos diseñadores deseosos de ensayar con este tipo de metodología, una guía pedagógica capaz y con experiencia y profesores profundamente conocedores de sus disciplinas, todos posibles de encontrar en la Universidad Nacional de Colombia.

El interés y la curiosidad de muchos profesores fue grande y se decidió con el grupo emprender la tarea por partes, iniciando con el primer semestre y prosiguiendo con los siguientes a medida que se avanzara. Con currículos tradicionales de base y en el contexto de unos estudiantes nada bien preparados para la Universidad y de una región con necesidades y potencialidades particulares y desconocidas en un comienzo, no era posible, ni lo es aún, visualizar completamente los 4 semestres de trabajo; ha sido preciso tener primero una idea de el o los proyectos que podrían ser adecuados en un primer semestre y partir de los logros iniciales y su evaluación para seguir con el diseño, semestre a semestre. Era y sigue siendo necesario, además, trabajar paso a paso en la comprensión y aceptación por parte de las facultades y departamentos de la forma muy diferente como se maneja el currículo tradicional de las carreras: no era factible crear un nuevo currículo para un grupo pequeño de estudiantes, con desarrollo de contenidos y habilidades basado en proyectos; esto hubiera necesitado el paso posterior por innumerables procesos de aprobación en distintas instancias de la Universidad. La prioridad inmediata era diseñar proyectos factibles y adaptados a los estudiantes y a la región, lograr la participación de profesores en ese diseño y en su puesta en práctica y lograr, igualmente, la comprensión de las facultades y departamentos de que en estos proyectos se cubren efectivamente los contenidos de asignaturas incluidas en los diferentes programas y su aval.

Los propósitos de las actividades de planeación del grupo fueron y siguen siendo los siguientes:

- Llegar a plantear, con la participación de profesores de la Universidad involucrados en los programas ofrecidos, verdaderos proyectos desde los cuales se estimulen auténticamente unos aprendizajes sustentados en la comprensión como desempeño (Perkins,1998; 2005; Perrone, 1998), en el trabajo auténtico en actividades de las carreras que se han escogido y en la conexión interdisciplinaria de los conocimientos.
- Llegar a trabajar con los estudiantes, dentro de esos proyectos, no solamente contenidos conectados de diferentes asignaturas sino el desarrollo de habilidades académicas como la conexión permanente entre conocimientos, la comprensión oral y la toma de notas, la lectura crítica, la escritura académica

con propósitos y organizaciones diversas, la argumentación oral y escrita, la investigación bibliográfica, la presentación de trabajos ante audiencias, etc.

- Lograr el mayor avance posible de los estudiantes en sus carreras, asegurando créditos en la mayor cantidad posible de asignaturas de fundamentación y de libre elección que puedan asociarse en los proyectos.
- Formar un grupo de profesores de las carreras ofrecidas con quienes se asegure la continuidad del programa, al lograr en ellos una experiencia real a partir del trabajo de diseño y enseñanza/aprendizaje en ambientes ABP.

En este momento se ha completado, con un muy reducido grupo de profesores interesados y constantes, trabajo de un semestre inicial y la casi finalización del desarrollo del segundo semestre. El comienzo de la planeación, antes de recibir el primer grupo de estudiantes, resultó muy fructífero en ideas diversas sobre posibles proyectos que se llegaron a pensar en algún detalle. Sin embargo los profesores resultaron inconsistentes en su participación en el grupo de trabajo, que se redujo notablemente al final del semestre de planeación y aún más al iniciar el primer semestre de trabajo con los estudiantes, y esta planeación inicial resultó apenas con el esbozo de un proyecto escogido, denominado "Conocer a Sumapaz desde el agua y las estrellas". Este proyecto fue desarrollado sobre la marcha durante el segundo semestre de 2016, ya con 17 estudiantes habitantes de la pequeña sede del PEAMA en Nazareth, Sumapaz, en préstamo de la Secretaría de Educación de Bogotá. La línea principal del proyecto fue liderada por profesores del Departamento de Química y con ellos trabajaron un profesor de astronomía con dos de sus estudiantes de posgrado, un profesor de física, una profesora del área de salud pública en la Facultad de Enfermería y un profesor de la Facultad de Ciencias Agrarias. El propósito de este proyecto fue lograr entre los estudiantes un conocimiento básico de la localidad 20 de Bogotá, Sumapaz, sus potencialidades y problemáticas.

Los estudiantes realizaron experiencias para caracterizar la localidad en relación con su localización y delimitación y con el potencial y calidad de su agua e hicieron investigación bibliográfica en grupos acerca de los problemas a los que se enfrentan sus habitantes en relación con el uso del agua y del suelo para su sustento y desarrollo económico y en relación con la salud. Estas investigaciones resultaron en textos escritos que sufrieron un amplio proceso de edición durante el semestre y en varios tipos de exposiciones orales para audiencias diferentes, que fueron editadas repetidamente y cuestionadas y evaluadas siempre por un grupo de profesores de distintas facultades y, finalmente, por miembros de la comunidad de la localidad. En el transcurso del proyecto los estudiantes manejaron conocimientos de química y laboratorio de química, matemáticas básicas e introducción a la física, introducción a la ingeniería agrícola, a las ciencias agrarias y a la salud pública, y comenzaron una amplia y necesaria formación en habilidades de lectura y comunicación oral y escrita.

Para el segundo semestre y a partir de una segunda convocatoria de admisión, se recibieron 12 estudiantes nuevos que se incorporaron al trabajo en grupos mixtos de estudiantes de diferentes carreras y semestres, al nuevo proyecto de aprendizaje. Gracias a la participación permanente de la Facultad de Ciencias Agrarias, este proyecto básico ya está en este momento terminando y consiste en producción agraria, combinada y relacionada con alimentación y producción animales, en parcelas propias conformadas por los mismos

estudiantes en un pequeño lote que es parte de la sede de Nazareth. Los estudiantes estudian en grupos los suelos de la región, la biología general y de plantas que necesitan conocer para lograr éxito en sus cosechas y experimentan con diferentes posibilidades de producción agropecuaria en un contexto ecológico y de salud en el trabajo. Al tiempo comienzan sus estudios de inglés y continúan su formación en matemáticas y comunicación en español, desarrollando un proyecto de página web bilingüe sobre su programa, sus actividades y logros, que incluye además un centro de noticias sobre la localidad.

Actualmente avanza el proceso de diseño del proyecto el tercer semestre del programa. Se está planeando un proyecto que amplíe el proyecto productivo agropecuario que se está desarrollando en este momento, para guiar a los estudiantes a que den una mirada más ecológica e integral a su quehacer como productores y a la región en la que trabajan. En este proyecto agropecuario ampliado se considera la posibilidad de asociar nuevas asignaturas de fundamentación para las diferentes carreras: biofísica, bioquímica, microbiología, fisiología de plantas, botánica, salud animal y estadística. El proyecto básico del último semestre comenzará a planearse a mitad del tercer semestre, según se vaya desarrollando este proyecto productivo-ecológico.

El éxito del aprendizaje de los estudiantes en estos proyectos está asegurado por el trabajo colaborativo del grupo de profesores participantes, de un grupo de egresados que coordina lo administrativo y otro grupo de egresados que cumple funciones de tutoría académica permanente y vive con los estudiantes PEAMA en el centro poblado Nazareth. El grupo de profesores determina las acciones de ejecución específicas del proyecto semana a semana, a partir de la planeación general realizada en el semestre anterior y bajo la dirección de dos profesoras coordinadoras de lo académico y lo pedagógico, que aseguran el cubrimiento curricular, la incorporación del trabajo de profesores de las diferentes áreas de conocimiento y la naturaleza pedagógica del proyecto. Además el trabajo de este grupo se alimenta de los informes permanentes del grupo de tutores que trabaja con los estudiantes *in situ* y presta apoyo continuo a los estudiantes en sus actividades de estudio, en la organización de su trabajo y en la disponibilidad permanente de los recursos que necesitan para su trabajo académico.

Para la evaluación del desarrollo de la comprensión de contenidos y de habilidades académicas importantes, el ABP exige formas diferentes a las utilizadas en la educación tradicional; sin embargo a la vez se asegura que los estudiantes tengan experiencias de evaluación iguales a las que tendrán al incorporarse a sus carreras en la Sede Bogotá. Por esta razón se utiliza un sistema mixto: Un porcentaje de las notas finales de cada asignatura asociada a los proyectos está dado por evaluaciones tradicionales que diseñan y administran los profesores encargados de cada una (tareas, quizzes y parciales). Pero hay un porcentaje de las notas que es común a todas las asignaturas y que se relaciona con el proyecto básico de cada semestre.

Los productos comunes de los proyectos son informes analíticos orales y escritos desarrollados en equipos y presentados por los equipos completos y/o por los participantes individuales. Estas presentaciones y textos escritos se evalúan con matrices que incluyen una diversidad de criterios que deben observarse en los trabajos, calificados en una escala de niveles de calidad que corresponden a notas numéricas. Los estudiantes reciben estas matrices desde que reciben las instrucciones de los trabajos, con el objeto de que sepan cómo se van a juzgar desde antes de empezarlos. Durante ya casi dos semestres todos los estudiantes han debido hacer sus presentaciones orales ante un panel compuesto por varios de los profesores que participan en el programa y sus tutores académicos. Todos hacen la evaluación de lo observado y las notas resultan del cómputo de las notas otorgadas por los diferentes observadores. Como parte de la evaluación formativa del trabajo de los

estudiantes, también han tenido que hacer sus presentaciones ante la comunidad de la localidad de Sumapaz y ante la comunidad de la Sede Bogotá. Por su parte los textos escritos se desarrollan como procesos auténticos de escritura, con revisiones múltiples de borradores por parte de los profesores que diseñan el trabajo y de los tutores académicos. Los estudiantes deben cumplir varias entregas, a través de las cuales mejoran permanentemente sus textos y reciben notas finales de profesores y tutores, dirigidas por las matrices de evaluación. El peso de las notas comunes y las tradicionales en las notas finales de las asignaturas se determina en el grupo de profesores participantes, de común acuerdo, al comienzo de cada semestre.

4 Evaluación del programa

4.1 Ventajas del trabajo por proyectos

Los procesos de desarrollo de los proyectos les han permitido a los profesores y tutores académicos que trabajan con los estudiantes el manejo de dos aspectos fundamentales del aprendizaje:

- La presentación, estudio y discusión permanentes entre profesores, tutores y estudiantes de contenidos académicos asociados con acciones y fenómenos de ocurrencia real y conectados transdisciplinarmente. Esto permite que los profesores y tutores observen directamente el proceso de desarrollo de la comprensión de los estudiantes sobre estos contenidos e intervengan en ese proceso. Así se hace posible trabajar conjuntamente con los estudiantes en la profundización y mejora permanentes de la comprensión que estos últimos van desarrollando de aquello que es importante que aprendan. Esto nunca es posible en el método tradicional de transmisión de conocimientos, que solamente se ocupa de la presentación de contenido y la evaluación de productos de aprendizaje, manteniendo ocultos a los ojos de los profesores los procesos de comprensión que llevan a cabo (o a menudo no llevan a cabo) los estudiantes.

- Por razón de esta posibilidad de observar directamente procesos de comprensión y de intervenir en ellos, es posible también el soporte directo para el desarrollo de habilidades académicas que los estudiantes no traen consolidadas de la educación básica. Los estudiantes deben realizar frecuentes actividades de búsqueda de información en diversas fuentes, lectura, preparación de exposiciones orales y de textos escritos, y en todos estos procesos pueden intervenir profesores y tutores académicos entendiendo ellos, por un lado, cómo proceden y en que fallan los estudiantes al realizarlos, y a la vez actuando sobre lo que los estudiantes hacen y dejan de hacer cuando están trabajando. Esto permite el soporte directo para la mejora de las habilidades de lectura, escritura, comprensión y expresión orales, y en general para el desarrollo del lenguaje académico con verdadera comprensión.

Otra ventaja patente del trabajo por proyectos es que el uso de los conocimientos no termina con el final de un semestre. Los contenidos de las diferentes asignaturas, que se denominan preferentemente dentro del grupo *áreas de conocimiento*, continúan trabajándose y conectándose en los proyectos subsiguientes. Inclusive hay contenidos que ya aparecen y comienzan a trabajarse antes de que la materia se registre en determinado

semestre. Ya ha habido oportunidad de corroborar que esto ocurre, por cuanto en el proyecto productivo del segundo semestre, que está en su etapa de culminación, los estudiantes siguen trabajando y conectando a niveles cada vez más complejos contenidos de las introducciones a las ingenierías agrícola y agronómica que desarrollaron en el primer semestre, así como contenidos de química, matemáticas y salud pública. De la misma manera durante el primer semestre tuvieron contacto con importantes contenidos de física, cálculo y las introducciones a la medicina veterinaria y la zootecnia, asignaturas en las que están registrados durante este segundo semestre de trabajo o en las que lo estarán en el período intersemestral próximo.

4.2 Búsqueda de evidencias de evaluación

Como primera e importante acción de evaluación de los logros académicos con los estudiantes, ya está organizado que ellos se enfrenten a asignaturas normales de la universidad, ofrecidas durante el período intersemestral que comienza en el próximo mes de junio. Esto pondrá a prueba sus habilidades desarrolladas, al enfrentarlos al sistema tradicional de la Universidad. Se dictará el curso inicial de Fundamentos de mecánica, para estudiantes de las ingenierías, el curso de Introducción a la veterinaria y el curso de Morfofisiología, asignatura de fundamentación de la carrera de enfermería.

El grupo de profesores y tutores del programa considera que al final del tercer semestre, en diciembre del presente año, existe la posibilidad de incorporar algunos estudiantes que completen satisfactoriamente su trabajo académico, a sus programas de carrera en Bogotá. Esta decisión se tomará en equipo, según el desempeño que los posibles candidatos muestren durante el período intersemestral y el tercer semestre, y únicamente si se considera que pueden estar ya preparados para enfrentar con éxito y autonomía las exigencias y retos que impone la situación académica normal de la Universidad.

Como evidencia completa de evaluación, el programa solamente cuenta hasta el momento con los resultados observados del primer semestre de trabajo de los estudiantes. Estos demuestran que solamente se ha presentado deserción de una estudiante que habían presentado difíciles condiciones familiares durante el semestre (una mujer cuyo esposo no estaba de acuerdo con sus estudios y puso trabas importantes para que tuviera éxito) y peligro de deserción en otra (una joven embarazada que tuvo su bebé a final del semestre y no tiene aún organizados ni su vida ni su presupuesto familiares).

Los resultados académicos de los estudiantes que completaron el primer semestre, cuya calidad fue observada y calificada por grupos de profesores de diferentes carreras en sus trabajos escritos y en sus múltiples presentaciones orales, fueron satisfactorios y sus notas numéricas solamente mostraron pérdida de la materia Matemáticas Básicas en 3 estudiantes. Las calificaciones del semestre actual están todavía en desarrollo y, como denotan también la calidad de procesos de desarrollo de comprensiones y habilidades en los estudiantes, no constituyen todavía evidencia válida de la calidad de los procesos del presente semestre. Su observación informal muestra, sin embargo, avance lento pero permanente.

En cuanto al trabajo pedagógico de los profesores, ha sido complejo. La verdadera configuración de proyectos en los que ellos trabajen de manera interdisciplinar no se ha logrado en su totalidad, y ha resultado imposible evitar que algunos de los profesores que deberían incorporar el trabajo de sus áreas a los proyectos básicos que se realizan con los estudiantes terminen dictando clases magistrales en vez de dirigiendo el estudio autónomo y por grupos en conexión con los proyectos. El número de profesores involucrados creció para el trabajo del segundo semestre, y hemos visto la necesidad de incorporar colaboración pedagógica directa con

algunos de ellos, para el diseño de actividades relacionadas con sus áreas en los proyectos. Esperamos que este trabajo pueda incorporarse definitivamente a la actividad de los profesores en el PEAMA Sumapaz. La introducción de esta guía pedagógica ha venido haciéndose con gradualidad, de nuevo para no imponerla entre profesores que son expertos en sus disciplinas.

La evaluación formal de lo que llevamos del programa está a punto de iniciarse sistemáticamente por medio de un cuestionario para estudiantes, tutores y el grupo de profesores diseñadores de proyectos, con posibilidad de que los encuestados agreguen comentarios personales. Esta encuesta se está diseñando con base en la utilizada por Gómez-Pablos, Martín & García-Valcárcel (2017), con adecuaciones al contexto del Sumapaz y del programa PEAMA. Permitirá evaluar diferentes indicadores de los siguientes aspectos del programa: contexto físico (Nazareth- Sumapaz), características del(los) proyecto(s) realizado(s), roles de los profesores, roles de los tutores, herramientas de evaluación utilizadas, roles de los estudiantes y resultados obtenidos. Para facilitar el análisis cuantitativo de los resultados la encuesta tendrá una escala de respuesta entre 0 (Totalmente en desacuerdo) y 4 (Totalmente de acuerdo); estos resultados se complementarán e ilustrarán con un análisis cualitativo de los comentarios incluidos en las secciones que los permiten.

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La orientación del trabajo académico en Ingeniería

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Resumen

La Ingeniería ha se acercado cada vez más de las personas, aunque presente en la tecnología de televisores, coches, ropa, entre otros equipos y servicios, solamente en muy poco tiempo el ingeniero ha se acercado del público en general. Actualmente en Brasil el trabajo del ingeniero vino sobre las personas y sus problemas y por lo tanto la importancia de la formación de profesionales con habilidad para identificarlos, evaluarlos y solucionarlos. El objetivo principal de este artículo es presentar la metodología de enseñanza adoptada en la Disciplina de Proyecto Supervisado para la creación del Trabajo de Grado de las Ingenierías y demostrar algunos trabajos realizados cercano de las personas y sus "interfaces" con el área de la salud. En el curso de Ingeniería Informática el proceso de creación del Trabajo de Grado en la Universidad de Sorocaba (UNISO) adoptó una metodología de aprendizaje activo basada en el *Problem-Based Learning* (PBL) y en proyectos que condujeron los estudiantes hacer contacto con la comunidad donde viven y donde hay problemas y necesidades los cuales buscaron soluciones a los mismos. Es importante resaltar que los estudiantes eligieron los temas libremente y que los temas están enfocados en problemas de la salud, discapacidad y sostenibilidad. La construcción del conocimiento se realizó a través de la discusión de la teoría en práctica en una investigación aplicada, descriptiva y cualitativa sobre esta experiencia. Los estudiantes atendieron las necesidades de los temas del trabajo desarrollado, tales como: 1) Pité (robot terapéutico que ayuda en el tratamiento de enfermedades de la infancia); 2) prototipos para ayudar a la movilidad de las personas con tetraplejía que usan sillas de ruedas. La propuesta del trabajo con el PBL y el aprendizaje basado en proyectos fue importante para el desarrollo de habilidades de autonomía y responsabilidad social que ayudó en la formación de ciudadanos participativos y responsables en su comunidad.

***Palabras-clave*:** PBL, Ingeniería, aprendizaje, problemas humanos

Type of contribution: Best practice paper

1 Introducción

En seguimiento a las nuevas propuestas relacionadas al aprendizaje de la ingeniería, la Universidad de Sorocaba (UNISO), es una universidad privada ubicada en la ciudad llamada Sorocaba, estado de São Paulo - Brasil, donde tiene tres campus: ciudad universitaria Campus profesor Aldo Vannucchi, inaugurada en 1999; Campus de Trujillo, donde se desplegó a la Facultad de filosofía, Ciencias y letras en 1954 y el Campus Seminario en 1994. La universidad UNISO fue fundada en 1951, pero empezó sus actividades sólo en 1954 cuando comenzó los cursos de graduación en: Pedagogía y Letras NeoLatinos solamente con 27 alumnos.

Actualmente la UNISO tiene más de 60 cursos de graduación y ofrece cursos de lato sensu y stricto sensu, como también cursos de extensión. (UNISO, 2017).

La UNISO ofrece 12 cursos de especializaciones en ingeniería: Medio Ambiente, Bioprocesos, Biotecnología, Eléctrico, Civil, Control y Automatización, Mecánica, Materiales, Química, Producción de Alimentos y ingeniería Informática. Los ingenieros concluyen su formación en ingeniería en cinco años de estudio (UNISO, 2017). La forma de enseñanza de la Universidad UNISO es tradicional y siempre busca motivar sus profesores a buscar nuevas formas de aprendizaje.

Como parte de nuestro compromiso en la formación y con el fin de permitir a los estudiantes evaluaren sus desempeños generales, sus intereses y capacidad en pesquisas para continuar “aprendiendo por aprender”, así como su potencial en integración al mercado de trabajo o seguir cursos de postgrado académicos, los cursos de ingeniería que tienen la disciplina "Proyecto Supervisado", que es obligatoria para los estudiantes que está en los últimos dos años de curso. El proceso tiene como objetivo la construcción del "proyecto final" (Trabajo de Grado) que propone a los alumnos a través de los retos en el aprendizaje en contacto con las comunidades donde viven para identificar problemas y resolverlos.

La Disciplina Proyecto Supervisado es requisito obligatorio en el curso de Ingeniería Informática que contribuye en la formación de nuevos profesionales que actúan en las áreas de informática industrial, redes de comunicación industrial, sistemas de información aplicación a la ingeniería, sistemas informáticos y encajado de computación. Parte de su misión: especificar, desarrollar, implementar, adaptar, fabricar, instalar y mantener sistemas informáticos (UNISO, 2017).

El objetivo principal de este artículo es presentar la metodología de enseñanza adoptada en la disciplina de proyecto supervisado para la creación del Trabajo de Grado (TG) de graduación de la ingeniería y demostrar algunos trabajos realizados cercano de las personas y sus “interfaces” con el área de la salud.

Cuando están desarrollando el TG, los estudiantes son desafiados a aplicar los conocimientos adquiridos en el curso y buscan también nuevos conocimientos externos – es una clase que se convierte en un pequeño laboratorio de aprendizaje.

Entendemos que sólo una disciplina que se encuentra al final del curso no alcanzará todos los objetivos propuestos en este artículo para la formación de los estudiantes, pero puede ser un primer paso en la dirección de un cambio que es necesario en el proceso de enseñanza tradicional propuesto.

2 Problem-Based Learning (PBL) e Ingeniería

La búsqueda en el dinamismo en la enseñanza y mejores resultados en el aprendizaje siempre han sido objeto de estudios. La educación está se transformando frente a muchos cambios en la sociedad. La evolución del aprendizaje se convierte en aspectos relevantes de las competencias del conocimiento y de la construcción para convivir en una sociedad. Proporcionar configuración de aprendizaje diferenciadas que permite la aproximación e integración entre profesor y alumno favorece en la construcción colectiva de conocimiento (Sharma et al, 2015).

Según Schliemann (2016), las metodologías activas dependen de autonomía.

> "La metodología activa del aprendizaje puede definir como la práctica pedagógica basada en el principio de autonomía, asunción de la educación contemporánea que alumnos capaces de auto gestionar o auto gobernar sus propios procesos de formación. Una metodología que asume el estudiante como el protagonista de un escenario de

> aprendizaje centrado en la realidad y en el contexto de su ámbito profesional. La socialización de experiencias innovadoras puede motivar a las docentes para realizar un trabajo, reduciendo la resistencia de algunos profesionales en innovar por temor a realizar un trabajo "amateur" que no cumpla con las expectativas de los estudiantes en el escenario externo." (Schliemann et al 2016, p. 54).

Es importante también mencionar que cuando la opción es aprender por Metodologías Activos del Aprendizaje, una serie de actividades y técnicas se propongan, entre ellas, El aprendizaje basada por problemas (del inglés *"Problem-Based Learning" o PBL)*

La literatura asocia el PBL a un cambio de plan de estudios que comenzó en la Universidad de McMaster en Canadá y la Universidad de Maastricht en los Países Bajos a finales de 1960. Los maestros y coordinadores de estas universidades se enfocaron en esfuerzos para superar algunos problemas relacionados a enseñanza tradicional, especialmente los relacionados con el contenido de aprendizaje por estudiantes de medicina y su uso posterior en su práctica profesional (Conrado y Nunes-Neto y El-Hani, 2014).

Según Freitas (2012, p. 406), el PBL tiene sus principios:

- **La educación centrada en el estudiante y fuertemente orientado en sus propios procesos de aprendizaje -** se entiende que se crean las condiciones ideales para el aprendizaje;
- **El aprendizaje es de responsabilidad del estudiante -** él debe entender el problema y desarrollarlo, lo que reduce drásticamente su papel pasivo en el aula;
- **Consideración en experiencia vivida anteriormente -** pueden estropear, pero debiese entender que los estudiantes comprendan el tema para evitar interpretaciones erróneas;
- **El aprendizaje activo, interactivo y colaborativo -** desarrolla el pensamiento crítico del estudiante y despierta su implicación con la escucha atenta y respetuosa, colaboración con el equipo, capacidad de análisis, síntesis y el juicio mediante la verificación de la pertinencia de su aplicación al problema;
- **Contextualización de la enseñanza -** estudio de la teoría y la práctica aplicada a la realidad de las profesiones;
- **El aprendizaje es inductivo -** soluciones deducidas por los alumnos a través del aprendizaje aplicado;
- **El principal papel del maestro como un instructor o tutor -** él presentase más activo en actividades como un facilitador o tutor;
- **El problema o la situación-problema siempre precede a la teoría -** trabajar en el entendimiento de los problemas reales para definir los objetivos del aprendizaje y luego buscar el conocimiento que subyacen y que expliquen científicamente la solución adoptada.

La práctica de la ingeniería está muy cerca de estos principios presentados.

La evolución de la humanidad ha estado directamente relacionada con la ingeniería. Se sabe que los principales hitos de la historia, como las guerras o grandes catástrofes sirven para conducir grandes logros y garantizar la vida de la humanidad. No si objetiva los desastres, pero se observa que estos son momentos de gran presión cultural y social que se convierte en la ingeniería (Freitas, 2014).

Ingeniar involucra la idea de poner la experiencia de un especialista con el conocimiento científico en favor del hombre. El gran desafío es investigar, desarrollar, adaptar y, a veces, encontrar soluciones para problemas que padecen la humanidad. Podemos ver, entre los ejemplos a seguir, que la ingeniería en un contexto histórico mediante la combinación de conocimientos, capacidades y habilidades humanas para

construir la pirámide de Giza en Egipto, ingenio esto que precede la invención del motor vapor (Bazzo y Pereira, 2006).

A pesar de los profesionales de ingeniería se han vuelto indispensables a medio de la década de 50, la creación de objetos y aparatos que tenemos hoy en día y la aproximación de la vida diaria de las personas, históricamente vemos que la evolución de los productos de ingeniería y tecnología tenían características místicas que siempre parecían "listas" y poco se sabe de las personas que desarrollaron la tecnología. Profesionales de la ingeniería siempre estaban en laboratorios y, a menudo lejos de las personas, lo que entendiese que había una distancia entre estos profesionales e las personas.

Hoy la realidad ha cambiado. Con la evolución y la popularización de la tecnología, los ingenieros están en programas de televisión, en representaciones de empresas, en frente la audiencia de consumidores con el objetivando una comunicación cercana con los seres humanos y no sólo con los problemas tecnológicos. A continuación, el papel del ingeniero cambia de "creador del producto" a "personas ayudantes" en la solución de problemas.

Con este cambio de convivencia, también era necesario, un cambio en el aprendizaje de la ingeniería. El trabajo del ingeniero junto con el problema de la humanidad tiene obligado a los maestros a pensar en el curso, pensar en la enseñanza y formación de los estudiantes para esta condición. A través de estas reflexiones se llegó a la necesidad de desarrollar simulaciones de aprendizaje vividas en el cotidiano.

Los ingenieros deben ser identificadores, formuladores y solucionadores de problemas. En su actividad profesional, cuentan con información que, adecuadamente recogidos, clasificados y trabajados, se puede transformar en resultados prácticos y útiles. En ingeniería se puede Identificar, formular y resolver problemas que resultan en el desarrollo de un nuevo producto, sistema o proceso o su mejora (Bazzo y Pereira, 2006).

En un proyecto de ingeniería, se considera:

- El proceso de aprendizaje es dirigido, pero orientado por la necesita del proyecto;
- Los ingenieros son responsables por el desarrollo del proyecto;
- Los aprendizajes anteriores son importantes para llegar a soluciones;
- La intensa iteración y colaboración del equipo del proyecto, clientes y proveedores;
- Aprender a aplicar;
- Análisis de los problemas antes del diseño del proyecto.

Se concluye que tales consideraciones acercan el “Aprendizaje Basado en Proyectos” y el “PBL” con los proyectos de ingeniería.

3 Metodología

La disciplina "Proyecto Supervisado" se basa en la construcción del conocimiento a través de la práctica que condujo los estudiantes a realizar una encuesta aplicada, descriptiva y cualitativa sobre la experiencia del aprendizaje basado en proyectos.

De acuerdo a Hernández y Ventura (1998), la enseñanza basada en proyectos trae la oportunidad de trabajar el conocimiento global y relacional.

Según Suertegaray (2003) son temas que están directamente vinculadas a la interdisciplinariedad que constituyen una práctica colectiva, oriunda de organizaciones por grupos y tiene como objetivo la

búsqueda de la comprensión y explicación de un problema formulado por todos los investigadores científicos.

En todo el tiempo, el estudiante es responsable de su proyecto y el profesor actúa como guía de la investigación, dirigiendo el trabajo con el fin de cumplir con los objetivos proyectados. El profesor actúa con sugerencias que, sumados a los datos recogidos en la investigación, proporciona el aprendizaje inductivo.

En todas las clases se discute temas tales como:

- Lo progreso del proyecto hacia la meta;
- ¿Cuáles son las dificultades enfrentadas y las posibilidades para evitarlas?;
- Los pasos siguientes y las entregas correspondientes para las clases que van a seguir

Estas actividades hacen con la problematización que fue traída para la clase, genere respuesta por la idealización del máquinas y equipos construidos por los estudiantes con la supervisión del profesor.

Los alumnos desarrollaron sus Trabajos de Grado respetando las siguientes reglas:

- Buscar condiciones en la comunidad en que el uso de la ingeniería puede facilitar o transformar la vida de las personas;
- Pesquisar y comprender la problematización que hay en otros trabajos científicos hasta que se cumpla totalmente la condición de la comunidad que se estudia;
- En el aula, contextualizar la situación y entender la problemática a través de discusiones con el profesor orientador de la disciplina;
- Crear hipótesis para estudiar posibles soluciones utilizando la formación previa;
- Construir nuevas hipótesis considerando posibilidades a través de estudios no conocidos;
- Crear un proyecto de investigación para definir todo el alcance del proyecto con toda la técnica y teoría que se consideren necesarios;
- Presentar el proyecto a la opinión de otros colegas en el aula. Un momento muy rico donde todos tienen la oportunidad de colaborar en la búsqueda de una solución ideal;
- Investigar sobre los temas necesarios para el desarrollo del proyecto. En ese momento es importante para trabajar las condiciones técnicas;
- Probar la hipótesis mediante la construcción de un prototipo funcional y presentable que puede ser escalado para la aplicación a la solución real del problema. En muchos casos los estudiantes necesitan volver para la investigación, por lo general por razones de viabilidad técnica, y luego trabajar en los ajustes necesarios;
- Presentar el prototipo para varios tipos de pruebas que se pueden aplicar en su elaboración y su escala de la construcción;
- Crear la documentación técnica sobre a construcción del prototipo;
- Promover la discusión acerca de todo el proceso de execusión del proyecto en un tiempo determinado en forma documental y también reconocer el aprendizaje en todo el proceso;
- Consolidar todo el proyecto en formato documento dentro de las metodologías científicas y académicas que llamamos de "Trabajo de Grado";
- Presentar los trabajos escritos y el prototipo para los evaluadores de Trabajo de Grado que son profesores universitarios e invitados.

La adaptación de PBL y el aprendizaje basado en proyectos formó la base para el desarrollo de los proyectos de los estudiantes.

4 Desarrollo de los Trabajos de Grado

Los trabajos respetaron las cuestiones de formación en Ingeniería Informática que combinaron el uso de *hardware* y *software* dirigido a una aplicación en ingeniería, mediante la construcción de un prototipo funcional y presentable frente a un problema del cotidiano.

La disciplina “Proyecto Supervisado” propuso a veinte estudiantes que asistieron a las clases, el desafío de aprendizaje junto a la comunidad, en primer lugar, buscando los problemas que enfrentan las personas todos los días y que la ingeniería puede ayudar a resolverlos. Dividido en tres módulos, el curso se da en un año y medio con una carga de trabajo total de 200 horas, por un total de 240 clases de 50 minutos de duración.

En el primer módulo denominado "Proyecto Supervisado I", los estudiantes entienden lo que es un proyecto de ingeniería, se mueven hasta la comunidad para buscar temas cercanos de los problemas humanos y luego los traen como sujeto para el Trabajo de Grado, así como crear un proyecto de investigación que detalla cada paso de la ejecución, utilizando métodos de construcción del trabajo científico propuesto por la Universidad. El criterio de evaluación es mediante la presentación del proyecto de investigación estructurado y fundamentado científicamente que demuestra la factibilidad del proyecto de ingeniería.

El segundo módulo, "Proyecto Supervisado II", proporciona a los estudiantes la experiencia de conducir el proyecto de investigación construido en los seis meses anteriores, con la documentación de su aplicación, los cambios necesarios para la viabilidad del proyecto de ingeniería. En ese momento el estudiante tiene la oportunidad de probar todo el sentido de la investigación con la práctica. La evaluación en esta etapa requiere de los estudiantes la presentación de un prototipo de trabajo que atienda el problema estudiado.

En el último módulo, "Proyecto Supervisado III", se evalúa la entrega del prototipo funcional y presentable. El prototipo ser "presentable" significa que puede ser presentado al público objetivo y no presente fallos de funcionamiento en el entorno al que se va a aplicar. Al mismo tiempo, el estudiante debe presentar un artículo científico. La evaluación final se lleva a cabo a través de los evaluadores que son dos profesores universitarios y el orientador del trabajo que analizan la obra escrita, el prototipo y la presentación del proyecto, con el objetivo de validar los conocimientos del alumno en su área de formación, el empleo de nuevos conocimientos y la solución de ingeniería propuesto. Además de la evaluación del rendimiento de los estudiantes, se establece un conjunto de parámetros para la correcta introducción del estudiante en la comunidad científica, la búsqueda de la satisfacción intelectual y personal y la preparación para el mercado laboral.

Las opciones temáticas desarrolladas son libre y espontáneas y abordan temas relacionados con el área de salud. Durante el período, cuatro proyectos fueron finalizados y se describen en la siguiente tabla:

Tabla 1: Identificación de los Trabajo de Grado en el año 2016

Título	Objetivo	Relación con la comunidad	Nota
TECNOLOGÍA DE ASISTENCIA PARA PERSONAS TETRAPLÉJICAS	Ayudar en la locomoción de los pacientes con tetraplejia	Con el movimiento de la cabeza, que es la única condición posible del cuerpo en tetraplejia, el paciente obtiene la independencia y la autonomía de moverse y controlar los motores de sillas de ruedas	10
USO TECNOLOGÍA A LA ALTURA DE LA SEGURIDAD	Desarrollar una aplicación de teléfono inteligente que avisa de	Con tantos crímenes sucediendo, el usuario informa a su familia de que todo está bien o envía un	9

PERSONAL	forma automática la familia del usuario, con el envío de su ubicación.	mensaje de emergencia para pedir ayuda y la ubicación	
BRAILE TOUCH – TECLADO VIRTUAL	Asistencia para aprender Braille para deficientes visuales	El aprendizaje de Braille no es una tarea fácil y requiere mucho entrenamiento y concentración. La aplicación, a través de una pantalla de película impresa con células Brailles, guía el estudiante para identificar qué letra corresponde a la célula de Braille que se siente en la punta de los dedos a través del sonido.	10
MUÑECA PITÉ: ROBOT TERAPÉUTICO DE ASISTENCIA A LOS NIÑOS	Ayuda a los niños en la comprensión del proceso de hospitalización.	Proporcionar al niño, de una manera lúdica a través de un robot y una historia animada en un *Tablet* que, al mismo tiempo, trae una distracción, proporciona la comprensión y la aceptación en el proceso de hospitalización.	10

4.1 Resultados de la utilización de la metodología a través de los objetivos alcanzados por los Trabajos de Grado

A continuación, hay dos resúmenes de obras que han recibido la nota final diez (que es la mayor nota), para demostrar que la metodología aplicada, hace posible que los desarrollos de los Trabajos de Grado alcancen sus objetivos con la comunidad y, más que eso, el aprendizaje y la construcción del conocimiento. Todas las reglas enumeradas en la metodología presente en este trabajo fueron aplicadas a los estudiantes.

Pité – Robot terapéutico

Investigación desarrollada por los estudiantes Adriano Bastos y Fernando José Viana bajo la dirección del profesor William Patrick Geraldo trae la propuesta en el resumen a continuación y con la ilustración 1:

> "La investigación apareció en forma interdisciplinaria con estudiantes y profesores de Ingeniería Informática y Psicología para promover la humanización de la enfermedad en la infancia. La hospitalización se considera una experiencia estresante para el niño, la ruptura de los lazos con la familia y el entorno en el que vive, y mantener la normalidad a través del juego es fundamental para abordar este tiempo de vida. Cuando un niño se enferma, su realidad y su vida diaria cambian resultando en sentimientos de miedo y impotencia que son cruciales en este período de la vida y que son peores en el momento de hospitalización. El juego desmitifica el entorno hospitalario como hostil y puede ganar una bonita vista, así como permitir la expresión emocional y el desarrollo del niño, además hace que el niño tenga una conexión con los profesionales que se preocupan por ella y aumenta su interacción con los padres que a menudo están invitados a participar. En respuesta a las preguntas formuladas en esta investigación, hemos desarrollado un robot controlado a través de una aplicación a través de *bluetooth*, sincronizado con el vídeo, que informa las experiencias de una niña de siete años con el proceso de hospitalización (la muñeca Pité)" (Bastos & Viana, 2016).

Ilustración 1: Aplicación utilizada por el robot para contar la historia

La historia se presenta a través de la animación con una duración de cinco minutos para "*Tablet*" y "*Smartphone*" contadas por el robot Pité como se muestra en la Ilustración 2 (Bastos y Viana, 2016).

Ilustración 2: Robot Pité –la muñeca de paño terapéutica

> "La ayuda de la tecnología del *Tablet* y el robot en el medio hospitalario trae impacto y curiosidad en los niños, lo que facilita el contacto. La presentación de la historia con la tecnología facilita la interacción y la comprensión del niño frente a los procedimientos hospitalarios ejemplificados en el video y del proceso de la enfermedad y/o muerte de los niños y adolescentes." (Bastos y Viana, 2016).

Prototipo para auxiliar la movilidad en silla de ruedas para las personas con tetraplejia

La investigación desarrollada por los estudiantes Tobias Afonso dos Santos Bastos y Kaisa Soares de Almeida bajo la dirección del profesor William Patrick Geraldo trae la propuesta en el resumen a continuación y se ilustra en la ilustración 3:

> "Este estudio tuvo como objetivo desarrollar una aplicación *Android* con la función de ayudar a las personas que sufren de tetraplejia. A través del reconocimiento facial que tiene la biblioteca OpenCV, la aplicación tiene la capacidad de enviar comandos a través de *Bluetooth* a un prototipo de una silla de ruedas construido con el microcontrolador Arduino. El origen de este proyecto se basa en la percepción de la necesidad que personas con discapacidad física, especialmente tetraplejia, tienen de dispositivos menos costosos y accesibles para poder ofrecerles una mayor independencia. Este conocimiento se aplicó y sirvió para que este proyecto pudiese tener un resultado final satisfactorio." (Bastos y Almeida, 2016).

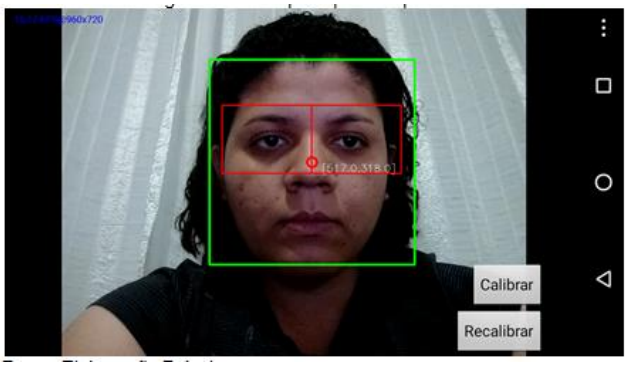

Ilustración 3: Identificación y clasificación de imágenes para mover los motores de cara

Los estudiantes también informaron la experiencia cotidiana de los ingenieros en torno a cuestiones adversas enfrentadas durante la ejecución del proyecto,

> "Debido a las limitaciones encontradas en el transcurso de lo mismo, no fue posible desarrollar un prototipo más cercano de lo que es una silla de ruedas, pero el producto final puede dar una visión muy estrecha de la forma en que se debe aplicar en el futuro para las instalaciones que ayuden a reproducir mejor una silla. Se obtuvieron algunas conclusiones importantes sobre el uso de la visión artificial y bibliotecas disponibles en la actualidad, lo que permite el desarrollo de herramientas que ayudan a mejorar la vida de muchas personas con dificultades. Se demostró que no es necesario acceder herramientas muy avanzadas para ter dispositivos muy útiles y que el microcontrolador Arduino, que tiene una programación simple, puede proporcionar una eficacia muy alta y se puede ser utilizado para muchos proyectos incluso en la salud." (Bastos y Almeida, 2016).

5 Discusión: identificación de los problemas y los impactos de las soluciones producidas.

El impacto de los trabajos presentados acá demuestra los beneficios a los sujetos estudiados, y se reproducidos en una comunidad, genera significativos logros en la vida de las personas, tales como: "Felicidad de los niños al conocer Pité y saber que ella pasó por los momentos que los niños estaban vivenciando"; "La posibilidad de locomoción autónomamente incluso con las limitaciones de una silla de ruedas"; "Reutilización sano del agua generada por el equipo de aire acondicionado". A medida que esas soluciones fueron aplicadas, han proporcionado nuevas oportunidades para mejorar o nuevos desafíos, que llevaron a la búsqueda de nuevas soluciones, lo que nos lleva a decir que esta forma de trabajo de ejercicio en ingeniería, hace con que a ingeniería sea realimentada constantemente.

Para los estudiantes, esta experiencia trujo un aprendizaje significativo, de manera que está en contacto con los desafíos de la profesión de ingeniería. Es evidente la construcción del conocimiento, la aplicación de lo mismo y la exposición a constantes y diferentes niveles de aprendizaje.

6 Observaciones finales

En reanudación del objetivo de esta presentación, fue posible exponer la disciplina y algunos de los trabajos desarrollados. Sobre la base de los principios de PBL fue posible demostrar la singularidad a través de la realización del Trabajo de Grado realizado en la disciplina llamada "Proyecto Supervisado" con los alumnos de Ingeniería Informática de la Universidad de Sorocaba (UNISO).

El PBL propone un tiempo de reflexión de la práctica académica cotidiana, desde el marco teórico del aprendizaje significativo frente a la dinámica de trabajo a través del Aprendizaje Basado en Problemas. La técnica estimula la reflexión sobre "El aprender a aprender" frente a la necesidad de reorganizar el conocimiento hacia las soluciones adoptadas.

Para el maestro, lo que más destaca es la oportunidad de aprender frente al conocimiento construido por los estudiantes y asegurarse de que en ese momento ocurrió el verdadero aprendizaje.

Cuanto a los estudiantes, la experiencia de construir soluciones para la vida cotidiana de las personas y proporcionarles una mejor calidad de vida, contribuyó para la formación de verdaderos ingenieros y grandes ciudadanos.

Esta experiencia de implementación es discutida con la comisión para que otras disciplinas puedan actuar en el mismo punto de vista sobre la formación de los estudiantes de Ingeniería Informática.

Se espera que los resultados presentados aquí han mostrado la importancia de esta disciplina para la formación de ciudadanos participativos e ingenieros responsables de renombre, más cercanos de las personas y de la vida cotidiana.

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Ingeniería para alcanzar un país en paz, sustentable y con desarrollo: Análisis mediante grupos focales

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Resumen

El estado de insostenibilidad en el que se está viendo envuelta la humanidad, llevándola a una profunda crisis en diferentes esferas, alerta sobre la postura que estamos asumiendo para afrontarla. En particular, cómo se están preparando las futuras generaciones para enfrentarla de modo que les permita vivir y desarrollarse en este nuevo contexto.

Los procesos de educación permiten que las personas adquieran la capacidad de describir, pensar y transformar el universo en el que viven. Una de las disciplinas que alienta al espíritu humano para crear e innovar es la ingeniería, un campo que permite convertir ideas en realidades y tiene un impacto directo sobre la sociedad.

Algunos de los desafíos a los que se enfrentan los ingenieros no son fáciles de sortear. Por ejemplo, los fenómenos socioeconómicos y ambientales como el aumento de la población, agotamiento de los recursos, déficit en la calidad y acceso a los sistemas de salud, sumado a un modelo de desarrollo ligado al crecimiento ininterrumpido de necesidades, provocando un aumento desmedido tanto de producción como de consumo. El contexto nacional evidencia la exacerbación de las problemáticas derivadas del cambio climático, altos niveles de pobreza, inequidad, violencia y corrupción.

El aprendizaje basado en problemas estimula el aprendizaje a la vez que permite trabajar en proyectos que busquen soluciones a contextos reales. Es común que la implementación de este enfoque proponga iniciar con entender el problema. Para ello, se realizó un taller con decanos de facultades de ingeniería, usando la metodología de grupos focales. Con la participación de 50 decanos y docentes, se conformaron seis grupos donde se les preguntó cómo la ingeniería puede contribuir en el alcance de un país en paz, sustentable y con desarrollo. En este artículo se describe la realización del taller, la metodología utilizada y los resultados alcanzados.

Palabras claves: sustentabilidad, paz, desarrollo, educación, ingeniería

Tipo de contribución: mejores prácticasIntroducción

El actual sistema mundial es insostenible desde diversos puntos de vista, porque hemos dejado de pensar en los fines de la acción humana (Bergoglio, 2015). Si el problema de insustentabilidad de la vida en el planeta se entiende como síntoma de crisis de la civilización, se puede asumir que la construcción del futuro (sustentable) no puede descansar en falsas certidumbres sobre la eficacia del mercado y la tecnología —ni siquiera de la ecología— para encontrar el equilibrio entre crecimiento económico y preservación ambiental (Leff, 2000). La actividad humana transforma la superficie de la Tierra, altera los

ciclos biogeoquímicos y modifica la condición biológica de los ecosistemas evidenciados principalmente en el cambio climático impactando significativamente los ecosistemas, la vida en general y la vida humana en particular, y la diversidad biológica (Pierri, 2005).

En este punto es preciso reconocer el papel histórico de las universidades en la transformación de sociedades, a través de sus tomadores de decisiones, líderes, empresarios y académicos (Cortese, 2003; Lozano, Lozano, Mulder, Huisingh, y Waas, 2013). Por lo que tiene el potencial de generar el cambio en la forma en la que interactúa el ser humano y su entorno (Lavarack y Elliot 2012) a través del desarrollo de habilidades para encontrar soluciones y crear nuevos senderos hacia un futuro mejor (Organización de las Naciones Unidas para la Educación, la Ciencia y la Cultura UNESCO, 2012).

En particular, en el contexto que se encuentra Colombia, con la firma del acuerdo de paz por parte del gobierno colombiano y las Fuerzas Armadas Revolucionarias de Colombia Ejército del Pueblo (FARC EP) del 24 de noviembre del 2016, que promueve el fin del conflicto armado entre las dos partes, teniendo en cuenta el enfoque territorial que se le da, en el cual es fundamental considerar las necesidades económicas, culturales y sociales de cada uno de los territorios, que busca comprometerse con la sustentabilidad (Gobierno Nacional de Colombia, 2016), es necesario no perder de vista las oportunidades que se presentan desde la educación y más aún desde la educación superior, de que las personas que se ven o se vieron afectadas por los diversos procesos, encuentren mejores condiciones desde la perspectiva de la justicia social.

Las facultades de ingeniería desempeñan un rol fundamental en medio de la situación y desafíos que enfrenta actualmente el país. Por un lado, la necesidad de incorporar la sustentabilidad en su quehacer, permeando la docencia, investigación, extensión, operaciones y comunicación (Cortese, 2003; Lidgren, Rodhe, Huisingh, 2006; Velazquez, Munguia, Platt, & Taddei, 2006; Lozano, 2006) y de esta manera alcanzar un campus sustentable. Adicionalmente, es fundamental que las generaciones de ingenieros estén preparadas para resolver problemas multidisciplinarios y multifacéticos en un contexto nacional y global cambiante, conectando sus conocimientos con el mundo real (Antaya et al., 2014; Rosano & Biswas, 2015).

A la luz de este escenario, es inevitable cuestionarse cuál es el papel de las facultades de ingeniería en la construcción de un país en paz, sustentable y con desarrollo. Con el fin de convertir las problemática en posibilidades y para determinar cuáles son los mejores campos de acción para trabajar desde la facultades de ingeniería, el programa de Ingeniería Sustentable - PINSUS- de la Facultad de Ingeniería de la Universidad Nacional de Colombia decidió implementar un ejercicio bajo la metodología de Aprendizaje Basado en Problemas - PBL, que propone tres elementos en la identificación del problema: conocer el problema, determinar lo que se conoce y se debe conocer y definir el problema.

Pero, cómo activar el cambio institucional dentro de las facultades de ingeniería: ¿de arriba hacia abajo o de abajo hacia arriba? El cambio cultural es crucial para las facultades de ingeniería. Si la cultura no cambia, las reformas educativas desaparecerán tan pronto como el clima político lo permita. Por lo tanto, el cambio de abajo hacia arriba es esencial. La comunidad universitaria debe estar convencida de que la integración de la sustentabilidad en todas las actividades tiene sentido (Mulder et al., 2012).

Para entender la problemática como oportunidades de acción y así aportar a la construcción de campus sustentables, PINSUS junto con la Asociación Colombiana de Facultades de Ingeniería- ACOFI- realizaron un taller denominado Sustentabilidad en las Facultades de Ingeniería realizado en el Encuentro Internacional de Educación en Ingeniería del año 2016 dieron respuesta a la pregunta: cuál es el papel de las facultades de ingeniería en la construcción de un país en paz, sustentable y con desarrollo.

El taller desarrolló la técnica de grupos focales para ayudar a determinar los elementos de la identificación del problema de la metodología PBL. Los grupos focales son un espacio de opinión para captar el sentir, pensar y vivir de los individuos, provocando auto explicaciones para obtener datos cualitativos (Hamui-Sutton A et al, 2013). Mientras que con el enfoque PBL se fomenta el pensamiento sistémico y la colaboración interdisciplinaria, así como un enfoque transformador holístico de resolución de problemas, todos ellos, elementos de la sustentabilidad. Este artículo presenta los resultados del taller. En primer lugar, se presenta la definición de los conceptos, seguido por la descripción de la metodología usada para el desarrollo del taller, por último, los resultados y las conclusiones.

1 Marco conceptual

Una de las prioridades en la actualidad es la necesidad de la integración del concepto de sustentabilidad en los programas de ingeniería (Glavic, 2006), ya que se puede prever entre otras, un aumento de la demanda de ingenieros con altas competencias en tecnologías de producción limpia y gestión ambiental integral (Staniskis & Arbaciauskas, 2003).

La sustentabilidad se entiende como un paradigma para pensar en el futuro en el que las consideraciones ambientales, sociales y económicas se balancean en la búsqueda de desarrollo y una mejor calidad de vida (Mckeown, Hopkins, Rizzi, & Chrystallbridge, 2002). De acuerdo a Boff (2013) la sustentabilidad se define como:

> Toda acción destinada a mantener las condiciones energéticas, informacionales y físico- químicas que sustentan a todos los seres, en especial la Tierra viva, la comunidad de vida y la vida humana, en orden a su continuidad, además de atender a las necesidades de la generación actual y de las generaciones futuras, así como de la comunidad de vida que las acompaña, de tal forma que el capital natural sea mantenido y enriquecido en su capacidad de regeneración, reproducción y coevolución (p. 120).

Este es un asunto que ha estado en varias agendas oficiales, durante por lo menos 15 años en los sectores privado, gubernamental y educativo, para hacer frente a los problemas socioeconómicos y ambientales (Velazquez et al., 2006). Alshuwaikhat y Abubakar (2008) afirman que en el sector educativo, particularmente las instituciones de educación superior (IES), la incorporación de la sustentabilidad en su quehacer ha sido impulsado por diferentes factores como la presión de las agencias gubernamentales de protección ambiental, los movimientos de sustentabilidad, los intereses de las diferentes partes interesadas e involucradas de la universidad, así como el impulso de otras fuerzas como el activismo estudiantil y las organizaciones no gubernamentales. Como resultado de las múltiples presiones, varias universidades se han embarcado en proyectos e iniciativas para incorporar la sustentabilidad en sus sistemas (Alshuwaikhat & Abubakar, 2008) en la búsqueda de una universidad sustentable.

Mulder propone interrogantes a atender para implementar la sustentabilidad en ingeniería:

¿Qué deben aprender los ingenieros en sustentabilidad? ¿Cuáles son los problemas a tratar y cómo resolverlos? Esto implica que un ingeniero debe comprender las complejidades del entorno social en el que él/ella se encuentra desarrollando soluciones y la complejidad de hacer mejoras a corto plazo que se ajusten en un camino a largo plazo de sustentabilidad (Mulder et al., 2012).

Un campus universitario sostenible hace referencia a una institución de educación superior, que direcciona, involucra y promueve la minimización de efectos negativos ambientales, económicos, sociales y en la salud en el uso de sus recursos en sus principales funciones de docencia, investigación, extensión y asociación y administración para ayudar a la sociedad a hacer la transición a los estilos de vida sostenibles

(Velazquez et al., 2006).

A la luz de las definiciones de Velazquez et al. (2006) es claro que alcanzar un campus sustentable no es tarea fácil, de acuerdo a Bauer (2004) para lograr una incorporación efectiva de la sustentabilidad en instituciones de educación superior, es necesario infiltrarlo en todos los aspectos de la universidad (Citado por Velazquez et al., 2006). En concordancia con lo anterior, la sustentabilidad debe permear los diferentes elementos del sistema universitario: Educación (refiriéndose a cursos y plan de estudios), Investigación, Operaciones del campus, Alcance en la comunidad y Comunicación (Cortese, 2003; Lidgren et. al, 2006; Velázquez et. al, 2006; Lozano, 2006). Estos cambios pueden darse por medio de la integración de los diferentes actores dentro de la IES: profesores, investigadores, estudiantes y administrativos; junto a la integración de los actores externos que puedan ser afectados por las actividades de la IES (Lidgren et al., 2006)

Las IES tienen como funciones principales la de educar a los estudiantes y la de producir investigación, que en su conjunto son definidas como la creación de conocimiento. Por lo tanto, la docencia es pensada como el conocimiento que los estudiantes deberían recibir, aquel que les permite potenciar sus capacidades, prepararse para futuros empleos, que introduce en ellos la conciencia y la identificación de las contrariedades del mundo. Así, adquieren la capacidad de transformar la sociedad y por ende mejorar el mundo para que pueda llegarse a una visión de lo que sería una sociedad sustentable.

La investigación constituye el canal para que estudiantes y profesores desarrollen conocimiento, como parte integral del aprendizaje, además de ser puente a las comunidades involucradas e integradas en la investigación (Lidgren et al., 2006), mecanismo para cumplir con una de las funciones de la IES, contribuir al cambio social. Y es por medio del trabajo con las comunidades locales y regionales que se les puede dar soporte para conducir al cambio, liderando la apropiación, por parte de éstas, del conocimiento y del camino hacia la sustentabilidad (Cortese, 2003), lo que corresponde a la proyección social.

Además, existe la necesidad de entender cómo funciona la IES, cuáles son las operaciones que desarrolla para su funcionamiento. Para así, en la gestión de estas operaciones, tender a la reducción de las externalidades negativas que puedan ser producidas y trasgredan la sustentabilidad de la IES (Cortese, 2003). Por último, realizar mediciones y evaluaciones, y, además, comunicar las actividades e iniciativas en torno a la sustentabilidad que se realizan dentro de la IES es necesario para su mejoramiento general (Lozano-Ros, 2003).

El Aprendizaje basado en problemas (PBL por su sigla en inglés) se enfoca en el aprendizaje experiencial, organizado alrededor de la investigación, explicación y resolución de problemas significativos (Barrow, 2000 citado por Hmelo-silver, 2004). De acuerdo a Barrows (1986), los problemas usados pueden variar de preguntas planteadas, fenómenos inexplicables o casos de estudio. Este enfoque se basa en principios como el aprendizaje contextual, crítico, participativo, autodirigido, experiencial y colaborativo (Guerra 2014).

Este enfoque fue desarrollado en la Escuela de medicina de la Universidad de McMaster ha ido evolucionando y adaptándose a diferentes campos como en la ingeniería. Sin embargo, el método original se caracteriza por un aprendizaje centrado en el alumno, en grupos pequeños, la participación de los docentes consiste en ser facilitadores o guías, los problemas son el estímulo para el aprendizaje y son el vehículo para el desarrollo de habilidades en la resolución de problemas, además el aprendizaje autodirigido garantiza la adquisición de nueva información (Barrows, 1996).

La plantilla de enseñanza aprendizaje en PBL de la Academia de Matemáticas y Ciencia de Illinois - IMSA

propone tres fases: entender el problema, explorar el currículo y resolver el problema. En la primera fase se desarrollan tres elementos: conocer el problema, determinar lo que se conoce y se debe conocer y definir el problema. La segunda fase inicia con reunir la información, compartirla y generar las posibles soluciones. Finalmente, en la tercera fase, se determina la mejor solución, se presenta la solución y se debate el problema (DiGiorgio, 2011).

2 Metodología

La técnica de grupos focales privilegia el habla, y tiene como objetivo captar la forma de pensar, sentir y vivir de los individuos que conforman el grupo. Incluyen una temática específica y preguntas de investigación planteadas (Hamui-Sutton A et al, 2013). Para este caso, únicamente se trabajó con una pregunta y una única sesión de trabajo.

Con el fin de explorar la primera fase propuesta por la plantilla de PBL de la IMSA, prepar el taller y establecer las prioridades y definir los problemas para trabajar, se pidió a los decanos de facultades de ingeniería del país que, mediante un artículo, respondieran a la pregunta: ¿Qué acciones, modificaciones de currículo, contenidos y formas de trabajo de los planes de estudio, entre otros, emprenderá su facultad para llegar a ser sustentable y alcanzar un país sustentable, en paz y con desarrollo? Se recibieron en total 17 artículos los cuales fueron revisados y su contenido analizado en el software NVivo(R).

Las categorías utilizadas inicialmente en el análisis de contenido, corresponden a las identificadas en la literatura académica como las actividades típicas de una universidad que típicamente están formuladas como operaciones del campus (gestión), currículo (docencia), investigación, extensión (proyección social) (Lidgren et. al, 2006; Velázquez et. al, 2006) además de la evaluación y presentación de informes (Lozano, 2006). Adicionalmente, durante el análisis de contenido surgió una sexta categoría que resalta la importancia de la contextualización para que las iniciativas sean pertinentes y efectivas. Fue denominada contexto,

Una vez identificadas las seis categorías, se llamó de nuevo a los decanos para realizar un taller presencial en el marco del Encuentro Internacional de Educación en Ingeniería ACOFI 2016 al cual asistieron 50 participantes entre decanos y profesores de ingeniería de universidades colombianas. Los participantes se dividieron en los seis grupos de las categorías identificadas y fueron entregadas a cada grupo las iniciativas y propuestas encontradas en los artículos. Se pidió a cada grupo que revisara las iniciativas, agregara las que considerara pertinentes y realizara, una jerarquización de las iniciativas para determinar cuáles eran las propuestas fundamentales para desarrollar en las facultades de ingeniería del país mediante un árbol de prioridades,. Al final de la sesión, cada grupo presentaba su árbol de prioridades al público. En la raíz del árbol, el grupo debía ubicar el elemento que consideraran prioritario, esencial que después podría convertirse en una iniciativa o posibilidad desde la cual se debería iniciar. En el tallo se ubican los elementos del campus que posibilitan el desarrollo de la raíz y en las hojas se disponen las categorías que se desprenden del tallo. De este modo, la identificación del problema se convierte en posibilidades de acción para las facultades de ingeniería.

3 Resultados y análisis

Como resultado del taller se obtuvieron seis árboles de prioridades, uno por cada dimensión. En primer lugar, se presenta el árbol denominado contexto (Figura 1.), donde la prioridad es alcanzar un mundo sostenible, que contemple las dimensiones de lo social, ambiental y económico además de involucrar

políticas y tecnología siempre teniendo en cuenta la ética y moral. De esta manera, los decanos de las facultades consideran que alcanzar un mundo sostenible es una oportunidad que puede desde las universidades, teniendo en cuenta los elementos sociales, ambientales, económicos, políticos y tecnológicos en el marco de la ética y la moral.

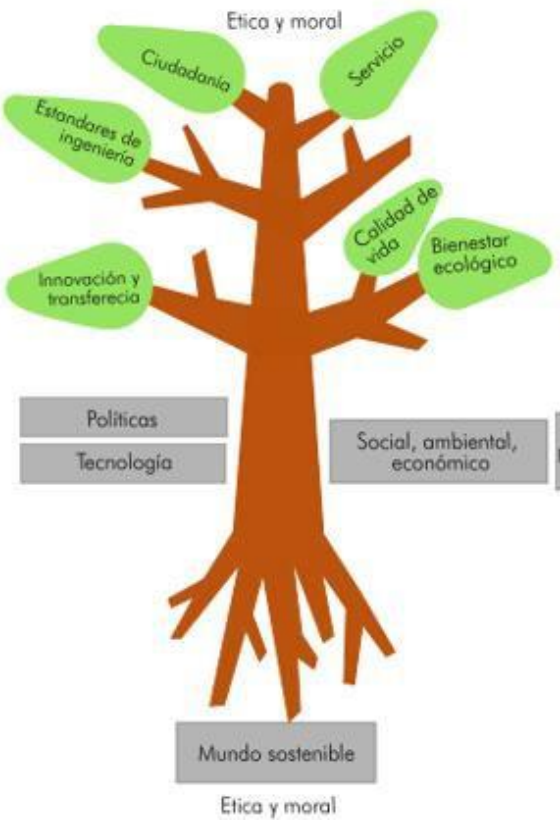

Figura 1. Dimensión de contexto.

Elaboración propia.

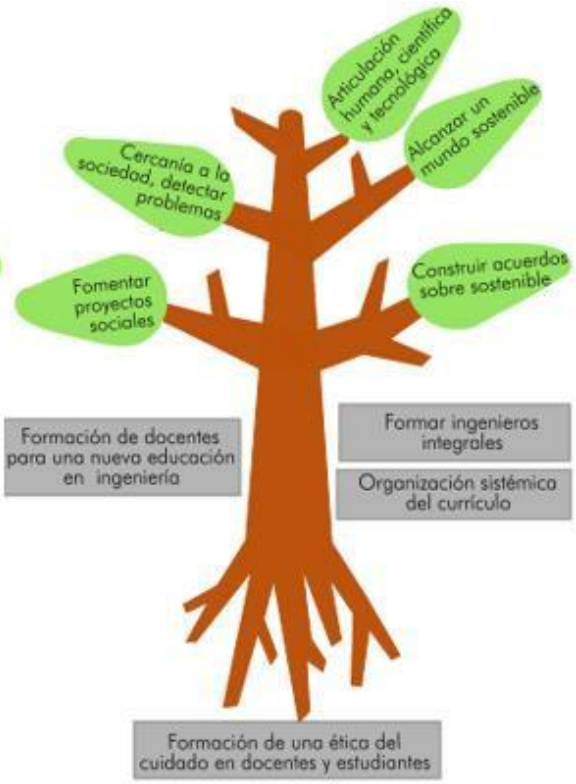

Figura 2. Dimensión de docencia.

Elaboración propia.

En la dimensión de la docencia (Figura 2.), un elemento prioritario es la formación de una ética del cuidado tanto en docentes como en estudiantes, donde elementos como la organización sistémica del currículo, la formación de ingenieros integrales y la necesidad de una formación en docentes para una nueva educación en ingeniería son los pilares indispensables para alcanzar dicha formación. La docencia que requiere el país necesita la articulación humana, científica y tecnológica, donde el factor social tenga una prioridad, la identificación de problemas sea el resultado de la cercanía entre la academia y la sociedad, y la formulación de proyectos sociales tenga una mayor relevancia.

Por su parte la investigación (Figura 3) requiere un direccionamiento hacia lo pertinente, con impacto social positivo y visible. Este direccionamiento requiere un ajuste de las políticas institucionales, acompañado de un desarrollo de modelos y análisis prospectivos, elementos que facilitaran una mejor orientación de los recursos, el fomento de la investigación en la industria en diferentes sectores a través de alianzas, una investigación asociada a los problemas del país, orientada al desarrollo social e inclusión y que incorpore la sustentabilidad.

La proyección social de las facultades (Figura 4) se debe enfocar en la construcción de la sociedad, una sociedad resiliente, ética, con equidad y con múltiples interacciones. Para ello es necesario la creación y ajuste de políticas y programas que faciliten el establecimiento de alianzas estratégicas, donde prime una conciencia colectiva caracterizada por la transparencia, la justicia social, responsabilidad, inclusión, y donde se evidencie un trabajo social encaminado hacia la paz.

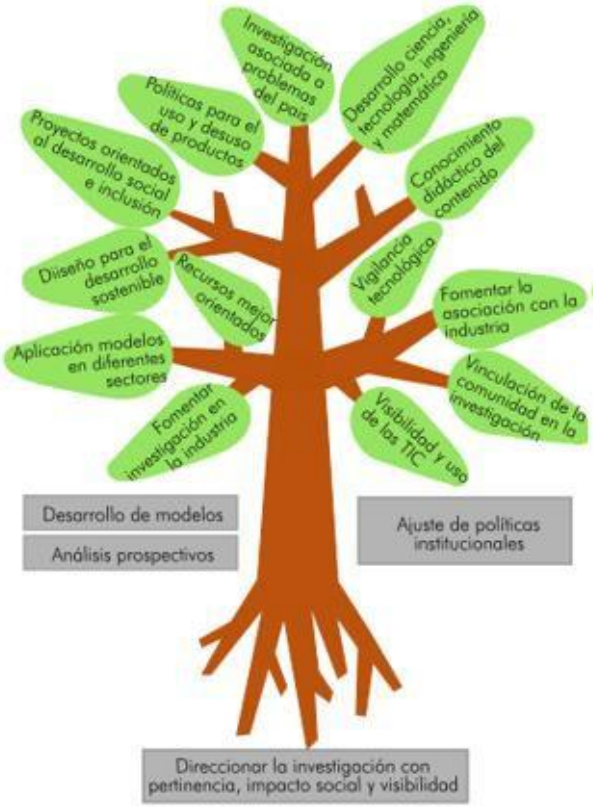

Figura 3. Dimensión de investigación.

Elaboración propia.

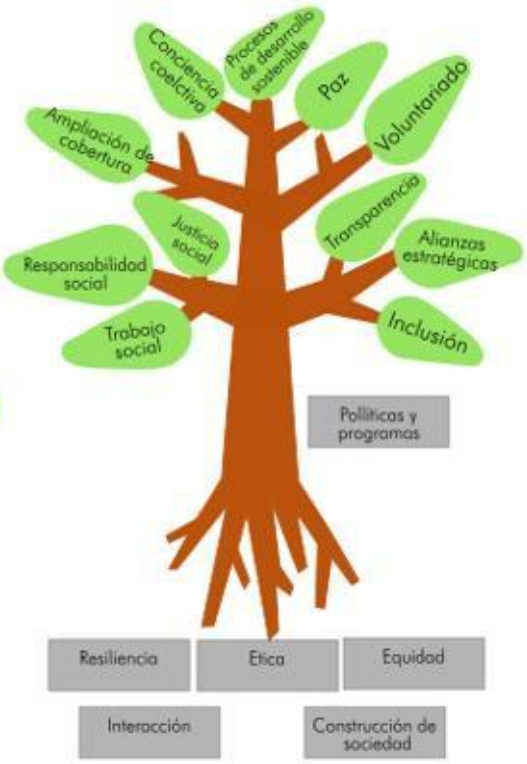

Figura 4. Dimensión de proyección social.

Elaboración propia.

La gestión (Figura 5) debe ser orientada por los principios y valores de sustentabilidad junto al establecimiento de políticas estratégicas que guíen las operaciones de la facultad y la promoción de iniciativas sustentables. Iniciativas como el cambio de infraestructura, la incorporación de tecnologías eficientes energéticas, la gestión integral de residuos, el contar con sistemas de gestión ambiental, además de incorporar criterios de sustentabilidad en la selección de proveedores son algunas de las propuestas de los decanos y docentes.

Así mismo la comunicación (Figura 6) se debe fundamentar en la construcción de sentidos de la realidad y en las necesidades de las comunidades. Debe ser un puente entre la academia y el estado, donde se sienten posiciones y se identifique el tipo de organización y tipo de desarrollo que requiere el país. La comunicación se debe llevar a cabo entre comunidades, universidades, gremios, órganos de regulación y gubernamentales, estudiantes, docentes y administrativos.

Adicionalmente, el ejercicio permitió que los decanos elaboraron una declaración que fue leída en la

clausura del Encuentro de ACOFI donde manifestaban su compromiso por la Sustentabilidad, la paz y el desarrollo de Colombia (Anexo 1).

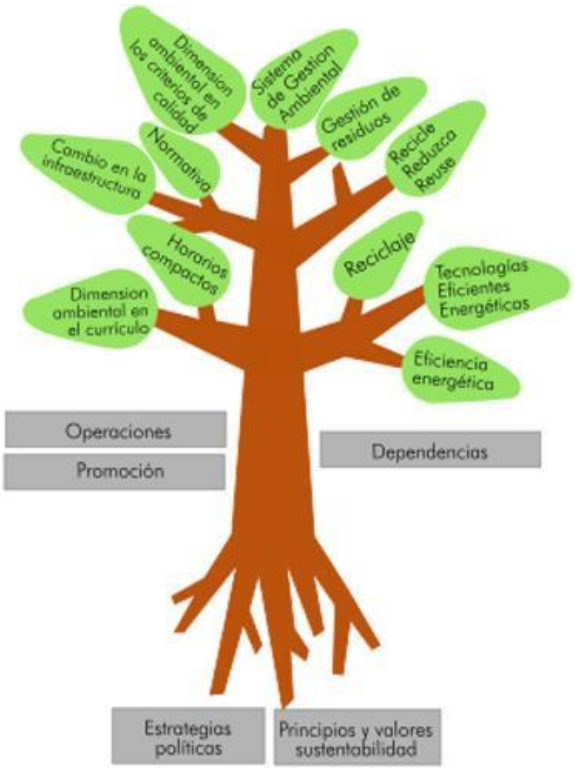

Figura 5. Dimensión de gestión.

Elaboración propia.

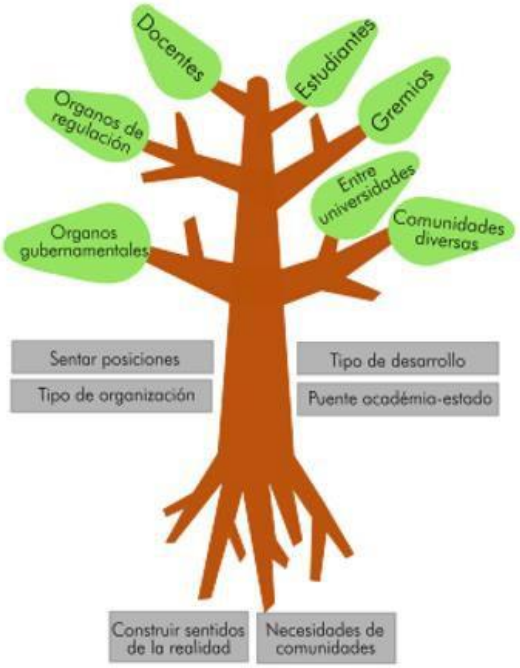

Figura 6. Dimensión de comunicación.

Elaboración propia.

4 Conclusiones

Con el desarrollo de esta actividad se reafirma el compromiso y el papel fundamental de las facultades de ingeniería en la construcción de país, también da cuenta de la ardua tarea que sobre ellas recae y el camino que queda por recorrer para contribuir en el alcance del país que los colombianos necesitan.

Es importante reconocer que la incorporación de la sustentabilidad en las facultades de ingeniería se da a través de pasos incrementales, de ahí la necesidad de contar con una hoja de ruta que facilite su incorporación. Los resultados y su respectivo análisis permitieron identificar esa posible ruta para que las facultades de ingeniería involucren la sustentabilidad en su quehacer, desde estrategias e iniciativas que van desde lo operacional hasta lo estratégico y desde el corto, mediano y largo plazo.

Los aspectos detectados en cada una de las dimensiones se convierten en el punto de partida para la realización de actividades académicas con enfoque de PBL que permita a los estudiantes aportar en el camino hacia la sustentabilidad de sus respectivas instituciones. Hay variadas iniciativas que pueden ser consideradas para la realización de estas actividades, que implican el trabajo interdisciplinario desde las facultades de Ingeniería.

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Anexo 1

Asociación Colombiana de Facultades de Ingeniería (ACOFI) PRONUNCIAMIENTO

Las facultades de ingeniería del país comprometidas con el desarrollo sustentable en el marco de la paz.

Los decanos de las facultades de Ingeniería se reunieron en la ciudad de Cartagena de Indias, en el marco del Encuentro Internacional de Educación en Ingeniería (EIEI) ACOFI 2016. Debatieron sobre el papel de las facultades frente a los nuevos escenarios de desarrollo del país, a las problemáticas derivadas de los cambios climático, social, político, económico y cultural, y a los fenómenos de contaminación ambiental, sequía, inundaciones, abastecimiento de alimentos, agua potable, efectos negativos de las obras de ingeniería, escasez de recursos, inequidad, saneamiento básico, deficiente infraestructura y corrupción entre otros. Así mismo, discutieron sobre las transformaciones políticas requeridas en el país, la coyuntura actual representada en los resultados del plebiscito y la difícil situación política de incertidumbre que pueden llevar al incremento de las brechas históricas presentes en el país.

Las facultades de ingeniería asociadas en ACOFI nos comprometemos a la construcción de un mundo sustentable, de una sociedad ética, resiliente, equitativa, basada en la formación de ciudadanos e ingenieros comprometidos con una ética del cuidado del ser, del otro y de su entorno. Ofrecemos todas nuestras capacidades reafirmando la voluntad que tenemos de co- construir y respaldar las estrategias y políticas que permitan la consolidación de un país en paz, sustentable y con desarrollo.

Frente a los resultados del plebiscito del pasado domingo 2 de octubre, las facultades de ingeniería hacemos un llamado a los diversos actores políticos para dejar de lado la polarización y buscar un verdadero camino que supere el conflicto.

Las bases del premio Nobel estipulan que éste debe ser entregado a la persona que haya hecho el mejor o mayor trabajo a favor de la fraternidad entre las naciones, la supresión o reducción de ejércitos o en la participación y promoción de congresos de paz y derechos humanos en el año inmediatamente anterior". Reconocemos y saludamos la labor que el gobierno y el equipo negociador ha realizado y felicitamos al presidente Juan Manuel Santos por el reconocimiento otorgado.

Finalmente, invitamos a nuestras comunidades académicas a mantenerse informadas y a continuar siendo parte activa en los mecanismos de expresión y participación, fortaleciendo las bases de escenarios que permitan conseguir el mejoramiento de la calidad de vida y a su vez, la posibilidad de satisfacer las necesidades para las generaciones futuras.

Asociación Colombiana de Facultades de Ingeniería —ACOFI—

Impact of PBL and company interaction on the transition from engineering education to work

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Abstract

In order to identify transition issues from engineering education to work, the PROCEED-2-Work project follows a cohort of Danish engineering students. The project is a continuation of a previous research project PROCEED (Programme of Research on Opportunities and Challenges in Engineering Education in Denmark) where one of the sub-projects has followed the students who started their studies in 2010. In the PROCEED-2-Work project, data was collected in 2015 among the engineering students on their expectations for work once they graduate.

A comparative analysis of engineering students from Aalborg University (AAU) in 2015 with the rest of the Danish engineering students educated at the other Danish engineering institutions has been conducted in order to study the implications of a comprehensive PBL model (problem and project based learning). The hypothesis is that students who have been educated in an intensive PBL environment would be better prepared for a work situation than other students.

The results indicate that there are significant differences between the two groups on a variety of factors. There is no significant difference between AAU students and other Danish engineering students in regard to technical knowledge and professional methods, but in the areas of society and environment, business and organisation, AAU engineering students all assess the variables significantly higher. The study shows that students with interaction with companies during the program, including collaboration on problem solving, internships and company visits, score significantly higher regarding the extent to which they think it has helped them prepare for work. Furthermore, the study shows that both internship and project work prepare students for work to a higher degree than the more theoretical courses. However, a comparison between internship and project shows that project work scores slightly better than an internship in relation to how prepared the students find themselves for work.

Keywords: Problem based learning, employability, university/company interaction

Type of contribution: Research paper

1 Introduction

Employability has been on the political as well as the research agenda for some decades as gaps have been identified between education and work; e.g. a McKinsey report indicates that we are far from creating bridges between work and education (Mourshed, Farell, & Barton, 2012). The Royal Academy, UK, also points at similar problems, noting that graduates are not able to go straight into a job and work, and that companies and organisations have to invest in this transition process since graduates do have a shortage of skills. There is a general belief that the curriculum should be improved in this regard (Lamb et al., 2010; Spinks, Silburn, & Birchall, 2006).

The transition from education to work is a rather complex process to study. In general, there may always be transition problems when moving from one institutional culture to another, such as from academia to business. Different institutions have different practices and thereby different cultures. Therefore, there are also methodological considerations required in order to study the transition, as it involves both:

- a diverse theoretical focus on educational learning combined with aspects of professional identity, culture, organisation and retention of knowledge.
- a diverse group of actors (from educational side: students, academic staff, parental background, family; from employer side: managers, Human Resource Units, colleagues etc.).

In reviewing the literature, there are many reports on employers' requirements and graduates' experiences, but fewer on academic actors' views on the transition issues. However, all recommendations point at a change in education (Kolmos, Holgaard, & Bylov, 2016).

In the literature, there are very few studies on academic attitudes to employability. A Swedish study indicates that academic staff with professional work experience are more positive compared to staff with no professional experience (Magnell, Geschwind, & Kolmos, 2016; Magnell & Kolmos, 2016). Other studies find that academic staff rate knowledge and competences contrary to employers' and graduates' views, especially in relation to critical thinking.

There are very few studies on students' approaches to and learning of the employability skills. Students will always react to a formal curriculum with the objective of passing their exams, and they will mirror the priorities set in the curriculum. However, students also want to get a job. Studies conclude that the students' priority of employability increases as their studies progress (Moreau & Leathwood, 2006) and that students expect their academic knowledge and competences to be of importance. They do, however, voluntary work outside university as a way of adding value to the academic competences (Tomlinson, 2008).

A longitudinal study of business students uncovered their view on which transferable skills might be necessary for a later work situation (Tymon, 2011). Data was collected in the first, second and final years. During their education, the students found that employability mattered more as time went on, and that the students' confidence in expressing themselves increased. The students also found that an internship was the most efficient way to learn about employability as well as teamwork, etc.

Problem and project-based learning (PBL) has been pointed at as a solution to bridge these gaps. A Swedish study indicates that the best way to integrate employability with education is through company projects where students learn to apply their academic knowledge on concrete problems and experience a work environment, or through co-curricular activities, which are often more open and problem-oriented compared to the traditional curriculum (Stiwne & Jungert, 2010). However, there are few studies showing evidence that PBL actually has a positive impact on their readiness to enter the workplace.

In this article, we will present data from the Danish PROCEED-2-Work project on Danish engineering students' expectations and readiness for their future work situation (Kolmos & Bylov, 2016; Kolmos & Koretke, 2017).

The PROCEED-2-Work study is a longitudinal study of the cohort of enrolled engineering students in 2010. It is a continuation of a completed project, funded by the Strategic Research Council: PROCEED (Programme of Research on Opportunities and Challenges in Engineering Education in Denmark). PROCEED-2-Work follows a cohort of students enrolled in 2010 and on into the labour market to analyse their understanding of the engineering profession and expectations of working life. Surveys were sent out to all Danish engineering students enrolled in 2010, and with follow up surveys in 2011, 2015 and 2016.

In Denmark, PBL is a common teaching and learning methodology for all engineering institutions, where institutions assign project work and initiate projects with companies. However, the degree of application of PBL in the curriculum may differ considerably from one institution to another and from one engineering program to another, in terms of: 1) how many projects students are involved in, 2) how much of the entire curriculum is based on projects, 3) how the progression is throughout the study, 4) how open and problem-oriented the projects are, 5) how the projects interact with the taught courses, and 6) how the projects are supervised or facilitated.

A full mapping of these questions does not exist, but what we know is that Aalborg University stands out compared to the other universities by having: 1) students involved in at least 10 projects for a master's degree, 2) 50% of the entire curriculum based on projects, 3) the students complete projects from the first semester onward that involve learning PBL competences, 4) a mix of open and more narrow problems to work on, 5) most projects interact with the taught courses in a semester and 6) all project groups work are assigned a supervisor/facilitator.

Therefore, we decided to make a comparison between:

1) the engineering students from Aalborg University with the rest of the Danish engineering students to see which impact an institution with a systemic PBL approach combined with traditional lectures would have on the students' experience of the transition from engineering education to work.
2) the students who have been involved in some kind of interaction with companies and students who have not had any experiences with company interaction.

As PBL is based on an intention to simulate a professional practice and contribute to real-life problem identification, problem analysis and problem solving, our hypothesis would be that students from larger scale PBL institutions would find themselves better prepared for work life compared with students from lower scale PBL institutions, and that students with some experience with companies would find themselves better prepared compared with students who have no engagement with companies.

2 Methodology

In the PROCEED-2-Work study 2015, we focused on students' views on the transition process, and we have selected two main variables to study this: students' experiences on how ready they feel and how they experience their own competences. As the study focuses on students in their final semester, their expectations and confidence in how ready they experience themselves to move into a new organisational culture is regarded as an important factor for their choices.

The construction of the survey is inspired by the Academic Pathways Studies of People Learning Engineering Survey (APPLES) by the Center for the Advancement of Engineering Education, US (ABET, 2011; Atman et al., 2010). According to Atman et al. (2010), their variables were inspired from the ABET criterion three program outcomes list (ABET, 2011) and the National Academy of Engineering report, *The Engineer of 2020* (National Academy of Engineering, 2004). In the PROCEED-2-Work project, an adjustment has been made to accommodate Danish conditions (Kolmos & Bylov, 2016).

It is a longitudinal study with a cohort of 3,969, including students starting out in 2010 and additional master's students enrolled at the master's level. Of the 3,969 students, 1,141 responded to the survey in 2015, resulting in a response rate of 29%. This response rate has not been corrected for the percentage of students who dropped out of the study since their enrolment in 2010, which will be about 25%. Out of the

1,141 respondents, there are 295 AAU students and 846 students from other Danish engineering education institutions, see table 1.

Table 1: Respondent group, gender and institution

	AAU	Other Danish Engineering Institutions
Women %	33.6%	28.3%
N	N=99	N=239
Men %	66.4%	71.7%
N	N=196	N=607
Total N	N=295	N=846

The analyses of the data have been partly based on frequency analysis, cross tabulations and t-tests in order to find whether there are significant differences between students from AAU and students from other Danish universities.

Table 2: Readiness factors (Kolmos & Bylov, 2016)

Variable	Constructed factor	Reliability test: Cronbach's alpha
Contemporary issues Ethics Global context Societal context Environmental impact Social responsibility	Factor 1: Society and environment	0.851 (N=986)
Conducting experiments Data analysis Engineering analysis Engineering tools Problem solving Maths Science	Factor 2: Technical knowledge	0.774 (N=976)
Business knowledge Communication Creativity Design Leadership Life-long learning Management skills Professionalism Teamwork	Factor 3: Business, organisation and transferable skills	0.752 (N=980)

Table 2 show the factor analysis of the readiness factors. Factor analysis has been carried out inductively and the varimax rotation principles have been applied. For all factors, the Kaiser-Meyer-Olkin Measure (KMO) has been conducted, requiring a total correlation of above 0.7 as an acceptable correlation (De Vaus,

2002). Additionally, the Cronbach's Alpha test was carried out as a reliability test. All factors have a coefficient of 0.7, and can be said to be reliable and useful for later analyses (De Vaus, 2002).

The factors are very well aligned with the theoretical understanding of the three different university modes: the academic-oriented mode 1, the market-driven mode 2, and the community-driven mode 3 (Jamison, Kolmos, & Holgaard, 2014). In the academic mode 1, theoretical knowledge is prioritised (Factor 2: technical knowledge), whereas the market-driven mode 2 is oriented toward business knowledge, management and competences, etc. (Factor 3: business, organisation and transferable skills). The community-driven mode 3 has a society orientation with a general education and value orientation (Factor 1: society and environment).

3 Findings

In Figure 1, the engineering students at AAU score slightly, yet significantly, higher on the readiness factors of "society and environment" and "business, organisation and transferable skills" than the engineering students at other institutions. For the readiness factor "technical knowledge", there is no significant difference. The factor analysis indicates that students at AAU, compared to students from the remaining Danish institutions, differ in particular in their readiness in relation to contextual aspects in engineering education; this is the case for both business and the broader society context.

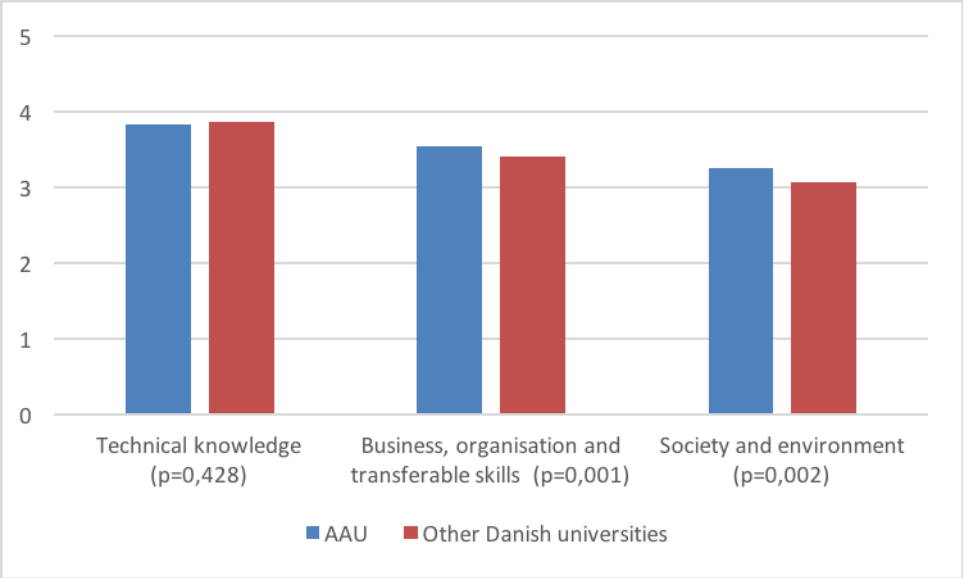

Figure 1: Readiness factors and institution. N=1000-1009. Average, T-test.

The single variables in the constructed factors show that the students from AAU find that they are better prepared regarding eight out of the nine significant single variables, compared to students from other institutions, se table 3. The students from other Danish institutions are better prepared in relation to mathematical skills. In the factor of "society and environment", students from AAU estimate that they are better prepared for all the single variables of "societal context", "contemporary issues", "social responsibility", and "environmental impact". For the factor of "business, organisation and transferable skills", there are significant differences in relation to, "communication", "teamwork" and "management

skills". Finally, the AAU students also scored significantly higher for the single variable "problem solving" in the factor relating to technical knowledge.

Table 3: Readiness and institution. *Only significant variables presented. Significant level: ***=p<0.01, **=p<0.05, *=p<0.1 N=1000-1009*

	AAU	Other Danish Institutions
*** Societal context	***	
*** Contemporary issues	***	
** Social responsibility	**	
* Environmental impact	*	
** Problem solving	**	
* Math		*
*** Teamwork	***	
** Communication	***	
** Management skills	**	

3.1 Readiness, institutions and project work

Looking at the findings, there is no doubt that for the Danish engineering students, PBL is a factor in the students' experience of readiness for their coming jobs. Furthermore, the Kolmos and Bylov report (2016) indicated that students experienced projects at the master's level of special importance for providing an understanding of their future profession. Following that argumentation, we have asked what kind of interaction the students had with companies in their projects.

Table 4: Degree of interaction with companies comparing students from AAU and other Danish institutions. N=863-881. ***=p<0.01, **=p<0.05, *=p<0.1.

	AAU	**Other Danish Institutions**
Company visits in relation to the semester theme	2.65	2.55
Worked on a project proposed by a company	2.18	2.19
Cooperated on problem solving	2.16**	1.98
Formulated the problem of the project in cooperation with a company	1.99*	1.85
Internship in a company (more than a month)	1.66**	1.52
Internship in a company (more than a week)	1.62**	1.42

Table 4 shows the results of the average level comparing the interaction with companies in project work for AAU students and students from other Danish institutions. The conclusion is that AAU students generally have a higher average for almost all variables, and the difference is significant regarding the variables "formulated a problem in cooperation with a company", "cooperation on problem solving", as well as "internship in a company (more than a month/week)". It appears that students from Aalborg University seem to have more interaction with companies than the average student from another Danish University.

When we look at whether the students felt that the interaction with companies did prepare them for the future labour market, AAU students generally score higher than students from other Danish universities, see table 5. There are significant differences in three of the six variables related to cooperation on problem solving, internship (more than a week) and the gain of company visits. Thus, students from AAU not only experienced a higher degree of interaction with companies in the program, but they also experienced that this interaction prepares them more for a work situation after graduation than for students at other Danish universities.

Table 5: Impact of relation to companies in project work on the readiness comparing students from AAU and other Danish institutions based on the question: To what extent do you think that the following activities have helped you to get ready for the labour market? N=573-756. ***=p<0.01, **=p<0.05, *=p<0.1.

	AAU	Other Danish Universities
Internship in a company (more than a month)	3.02	2.86
Cooperated on problem solving	2.97*	2.79
Worked on a project proposed by a company	2.86	2.87
Internship in a company (more than a week)	2.78*	2.58
Formulated the problem in project in cooperation with a company	2.75	2.74
Company visits in relation to the semester theme	2.55**	2.38

3.2 Company projects and readiness factors

As already indicated, all Danish institutions offer possibilities of project work, although this is not the same as requiring that all students will experience projects. In the following section, we will focus on the comparison of students who have had projects with companies or internship versus students who did not, in order to find out the impact on the students' experience of readiness for work. In table 6, we show the readiness factors for all students across all Danish institutions comparing students with or without experience with specific kinds of interaction with companies and related this to the three readiness factors: "society and environment", "technical knowledge", and "business, organisation and transferable skills".

It seems that relating to and cooperation in projects with companies during education makes students feel more prepared to apply competencies related to "society and the environment" and "business, organisation and transferable skills".

The internship variables appear to provide increased significant more readiness related to the factors "society and environment" and "business, organisation and transferable skills", while students who have not attended internship experience a significant higher degree of readiness in relation to technical

knowledge. These results can mirror what students are exposed to in the curriculum, if in the educational program there is more focus on the technical knowledge and less focus on the two other readiness factors.

Table 6: Types of relation to companies and readiness factors ***=p<0.01. **=p<0.05. *=p<0.1.

	Whether the study activity has been applied	Society and environment	Technical Knowledge	Business. organisation and transferable skills
Internship in a company (more than a month)	No (N=476-485)	3.04	**3.93*** **	3.35
	Applied (N=370-377)	**3.21** **	3.77	**3.53*** **
Internship in a company (more than a week)	No (N=522-531)	3.05	**3.92*** **	3.37
	Applied (N=326-330)	**3.20** **	3.77	**3.53*** **
Company visits in relation to the semester theme	No (N=191-195)	2.84	3.88	3.25
	Applied (N=656-664)	**3.20*** **	3.86	**3.49*** **
Cooperated on problem solving	No (N=341-346)	2.97	3.82	3.30
	Applied (N=492-499)	**3.22*** **	3.89	**3.52*** **
Formulated the problem of the project in cooperation with a company	No (N=372-378)	2.97	3.85	3.32
	Applied (N=476-484)	**3.22*** **	3.87	**3.53*** **
Worked on a project proposed by a company	No (N=246-248)	3.04	3.76	3.34
	Applied (N=603-615)	**3.15* **	**3.90** **	**3.47** **

On all the three project variables: “cooperated on problem solving”, “formulated the problem of the project in cooperation with a company”, and “worked on a project proposed by a company”, there is a similar pattern that the students felt themselves better prepared for the two contextual factors of “society and environment” and “business, organisation and transferable skills”. However, in the area of “technical

knowledge", the students who applied any of the project variables in education scored higher compared to the students who did not have applied projects, and, for one of the variables, there is even a significant difference: if students have "worked on a project proposed by a company" they perceived themselves to be significantly readier in relation to all the accounted factors.

4 Discussion

The PROCEED-2-Work study was not designed to study PBL, but indeed to study the transition from education to work where teaching and learning methods are some of the core variables. The data presented here represents two different perspectives: 1) comparison of AAU and other Danish engineering students' responses to their experience of readiness to the future work situation, 2) comparison of all respondents' type of activity combined with a view on company interaction and readiness factors.

The differences in the institutional frameworks in relation to PBL, however, make it possible to analyse the readiness of engineering students at AAU, who are educated in an intensive PBL environment, just as they are about to enter work life as a professional engineer. This study has identified significant differences even though many other Danish universities have implemented elements of PBL in their curricula.

PBL, institution and readiness

Kolmos and de Graff (2014) present three approaches to characterise PBL: a learning approach, a social approach and a contents approach (Anette Kolmos & Graaff, 2014). The learning approach stresses authentic real-life problems, not only as a starting point for learning, but also as a reference point for the learning process as such. The social approach underlines learning as a social but also as a participant-directed act. The contents approach stresses interdisciplinary and exemplary learning in PBL, and the need for interaction between theory and practice. With this focus on real-life problems, interdisciplinary co-creation of knowledge, exemplarity and participant-directed knowledge, it might not be that surprising that AAU, with their comprehensive PBL model, stands out in educating for business, organisation and transferable skills as well as for society and environment. However, it is remarkable that there are no significant differences when it comes to the technical knowledge factor, and when looking at the single variables, the only significant difference is connected to Maths (and only with $p<0.1$).

Taking the different knowledge modes into consideration, the results thereby indicate that PBL pushes the model of knowledge from mode 1 toward mode 2 and 3, and therefore can be a driver in educational change. The community-driven mode 3 has a society orientation with a general education and value orientation, which is often missing in engineering education and which is highly relevant for learning to analyse problems, ensuring that the relevant problems are solved. However, when considering the readiness factors, it is also worth noticing that when we compare the level of readiness in the different factors, the level of readiness still follows the same order at AAU as in other Danish universities. On average, students have the highest level of readiness in the field of technical knowledge, then business, organisation and transferable skills and lowest rated is society and the environment. The AAU data, however, show that it is possible to raise students' readiness to face the need for mode 2 and mode 3 knowledge, without making a comparable compromise with preparedness in relation to technical knowledge.

Of course, it can then be discussed whether it is considered to be the "right" knowledge, skills and competences for engineering students when they have, in fact, entered the workplace. Such discussion calls for further research.

Projects versus internships

The results of this study also indicate that there is a documented difference between internship and projects. Projects in education seem to give the students an idea and picture of their future profession. In the projects, they have the possibility for various forms of interaction with the external stakeholders – normally the companies. They have the opportunity to visit companies and to collaborate on analyses of the company problems and projects. However, they do not experience a daily routine in the same way as if they had been in an internship.

Internship on the other hand, gives students the opportunity to experience another organisation in which they have to share their academic knowledge in new ways. However, the outcome of internship is not always efficient and is very dependent on the company's ability to facilitate the student internally. Several EU projects have looked at developing guides and sharing experiences on how to improve the outcome of internships (Henriksen, 2013). Seen from a curriculum point of view, where institutions are always struggling with overloaded curricula, these guides and shared experience would provide an advantage.

Comparing the results on internship and projects in companies is quite relevant for finding ways of integrating practice into education. Projects and internships are two different methodologies, which sometimes can also be combined. Seen from a curriculum point of view, projects might be preferred as these still are done according to academic learning outcomes and are facilitated by academic staff.

5 Concluding remarks

This paper has presented a comparative analysis of engineering students from Aalborg University (AAU) with the Danish Engineering students educated at all other Danish engineering institutions. Even though Danish engineering education is characterised by an extensive use of PBL methods, AAU is one of the universities that stands out due to a comprehensive PBL model.

The hypothesis was that students who have been educated in an intensive PBL environment would be better prepared to the work situation than other students. The results indicate that there are significant differences between the two groups on a variety of factors. There is no significant difference between AAU students and other Danish engineering students in regard to technical expertise and professional methods, but in relation to factors of "society and the environment", "business, organisation and transferable skills", AAU engineering students all assess the variables significantly higher. This points to PBL as an effective method for educational change in engineering education that takes into consideration the business context as well as broader societal challenges.

Furthermore, the study shows that students from AAU experience more interaction with companies during the program, and at the same time the AAU students score significantly higher regarding the extent to which they think that cooperation in problem solving, internship and company visits has helped them to get ready for work. This is closely related to the contextual and exemplary nature of PBL. Real-life problems are contextually rooted and thereby should be addressed "out there" in close collaboration with the actors involved in identifying, analysing and solving the problems at hand. Academic communities are among those actors, but they are far from the only ones.

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Learning together – working together. PBL in cooperation with companies

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Abstract

In the context of a Project Based engineering School (PBS), every student carries on at least one capstone project. The project has, among its objectives, to bring the "real world" to the students, which is done through the collaboration of external agents, such as companies, institutions or NGOs. In this work we sought to identify the concerns experienced by students, teachers and companies involved in the projects developed in the PBS according to their perceptions. To do so, we made an online survey to teachers, students and companies taking part in the projects as well as an informal interview to companies' representatives. It seems that the perception of the students is influenced by the type of collaboration with the company (in the proposal, in giving feedback or just the evaluation of their results). They feel their work more important when they asses them and have more sense of responsibility as the project is real. However, they also feel anxiety and stress when making the final presentation in front of a company. In general, students recognized that projects with companies are a powerful experience as they provide closeness to the professional world. Teachers say that coordination between parties is a key factor in the definition of the concrete objectives of the project and the subjects involved. They find difficult to match the curricula matching with the company needs, but help them to learn in a closer way to their students' future as engineers. It seems that a global involvement of companies decreases not only the university-business distance, but also facilitates a rapprochement due to its involvement in the learning of future engineers.

Keywords: Companies-University, PBL, students' motivation

Type of contribution: research paper.

1 Introduction

Accrediting agencies in engineering education such as ABET (2015) or EUR-ACE (ENAEE, 2008) stand that universities should not only teach knowledge and develop skills but also prepare future professionals in a globalized world. Employers often criticize students are not prepared for real engineering problems and demand university focus on it (National Academy of Engineering, 2005; Markes, 2006; King, 2012).

In the UNESCO report for engineering education (2010) we can find that one of the most effective active learning methodologies is Project-Based Learning. With this methodology students will have to work with real engineering projects during their studies, learning the process through which the product is made. So, they will have to face the short and midterm challenges of the process having a deep impact in their learning process. Project-Based Learning (PBL), as a learning methodology, could help engineering students to develop the industry required competences.

1.1 Context

In this context, a 'Project Based engineering School' (hereafter PBS) was implemented at our university during the 2012-13 academic period (Terrón-López, et al., 2016). This PBS consists on including the PBL (Project Based Learning) methodology in all its degrees. Students learn through the realization of what we call 'capstone projects' in order to approach them to the projects that they will have to develop as future engineers, going from a traditional model of teaching to a more practical one in which the student is the axis.

There are two levels of implementation of the methodology within the School, through capstone projects inside the courses (integrative projects or subject projects) or through student club projects outside the courses. The School is committed to having at least one capstone project developed per student each year.

Student club projects are developed within a student club. This means that it is the students themselves, along with the teachers who coordinate the club, who decide their nature, duration and scope.

The subject projects are framed in a single subject, thus, smaller or simpler projects that make the student familiar with this way of working.

Integrative projects, on the other hand, cover more than two subjects. The project is related to different courses and the student must integrate the learnings of each one of them in order to find the solution to a previously stated challenge that has the appearance of a real project.

To enhance the students' experience, at the end of each academic year, teachers choose their students' bests projects. These are presented at the university auditorium in an especial session with the attendance of the entire faculty, students and companies' representatives. These industry representatives, along with teachers and academic directors will act as judges to award the best project of each field of study.

1.2 Objectives

During the PBS implementation it was detected an interest from companies and students to have the projects developed in the classrooms closer to the industry (Terrón-López, et al., 2016). In fact, it was intended that as far as possible an external agent to the university participates in its design, development and subsequent evaluation.

The objective of this paper is to explore how the collaboration of our university with industries is significant not only for students but also for the companies participating in the PBS.

The collaboration with industries can be significant not only for a curricula design and revision, stablished on PBL, but also for students for whom projects linked to industry will create opportunities to put them in real contexts (Chandrasekaran, et al., 2013).

Nowadays this collaboration can take place in three different moments during the project development:

- At the beginning: the company suggests a project or situation that students should solve during the subject.
- During the project: the company gives feedback to students to help them in the taking-decisions process.
- At the end of the project: to assess the projects made by students or just to see the projects made by the students.

Therefore our intention was to see to what extent these three kind of collaboration are significant for all the stakeholders in the PBS (university and companies).

2 Development of the experience and results

Every capstone project starts in the same way. The teacher (or teachers, if it is an integrative project) presents a challenge that students must achieve in teams. During the capstone project work period, the teachers monitor the progress of the teams and guide students if necessary. Once finished, students submit their project. The final grade obtained has repercussions in all subjects related to the project.

At the end of each academic year, a "Ceremony of awards for the best integrating projects" is celebrated to motivate the students, to reward their good work, and to reinforce the link between the student and the business sector where the best projects are awarded. The teachers propose the award-winning integrating projects and a commission made up of internal staff selects the finalists (three projects per area).

On the day of the award, companies, foundations and NGOs, who have not participated as collaborators in the elaboration of the integrating projects, are invited as members of the jury that value and decide the winners. In the last edition, 9 companies and 11 professionals of the sector have collaborated.

Taking advantage of this session, informal interviews to representatives from the companies who attended to this event were done. These interviews were done in order to gather their overall perception about the projects processes and results, about the possibility to repeat their participation and to suggest us any improvement they could consider that should be done. We wanted to know whether a global involvement of companies decreases not only the university-business distance, but also facilitates a rapprochement due to its involvement in the learning of future engineers.

2.1 Results about students' perceptions

An online survey to the students participating in projects was performed at the end of each project. The survey was anonymous and 137 students answered it (88% of the total students participating).This survey had 6 questions related to the collaboration of a company. At the end of the survey, three open questions were asked about the capstone project developed: what was the best, what was the worst and how will you improve it. These answers were qualitatively analyzed in order to extract the students' perceptions (Berg, 2004). Students where coded with [Std_x], being 'x' a given number.

The first three questions were about their opinion about having a company in their projects (Figure 1). The answers were given on a Likert scale (1 is strongly disagree, 2 disagree, 3 neither agree nor disagree, 4 agree and 5 strongly agree). The questions were:

- I think that it is a great opportunity that an external company participates in the project [opportunity]
- I think that the work developed in the capstone project is very similar to the one I will be doing as a professional in the future [Similar to the profession]
- I think that learning through projects make the profession closer [profession closer]

Questions are labeled in the figures with the text in the square brackets.

It seems students are sure that the collaboration of companies is a great opportunity (83 % of students). In general, students recognized that projects with companies are a powerful experience as they provide closeness to the professional world (73,7%).

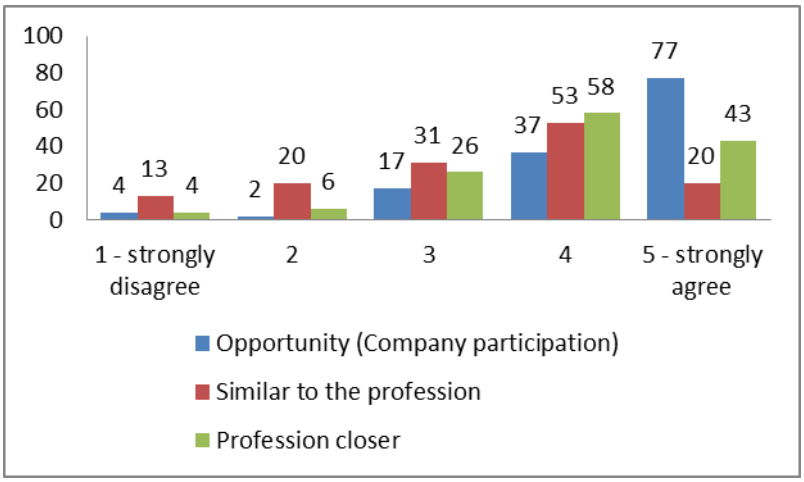

Figure 1: Student's opinion about a company participating in the PBL.

For instance, related to the rapprochement to the professional world we have the following students' positive quotes:

> 'I consider that working with students from other degrees and within tight deadlines, gives me an approach to the professional world' [StdD7]
>
> 'I consider that to propose a problem of the characteristics of the elevator of two plants is assimilated to problems that I will have to solve in my working life.' [Std7]
>
> 'From my point of view having to make a plan of work, working as a team sharing tasks, and making a formal written document makes you see things more like the real world' [Std11]
>
> 'Clearly the projects help us to assimilate concepts and get in touch with the professional world' [Std102]
>
> 'Working together with a company that is involved in the training and introduction of students to the world of work, in the end, what we study we have to apply it in the world of work' [Std118]
>
> 'You have to analyse everything studied during the course to be able to develop the project, besides that it is an approach to the working world and it is something very important that' [Std123]

There is one student that, even though he thinks it is a great opportunity, he doesn't like the way the implication of the company has been:

> 'It is an opportunity as long as the company is truly involved. That a company comes the first day of class to talk about what they want in the capstone project but that does not reappear is the same as if the talk had been given by the teacher.'[Std92]

However, there are 24 % of students who don't see there is a similarity with what they will see as engineers.

> 'As I said before, the projects teach us to work as a team and so on, but it does not look like the work I will do in the future, in our projects at least not' [Std47]

> 'Yes, it comes close to the professional world but I do not believe that in the professional world they do the way they are done in class' [Std92]

Then they were asked if they would like a collaboration of the companies in the proposal or in the assessment of the projects they develop or if this would scare them (Figure 2). The questions were:

- That a company participates in the proposal of the capstone project…
- That a company participates in the assessment of the capstone project…

Answers were in a 4-Likert scale: 1-"is indifferent to me", 2-"scares me", 3-"I like it" and 4-"I love it".

As we can see in figure 2, most of the students would like that a company participate either in the proposal or in the evaluation of the projects, but they make some suggestions about this collaborations. They feel their work more important when they asses them and have more sense of responsibility as the project is real. However, they also feel anxiety and stress when making the final presentation in front of a company.

> 'Let a company come to hear us, I like it, but, at the same time, it terrifies me because there is someone from outside the university who would come to listen and this would make me more nervous' [Std132]

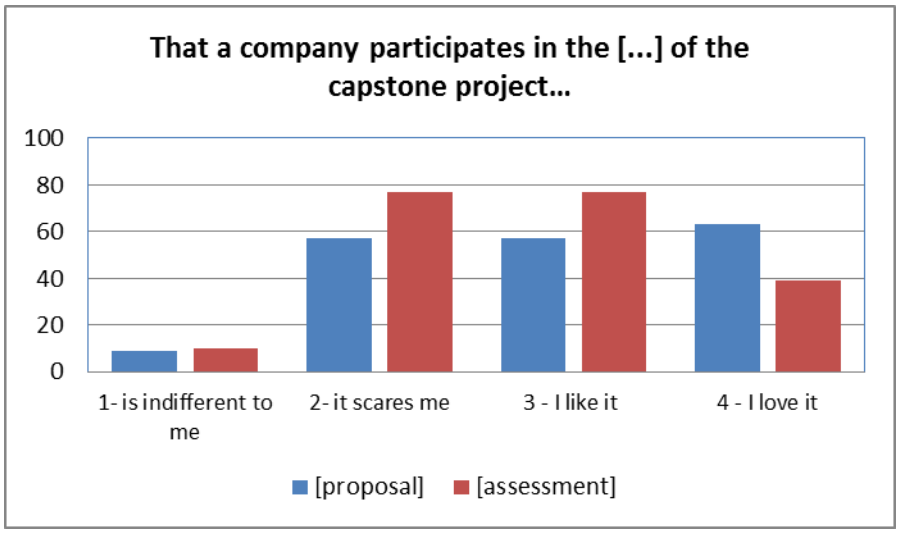

Figure 2: Student's thoughts about the participation of a company in the proposal or in the assessment of the projects.

Finally, they were asked: "If a company were involved, how would you like the company to participate in the capstone project?" (Figure 3). In that case it was a multiple-choice question (I would like it, I wouldn't like it or it is indifferent to me) for the different options detailed below:

- in the project proposal
- in the project tracking
- in the project evaluation
- in the final presentation of the project

- as part of a real project of a company
- none of them

As we can see in Figure 3 students told us the way they would prefer the collaboration of companies in the PBL. They weren't any students who answered they didn't want this collaboration at all.

Some students believe that it would be better if they have contact with their professional field at the beginning of their learning process and ask for teachers to give more feedback.

> 'It is important that companies are involved in giving us ideas and helping us to do the real project. But teachers must give us feedback and help us improve.' [Std 40]

The most valuable aspect in the quotes is that they think they have the opportunity to see that an external firm look at the projects they have developed.

> 'Being companies in the final presentation…, on the one hand it makes you nervous, but it motivates you very much. You think ... and if, because of the project, they'll hire me?' [Std9]

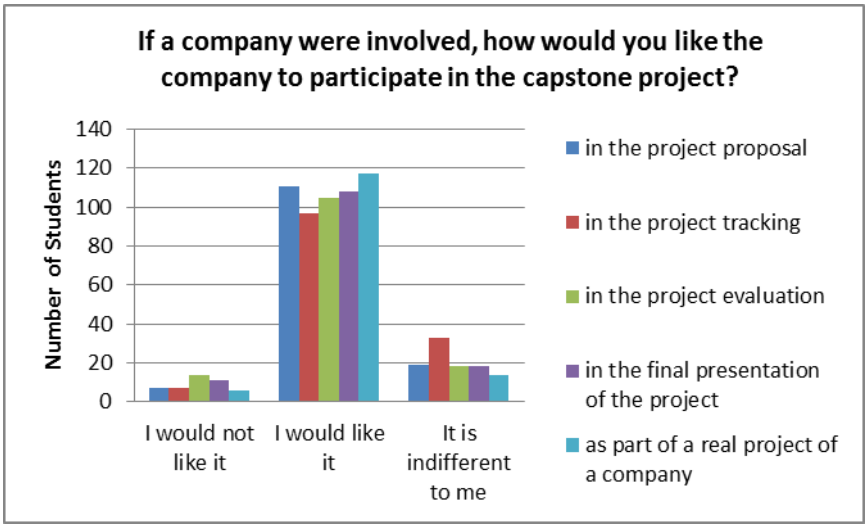

Figure 3: Students' answers to the question: "If a company were involved, how would you like the company to participate in the capstone project?"

As indicated before, at the end of the survey there was three open questions asking the students about what was the best, the worst and how will they improve the collaboration of the companies in the PBS. There are some interesting quotes about how to improve their projects. As it always happens, there are a lot of quotes in the subcategory named "problems with the team" or with time management.

> 'It has helped me to put into practice my abilities to work in groups and improve them, but I would have to dedicate more time to the project. It takes time for group members to adjust.' [Std 76]

> 'I consider it a very serious mistake not to be able to choose the partners with whom to carry out the project because in the working life, some will work more and others will work less but all will work because they depend on a salary. Instead there are people who do not like to pass the subject or not, and do not work and if you talk to them to do the project is hell as they either do not help or when they

want to reengage and contribute to the project cannot because they have not attended in many explanations and are a drag on the team.' [Std 89]

'The worst was the ability to combine other subjects with the realization of the project … the time management' [Std 105]

There are 3 students who think that the company wants to take advantage of their work:

'I would ask the company what are they looking for and if it is not something competent with the degree it should not be considered. I do not want the company to be very important, I prefer a company with many technical expectations (due to my degree) than a company that only wants to get profitability of my results.' [Std23]

2.2 Results about companies' perceptions

One of the biggest benefits expected of the implementation of our "project Based School" (PBS) was the impact that this model could have in the relation between university and local companies (Lima, Mesquita & Flores, 2014; Lima, et al., 2014). The integration between companies and the university means that professionals will be aware of the solid training received by our students. Due to this, we had an increase in the collaboration agreements with companies, having 21 companies involved in the 2016-17 academic year (Terrón-López, et al., 2016). These companies (and 34 more companies which weren't involved in the PBLs) were asked to answer an online line survey. However the responses ratio wasn't very high, but the comments written in the open fields had great richness. It was answered by 9 of the companies participating in projects (coded as 'xC_YesCP') and by 4 companies which weren't (coded as 'xC_NoCP', being the 'x' a number given to each company).

In the first section of the survey, after explaining what the capstone project is in the PBS, there are preliminary checkbox questions such as 'Type of company', 'working area of the company (ICT, Civil, Electronics, Aerospace,…)' and 'Participation of your entity in the Capstone Project (CP)? (check box)'(it hasn't participated; Proposal of the project -CP was proposed by the entity-; Design of the project -the entity worked, together with the teachers, in the design of the CP- ; Follow-up participating in intermediate CP milestones during the course; Final Evaluation of the CP; PBS Awards Session as a jury) .

In the second section, the questions were answered using a Likert scale (1 - strongly disagree, 2 - disagree, 3 - neither agree nor disagree, 4 - agree and 5 - strongly agree). Each one was followed by a "comments" open field. These questions were:

(1) I think it is very appropriate the participation of external entities in the proposal, development and / or evaluation of capstone projects
(2) I believe that the use of projects favours the knowledge and understanding of the technical contents acquired by the participating students
(3) I think that working with projects help students to develop important key skills necessary for an engineer such as communicative skills, teamwork, problem solving, responsibility or others.
(4) I think that involvement of companies in the students curricula is important for their training

And all of them were answered with 4 to 5.

Also, taking advantage of awards session attended by companies, their representatives were informally interviewed after the award session.

Although these results are not significant because they weren't enough, some good suggestions can be taken from their comments in the informal interviews, which were categorized in four dimensions: students' learnings, industry-university interaction and suggestions.

Industry perceptions about students' learnings

Companies' representatives, after seeing the students' projects, think that students have a deeper learning:

> 'Students would learn the difference between the day to day life of the University and the running of a company. The important aspects within the course of the classes are totally different from what is important at any moment in a company' [4C_NoCP]
>
> 'From our point of view, all the projects presented had a high professional quality and academic excellence. It is noteworthy both the effort and dedication of the students themselves and their tutors, which allows to reach such high quality.' [6C_YesCP]
>
> 'We understand that students working on projects learn best, first because the students themselves acquire greater responsibility in their own learning and can apply in projects both the skills and knowledge acquired in class. And that is what we have seen in their projects' [8C-YesCP]

They even think that it contributes in their motivation helping them to better develop some of the skills needed in the industry:

> 'We understand that this participation is fundamental for students' motivation since it allows them to increase their capacities, making them more competent and making them enjoy using them. This helps the student to think of it as the achievement of a personal project.' [9C_Y esCP]
>
> 'It is seen that students go beyond the syllabus, applying theoretical knowledge to manufactured products.' [8C-YesCP]

Industry perceptions their interaction with university through students' projects

A different perception about how students' projects can be useful to the industry need arose, as a representative talk about how the different point of view of students could help the industry in facing a problem:

> 'I believe that the students can be of great help in process improvements since they can contribute different ideas to attack problematic that we do not see from our "inner world" and to do it with creativity' [3C_NoCP]

They even say they love the innovation they presented:

> 'We loved the innovation presented by the students' [7C_YesCP]

Standing that the collaboration is important not only for the students because they feel their future profession closer, but because in that way they became aware of what students are learning.

'We consider that collaboration is a fundamental aspect as it is a way of linking what has been learned with business reality. It allows the student to apply what he has learned, knowing that there is an external entity after he is monitoring it and, on the other hand, also allows the company to know more about the students and to know the level of teaching of the University itself. This favours the latter when its students have to make their practices in these external entities.' [9C_YesCP]

As sometimes they think that they can make less than what they, in fact, are able to do:

'We sometimes think that we will not be able to think about something students can make, but then, when you come and see their projects, you get positively surprise!' [11C_YesCP]

So industries' representatives think that coming to the evaluation of projects session helps them to see the actual knowledge of students.

Industry suggestions for improvement

Companies' representatives require better participation between industry and university.

'It is a question of participating in more similar activities that put the student in a real working environment and justification of decisions, developments, etc.' ' [7C_YesCP]

They suggest more industry presence into the project organization and more visits or direct work in their companies.

'We should continue to focus on the interaction between the course and industry through projects. May be, in order to try a higher integration between companies and the academic content, students should make more visits and work directly with the companies in order to develop more practical concerns to both' [12C_YesCP]

Although one representative said that we should focus in teaching also in being more rigorous:

'However, a lack of Industrial rigor is detected at certain times of the project ("I think this works better", "so it may work").' [7C_YesCP]

It seems that a global involvement of companies decreases not only the university-business distance, but also facilitates a rapprochement due to its involvement in the learning of future engineers.

2.3 Results about teachers' perceptions

Teachers, on the other hand, were interviewed regarding this issue and their responses were recorded and analysed using qualitative analysis techniques. We interviewed a total of 16 teachers who have participated in subjects involved in projects.

All of them said that it seems very appropriate the participation of companies in the projects. On the one hand, they said so because they thought that this collaboration increased students' motivation:

'I detect an increase in my students' motivation. They were pride of the results obtained. '[Teacher4]

Increasing their participation in the classrooms, compared to other courses without a company behind:

> 'As a company was behind them, I saw more involvement and enthusiasm of the students than in other courses I taught' [Teacher2]

> 'I saw how the participation of the students increased when discussing aspects of the work in class.' [Teacher3]

Some teachers show fears related to the feeling that industry needs and curricula don't match very well.

> 'The participation of companies contributes added value to the project but it is difficult to find a point of connection between the teaching objectives and the needs of the companies. You cannot develop a project that interests companies, because they "do not trust" the results of a group of students, especially if everyone develops the same, and do not want to invest resources in a task that is merely teaching and does not report Benefit to your company. I see the altruistic participation of the companies difficult, which would be what we would need. If it exists, I think it can contribute a lot' [Teacher5]

> 'It was difficult to meet the needs of the external organization that supports the project with the needs of the subjects that form it' [Teacher11]

They also found difficulties because their students' complaint about time spent and team work problems:

> 'The work has become much more arduous than expected and in turn this has provoked more rejection to the completion of work to some students, with continuous complaints about the time spent on' [Teacher6]

Therefore, students required more assistance to their teachers

> 'It requires much more work than other types of activities: I have increased the number of tutorials (to help them solve group problems, to help them overcome technical difficulties, etc.)' [Teacher13]

Most of them felt that students develop important competences for work readiness and feel proud of them:

> 'I was… To see students grow in autonomy and the security they had to apply the subjects studied for the implementation of the project, made me feel proud of them'[Teacher4]

As students felt they were effectively working for a company they didn't give up the project although they knew they weren't going to pass the subject associated to it:

> 'Bringing a reasonably professional project to students, …, Most students completed the project, even when they thought they were not going to pass the subject. ' [Teacher2]

Teachers felt that their students identified the importance of the industry experiences within their subjects. As companies provided real examples of projects to be developed, they could see where theory and practice are interconnected and the connection with real world, appreciating this collaboration.

> 'Companies can provide examples of projects developed so that students can see what the final result is to reach. This type of participation has been much appreciated by my students' [Teacher14]

The saw how the students learnt that to perform a project effectively, it is important to make it systematically, understanding the whole process, with all its complexity, taking decisions based on the use of adequate methods as in real problems.

> 'One of the main values of the project is precisely that it has been developed in situ, which has made possible to become aware of the complexity and problematic of real situations' [Teacher12]

Teachers reported also the need of a better coordination between the company, the teachers and the students. For instance they reported that the project period in the university is too short compared to one in a company, having not enough time to seek for all the information needed.

> 'I noticed on the one hand the lack of time on the part of the students to reach the objectives raised by the external company. On the other hand, lack of time on my part as a tutor to monitor adequately the evolution of groups, work, and contribution of extra material or help in seeking for information. The project is intended to be done in a very short time (the quarter).' [Teacher9]

So they asked for periodic meetings company-teachers-students to understand the scope of the projects.

> 'As for the project with the company, it would be necessary to organize periodic meetings with the external company. We should make clear from the beginning that the result may not be usable, that the objective is learning and not obtaining a final product that can be directly used by the company.' [Teacher8]

Meetings are needed because, at times, the company is not able to cover a project of students in collaboration with the university, due to its other obligations

> 'The main problem of image that has had the project has been precisely the suspension, at the last minute, of the activities scheduled with 2 of the 5 organizations initially planned.' [Teacher10]

> 'I think that the students can take it more seriously if they see that some important company considers it important.' [Teacher7]

Also this lack of coordination is reflected in the inability to adequately convey the project objectives:

> 'By their comments I deduce that we have not known to transmit what the project contributions is.' [Teacher15]

3 Conclusions and learnings

PBL is a reliable methodological tool to create opportunities to put students inside real contexts. The development of a project involving several subjects allows the design of more ambitious projects and a degree of integration of competences from different areas of knowledge that make it more challenging and similar to real projects. The inclusion of an external agent reinforces this approach and allows the student a greater immersion in what will be his future profession. Findings point out the importance the interaction of industrial companies in project-based learning (de Graaff & Kolmos, 2003).

An important finding is the need for greater coordination among participating teachers and companies to ensure the convergence of each one's efforts in the same project and with the same objectives. Sharing learning outcomes and balancing the times of students' dedication to the different subjects, inside and outside the project, should be a collegial task. However, teachers have seen that it is difficult to create and maintain benefits for both parties, university and industry, because sometimes they have divergent goals, time orientations, and assumptions or ways of explaining a project (Cyert & Goodman, 1997).

Coordination between parties is a key factor in the definition of the concrete objectives of the project and the subjects involved. An important key for a good coordination is the communication, and so is the teacher as a guide supporting the development of the project (Lima et al., 2014).

Industries think that coming to the project's evaluation session helps them to be aware of the students' skills (technical and soft ones), but require students to be trained in presenting the projects with more rigor.

Students value positively the integration of the company in the capstone project as it increases their commitment in addition to providing a real approach. Knowing what awaits them in their future as engineers will ease the transition between the university and their working life (Thune, 2011).

Students think that learning to collaborate within a work group and to address different people forces them to develop important key skills to work as engineers. These cannot be taught in isolation from the technical context in which they will be used, as they do while working in their capstone projects (Martin, et al., 2005).

Students also find it beneficial to start building relationships with industries as they have the opportunity to demonstrate their work in front of employers. They consider it as a possibility of being hired at the end of their studies.

It seems that the perception of the students is influenced by the type of collaboration with the company (in the proposal, in giving feedback or just the evaluation of their results). They feel their work more important when a company asses them and have more sense of responsibility as the project is real. However, they also feel anxiety and stress when making the final presentation in front of a company.

It seems that a global involvement of companies decreases not only the university-business distance, but also facilitates a rapprochement due to its involvement in the learning of future engineers.

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The role of Problem-Based Learning in entrepreneurship education

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Abstract

This study examines how a Problem-Based Learning, Three-Career Building courses affect student entrepreneurial intentions before and after completion of the coursework. This study measures the factors affecting on entrepreneurial intentions. The research model is built up based on the theoretical of entrepreneurship education on entrepreneurial intentions. The model is adjusted by the results of qualitative research on students who complete Three - Career Building courses and faculty members at DTU. The proposed model is tested by using the quantitative method. Questionnaires were distributed to 271 students who finish Three- Career Building courses. The results show that student entrepreneurial intentions depend on four factors: Entrepreneurship Motivation, Teaching Methodologies, University Role, and Attitude Factors. The implementation of proposed recommendations to enhance the PBL in entrepreneurship education on entrepreneurial intentions is also discussed. This paper will be helpful to educators who are looking for ways to effectively promote entrepreneurship at their institutions.

Keywords: Problem-Based Learning (PBL), entrepreneurship education, entrepreneurship skills, entrepreneurial learning

Type of Contribution: Research paper

1 Introduction

Entrepreneurship and entrepreneurism are hot topics in Vietnam at the moment because of the national call for the development of core economic strengths of Vietnam besides increased pressure on the domestic economy due to accelerated unemployment rate. It has been estimated by the Ministry of Education & Training (The Ministry of Education & Training, 2016) recently that 300,000 new graduates from college were without a job during the last five years while many major commercial brands of Vietnam like Nguyen Kim Electronics, Highland Coffee, Pho 24, etc. were bought over by international conglomerates. Part of the reason has to do with the fact that the higher education system of Vietnam did not produce enough quality and skilled labor. Most Vietnamese college graduates were also very passive in their career development because of the nature of their previous training.

At Duy Tan University (DTU), around three years ago, most non-engineering faculties started to adopt the Problem-Based Learning (PBL) model to teach students about teamwork, group projects, interdisciplinary studies, and most importantly, entrepreneurship and start-ups. The emphasis of entrepreneurship education at DTU has been placed on community improvement projects and social ventures given the availability of programs and opportunities in such fields.

Many positive outcomes have resulted from this approach but at the same time, a good number of negative feedbacks were also provided as to the lack of previous entrepreneurship experience of

instructors, the passive cultural values of Vietnamese students, the inefficient collaboration between schools and businesses in Vietnam, or the usual shortage of start-up platforms and opportunities for Vietnamese students.

This research aims to assess the role of PBL in entrepreneurship education for students at DTU. The success of DTU's entrepreneurship education is applied through the formation of student entrepreneurial intentions after completion of the course. Based on the results of this research, we propose some recommendations to improve entrepreneurial intentions through entrepreneurship education.

2 A Literature Review On Problem-Based Learning In Entrepreneurship Education

2.1 Defining Entrepreneurship Education

An entrepreneur is an individual who organizes or operates businesses. Entrepreneurship is the process by which individuals pursue opportunities without regard to the resources they currently control (Hamburg, 2015). Shane and Venkataraman (2000) contended that an entrepreneur, based on entrepreneurship, was a process of discovering, evaluating or creating opportunities to innovate or integrate new values, products or services.

Bechard and Toulouse (1998) suggested that entrepreneurship education as a series of training courses to teach students about the concepts of business formation and development models. This view is supported by Denanyoh, Adjei, and Nyemekye (2015) who wrote that Entrepreneurship education is a range of skills and attributes that can be developed through educational programs that try to develop in the participants the intention to perform entrepreneurial behaviors or some elements that affect that intention such as entrepreneurial knowledge, the desirability of entrepreneurial activity, or its feasibility. Entrepreneurship education has a role in supporting students to achieve the knowledge and skills to act in an entrepreneurial way. Raposo and Do Paço (2011) pointed out that the core knowledge of entrepreneurship education should include the abilities to identify and develop innovative thinking; the abilities to think creatively and critically and the abilities to start and manage new companies.

In all the studies reviewed here, entrepreneurship education is educational system engineering, and it improves entrepreneurial awareness, thinking, and skills via educational methods. At the university level, therefore, entrepreneurship education can be employed to equip students with entrepreneurial skills and prepare them to pursue an entrepreneurial career. Additionally, students are cultivated to develop an innovative ability, the spirit of entrepreneurship, and practical knowledge and competence. (Chen et al., 2015)

2.2 Entrepreneurial Intentions

According to Ajzen (1991), Intentions are conceived as immediate antecedents of actual behavior. Entrepreneurial intention or intent in general is defined as, a state of mind directing a person's attention, experience and action towards a specific goal, or a path to achieve something. Entrepreneurial intentions are great impacted by university environment (Rengiah, 2013). Krueger, Reilly, and Carsrud (2000) maintain that intention-based models have attracted considerable attention of researchers as they offer a great opportunity to increase our understanding and predictive ability for entrepreneurship. Bell, Dearman, and Wilbanks (2015) found that these factors as contributors to entrepreneurial intentions are: a high need for achievement, a desire for autonomy, a proclivity for moderate risk taking, aggressive competitiveness, an internal locus of control and a flair for innovation.

2.3 Defining Project-Based Learning Method

Project-based learning is a comprehensive approach to classroom teaching and learning that is designed to engage students in the investigation of authentic problems (Blumenfeld et al., 1991). These students developed and pursued solutions to non-trivial problems by asking and refining questions, debating ideas, designing plans and/or experiments, communicating their ideas and findings to others and creating artifacts.

Thus, PBL can be understood as a guide method for learners to apply their in-class knowledge to their daily life problem solving. PBL is a method that the leaners receive knowledge and skill through a learning process, which is designed base on questionnaires, problems and tasks. In PBL, the central context of learning and teaching is the purpose. Students are self-seeking to determine the sources of information, which help them for solving the problem. Discussion is the core activities during teaching while the teacher is supported them.

The goal of using PBL: Considering awareness: To help learners have opportunities to embrace knowledge in width and depth. About skills: Learner can develop the capital of reading documents, research skills, solving problems, teamwork, presentation, debate, etc. About attitude: Learners can feeling engages, loving the subject and the value of learning. Moreover, they see that the value of teamwork for themselves (Thomas, 2000)

2.4 Project-Based Learning As A Teaching Method In Entrepreneurship Education

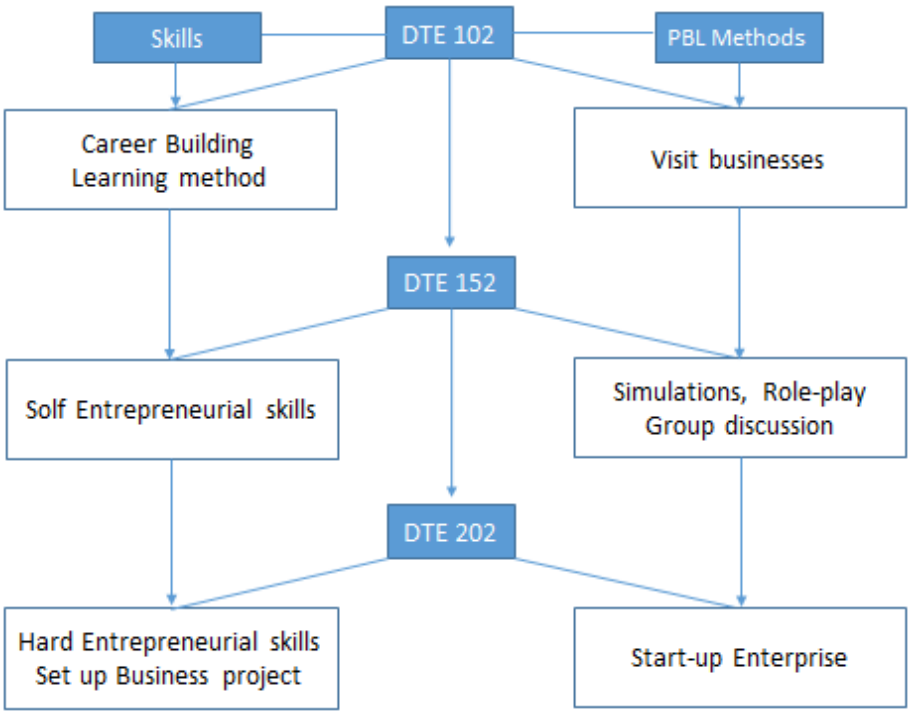
Through education focused on teaching entrepreneurial skills and processes, research supports the resulting effects of increased entrepreneurial intentions and firm creation (Addae, Singh, & Abbey, 2014). Rahman and Day (2015) summarized the general objectives of entrepreneurship education in various countries as comprising of: (a) increasing entrepreneurial spirit/culture/attitudes; (b) start-up and job creation; (c) making a contribution to the socie:

Okudan and Rzasa (2006) have been adopted for the course with the goal of stimulating abstract conceptualization and adoption of common terminology on leadership concepts. The method used to teach the leadership concepts is interactive and involves each student's reflection and presentation of his/her opinion. In addition, four small team projects are assigned as means for concrete experience and active experimentation, during which each student assumes a leadership position at least once.

3 PBL Settings For Entrepreneurship Education At DTU

Entrepreneurship is an emerging trend in Vietnam recently which brings many opportunities in self-creating employment for young labor. Entrepreneurship education improves the ability to self-creating employment for students to pose for society in general and the universities in particular. Duy Tan University has rapidly approached this trend by implementing Entrepreneurship Education from three years ago. In teaching methods, PBL was selected as a primary method to teach this course.

Table 1: PBL settings for Entrepreneurship Education at DTU



Entrepreneurship education has been developed through Three Career Building courses (DTE 102, DTE 152 and DTE 202). There are various ways of teaching entrepreneurship: Case studies, Preparing business plans, Group projects, Entrepreneurial apprenticeships (internship), Games and Simulations, Experiential examinations.

DTE 102: This First-year-level course provides an introduction to Career Building and active learning for students. The objective of this course is to help students to be familiar with the university's environment and teaching methods. Along with in-class hours, students are guided to visit businesses. These activities help students to build career and career path for themselves.

DTE 152: After DTE 102, DTE 152 provides the best learning and training models to ensure students acquire the necessary entrepreneurial knowledge, skill, attribute, and behavior. After taking this course, students are equipped solf entrepreneurial skills, such as personal financial management skills, time management skills, planning skills, change management skills, conflict management skills, critical thinking skills. The PPB method is applied flexibly through situational development by requiring a team to play the role and the others to work out the solution in each situation. With this exercise, students draw the advantages, disadvantages, shortcomings from which to improve their own skills. Along with in-class activities, students are encouraged to participate in clubs: Finance Club, Entrepreneur Club, Debate Club.

DTE 202: Unlike DTE 102 and 152, DTE 202 requires students to be directly involved in a real business projects. Students work in groups of 3-5 students. With the knowledge and skills have been equipped through two subjects before and under the teacher's guide, students will build their startup projects and business practices. Students can choose to do business in specific product categories available on the market, in their new developed products or collaborators for businesses. The grade is measured through: 50% Feasibility of the project (Profitable or loss): 50%: Project protection and feedback in class.

3.1 PBL settings for DTE 202 Step 1: Assign the project

Lecturer evokes business ideas from reality. Group discussion is to find out business ideas. Lecturer introduces the project process and instructional materials.

3.2 Step 2: Develop, and write the Business project

After selecting the business idea, the team proceeds to build the Business project. The student will have to gather information and learn new concepts, principles, or skills in the problem-solving process.

After completion, the student in each group presents their Project. The remaining groups criticize the projects and raise their difficulties when developing the project.

The lecturer will observe, summarize and answer the group's problem.

3.3 Step 3: Apply the project into practice

After building and successfully defending the business project, the teams put their project into practice. Groups report periodic business plans. Difficulties in implementing the project are discussed in class to find solutions.

3.4 Step 4: Finalize the project

At the end of the course, each group will complete the project and report the results in the form of a video about their project and showcase their actual startup products. In the final evaluation, the trainer will invite the University's start-up center to take part in the assessment the project.

At the end of the course, the teams conduct a cross-assessment of the project participants and submit the completed project to the trainers. Good projects will be selected for the School-Sponsored Competition.

In parallel with in-class activities, field trips, students are encouraged to participate in competitions, such as Social Venture Plan Competition, Business Ideas, CDIO, etc.

4 Evaluating The Effects Of Entrepreneurship Education On Student Entrepreneurial Intentions

4.1 Research methodology

This study used questionnaires and the questions were compiled by the re- searcher from the references of the literature review. To have an overview on Student Entrepreneurial Intentions, we conducted ten interviews with lecturers in November 2016. At the beginning of December 2016, group discussion with students finished DTE 202 about their Entrepreneurial Intentions. After these consultations, discussions, combined with theoretical models, the six factors evaluating the effects of entrepreneurship education on student entrepreneurial intentions are agreed.

The survey form is divided into four parts to collect students' information, to examine students' perception of the effects of a PBL in entrepreneurship education on student entrepreneurial intentions and to collect other recommendations. Likert's five-point scale was used with 5 points indicating very much agree, 4 to agree, 3 to fairly agree, 2 to disagree, and 1 to very much disagree. The higher score indicates stronger and higher entrepreneurial intentions, learning satisfaction and learning efficacy.

After the preliminary study, the questionnaires were structured with 40 variables and used in formal

research. Firstly, we conducted the Pilot Survey (January 2017) with 26 students. Base on this, the survey form was adjusted and spread in wide scale on February 2017. The responses were 271. Among that: 17 forms were invalid and by processing 254 forms were valid. The study uses 250 samples.

Descriptive statistics were used to find out the characteristic of the samples. Factor analysis identified groups of observed variables and eliminated non-impact variables; then Cronbach's alpha coefficient was used to determine the reliability of the model, eliminate inappropriate variables. Regression analysis determined whether the model was fit or not. Hypothesis testing helps to identify the relationship between dependent variables and independent variable.

4.2 Measures

In this research, entrepreneurial intentions depend on six factors:

Entrepreneurship Motivation (EM): According to Tu and Son (2015), an important factor for entrepreneurship education is entrepreneurship motivation. The measure used for entrepreneurial motivation was derived from a scale for harmonious passion which was adapted for entrepreneurship by (Murnieks, Mosakowski, & Cardon, 2014). This scale is a 5 item Likert scale which includes items such as: (EM1) Entrepreneurship is my passion; (EM2) I am willing to accept risks to become entrepreneur; (EM3) I always keep updated the news about entrepreneurship; (EM4) I am willing to take on any challenges to become an entrepreneur; (EM5) My career's goal is to become an entrepreneur; (EM6) I am sure that I will startup in the future; (EM7) I am thinking seriously about starting my own enterprise.

Feeling of Confidence (FC): According to Krueger and Brazeal (1994), feelings of confidence have the potential to carry out specific behaviors to startup. This scale has been verified by research by Nguyen (2015), specifically the feeling of confidence measured by individuals when performing the behavior: (FC1) Find a good business opportunity for entrepreneurship; (FC2) Mobilize enough money, (FC3) Hire employees; (FC4) Choose a good equipment; (FC5) Entrepreneurship market; (FC6) Attract customer; (FC7) Knowledge and skills.

Entrepreneurship Curricula (EC): In the research on entrepreneurship, Noll (1993) emphasized that a good model for entrepreneurship education should be based on a suitable entrepreneurship curricula. According to Cull (2006), Entrepreneurship curricula focus on developing life plans and passion for a career, helping young mentees to keep their vision in sight and to reflect what is happening. Softer skills such as listening, communicating as well as more technical ones including the review of business plans and meeting objectives are necessary. In this research, Entrepreneurship Curricula should include the following factors: (EC1) The university programs have equipped me well to compete with other businessmen; (EC2) The entrepreneurship course is developed to meet the criteria of the curriculum; (EC3) I prefer study entrepreneurship than other subjects; (EC4) I can develop entrepreneurship skills through the program; (EC5) Understanding about entrepreneurship as a result of taking up the entrepreneurship course; (EC6) Study entrepreneurship because this course provides real- world situations.

Attitude Factors (AF): Attitude factor is a predictive behavior, and social cognition and cognitive processes become as significant factors in choosing career (Robinson, Stimpson, Huefner, & Hunt, 1991). According to individuals with a positive attitude towards money are likely to have or want to be self-employed. Attitude factors are described by: (AF1) I want to be an entrepreneur because I will become rich; (AF2) If I have a high income, that is a sign of successful; (AF3) As an entrepreneur, I have to face many challenges unlike working as an employee; (AF4) I have to work hard in situations to compare against to the others; (AF5) I agree that the greater the risk, the higher its required return; (AF6) I want

to set myself the higher goals.

University Roles (UR): There is a significant relationship between the entrepreneurial intentions and universities roles. The environment of university encourages entrepreneurial activities for students, through University policies, infrastructure, and other support systems (Nurmi & Paasio, 2007). In this research, the role of university in entrepreneurship is described by: (UR1) Everyone talks about entrepreneurship in my University; (UR2) My University is focused towards entrepreneurship; (UR3) The policies in my University promote entrepreneurship education; (UR4) The university provides resources to assist students in entrepreneurship; (UR5) The University environment inspires me to develop innovative ideas for new business; (UR6) I think the University is the best place for students to be trained in entrepreneurship.

Teaching Methodologies (TM): Entrepreneurship education needs good a teaching method in university. The teaching of entrepreneurship courses should not be undertaken in mere classroom settings, but rather as a process which involves start-up businesses, and maintain it . The self-directed learning together with problem-based learning is proven to have a significant impact on students' entrepreneurial intention (Bin Yusoff, Zainol, Ibrahim, & Dahlan, 2015). Teaching methodologies need to include a reflective on practice to motivate students in entrepreneurship learns. Teaching methodologies are conducted on the four items:

(TM1) I enjoy PBL method in the entrepreneurship course; (TM2) I can develop entrepreneurship skills through the program; (TM3) Practical sessions help a lot in understanding the entrepreneurship subject; (TM4) I like to study entrepreneurship because it teaches real-world situations.

Entrepreneurial Intention (EI): According to Bell et al. (2015), there are identified relationships between entrepreneurship education, entrepreneurial intentions, and other somethings. Moreover, entrepreneurship education encourages students to become business owners, leading to increased entrepreneurial intentions. Entrepreneurship intention is conducted on the four items: (EI1) After these courses, I better understand how to become an entrepreneur. (EI2) After these courses, I may become an entrepreneur as soon as I graduate; (EI3) After these courses, I am more willing to take risks to become an entrepreneur; (EI4) After these courses, I am able to tackle entrepreneurship challenges.

4.3 Research results

Exploratory factor analysis (EFA): Bartlett's sphericity test has statistical significance. KMO = 0.826, Eigenvalues = 1.178. Average Variance Extracted is 60.869%. All coefficients are over

0.5. After the factor analysis, 23 observed variables were grouped into six determinants.

Model assessment with Cronbach Alpha: In the Cronbach's Alpha test, all coefficients are over

0.7 and all corrected item-total correlation coefficients are over 0.3. So, variables of this model are reliability.

Table 2: Cronbach's Alpha coefficient of determinants in the proposed model

Determinants	No. of observed variables		Cronbach's Alpha	Cronbach's Alpha if item deleted	Corrected Item-Total Correlation
	Before	After			
Entrepreneurship motivation	7	3	0.753	0.749	0.513
Feeling of Confidence	7	3	0.722	0.661	0.521
Entrepreneurship curricula	6	4	0.761	0.734	0.504
Attitude factors	6	6	0.770	0.748	0.478
University role	6	3	0.708	0.655	0.462
Teaching Methodologies	4	4	0.763	0.738	0.504
Entrepreneurial Intention	4	4	0.801	0.794	0.520

Pearson correlation coefficient analysis: In the Pearson correlation coefficient analysis, all Sig. values are under 0.05. Therefore, all pair of variables has correlation and statistical significance. Correlation coefficients of some independent variables vary from 0.182 to 0.422; this shows that these six independent variables have a quite close linear correlation with dependent variables.

Regression analysis: In the first regression analysis, there are two variables that have Sig. under 5%, respectively: X2 = 0.378 và X5 = 0.148. So the H2 and H5 hypotheses do not have statistical significance. After removing these variables, the result shows that all variables reach the 5% of confidence level (all Sig. values are under 0.05); and all reach the Tolerance interval > 0.0001; all variance inflation factors VIF are under 10. Therefore, these variables are completely fit in the model.

Table 3: Regression analysis of factors affecting on student entrepreneurial intention

	Unstandardized Coefficients		Std. Coefficients	t Stat	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
Constant	.535	.085		6.305	.000		
Attitude factors	.133	.056	.130	2.395	.017	.716	1.396
Teaching Methodologies	.197	.018	.323	10.846	.000	.819	1.221
Entrepreneurship motivation	.231	.020	.333	11.828	.000	.914	1.094
University role	.248	.048	.281	5.205	.000	.723	1.383

Adjusted R Square is 0.819; Durbin-Watson stat is 2.105, so we accept the hypothesis of no first-order serial correlation in the model. The multiple regression model satisfies all assessment and fits tests to

draw research results. The standardized regression model as follows:

$$Y = 0.130X1 + 0.323X3 + 0.333X4 + 0.281X6$$

"Entrepreneurship motivation" is the component that has the highest effect on entrepreneurial intention (0.333); followed by "Teaching Methodologies" (0.323); "University role" (0,281); and "Attitude factors" (0,130).

One-Sample Statistics is used to evaluate the student's entrepreneurial intentions measure model. The result shows that Sig. = 0.000, this means "Entrepreneurial intention" has statistical significance.

Based on the regression model, the study finds out the positive effects with statistical significance, included four factors: Entrepreneurship motivation, Teaching Methodologies, University role, and Attitude factors, on entrepreneurial intentions (average value of 3.21).

5 Discussion

Therefore, the implementation of PBL in entrepreneurship education has brought tremendous effects which improvement of student's motivation and awareness to become an entrepreneur; enhancing the skills for start-up. However, the implementation of PBL in entrepreneurship education at DTU still has some drawbacks:

Firstly, the current Vietnamese education system still focuses on training student to become an employee instead of an owner. Hence, students lack motivation to become entrepreneur and can not fully understand the purpose of honing their skills as well as maintaining a passion for their courses. Business ideas from students are obsolete and lack of creativity. Although DTU has held numerous competitions to boost the entrepreneurship in students, these did not spread widely among students.

Secondly, the lecturers' knowledge and skills are not evenly. In fact, one lecturer will handle all Three-Career Building courses through four academic years at DTU. The primary motive is to eliminate the student's drop-out. Therefore, it leads to a consequence. DTE 102 is quite simple; the lecturer is not necessarily to have much skills and methods. However, not any instructors have the required skills (to teach DTE 152) or the ability to mentor students implement their entrepreneur project (in DTE 202).

Thirdly, DTU has put a lot of effort in encouraging student entrepreneurship. However, putting student's projects into reality frequently face difficulties in resources as well as methods of mobilization funds.

6 Conclusion

Based on the regression model, the study finds out the positive effects with statistical significance, included four factors: Entrepreneurship Motivation, Teaching Methodologies, University Role, and Attitude factors, on Entrepreneurial Intentions. In the case of developing entrepreneurial intentions by entrepreneurial education, in which PBL is chosen as the core method, in the coming time, DTU should:

Firstly, in entrepreneurial education, promoting Entrepreneurship Motivation and shaping Attitude factors are the main goals. According to the survey results, students think that teaching methods are more important than courses. However, good methods are built based on good programs; the resonance will be higher. From the training programs, it is necessary to focus on developing the content of the

entrepreneurship education program for students because education has been considered as an important factor to formulate the idea of entrepreneurship and aspirations to do business. Besides, most of the training programs tend to provide the knowledge and motive to become employees rather than owners, so the development of relevant start-up courses is critical in the situation of increasing unemployment rate.

Secondly, in parallel with decent courses, teaching method (PBL) needs to be implemented more flexibility and efficiency. To achieve this goal, DTU needs to classify lecturers into each group that can teach a particular skill for all courses instead of teaching all skills for a whole course. Besides, DTU needs to create a relationship with enterprises. It should regularly, and periodically holds field trips, workshops between companies and students to help students approach practical knowledge from experts. From that, it helps to ignite the urge to do business and incubate start-up ideas in students.

Finally, universities also play a crucial role in nurturing start-up ideas. They need to create more playgrounds on entrepreneurship for students, so that they can experience difficulties, learn new skills, take opportunities and face risks. This activity must be conducted from the phase of nurturing start-up ideas to commercializing products. The first step is holding the start-up idea building competition among students and select the possible ideas. Then, the university will invite the enterprises, organizations to be shareholders of the projects to invest into those ideas. The last is commercializing the projects.

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Creative, Productive Collaboration between Companies and Students

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Abstract

In the 1990s, the Gifu Prefectural Government established a hub for information industries named "Softopia Japan" in Ogaki City with the intention of collecting IT-related companies. Softopia Japan Foundation engages in support that contributes to industrial advances, and as part of its efforts, it is implementing creative, productive activities called a "Creative Camp Project" where companies and students are linked with each other.

We describe the complete view of the practice of creating products as a project-based learning (PBL) type conducted in a Creative Camp Project, and also as a specific case, the process and the outcomes of creating products as a PBL type conducted in collaboration between some third-year students of National Institute of Technology (NIT), Gifu College and KAKKO E LLC. In the challenge, they created products with which electric vehicles would become attractive around town.

Keywords: PBL, Collaboration between Companies and Students, creating products, group work

Type of contribution: Research paper

1 Introduction

The Gifu Prefectural Government (Gifu Prefectural Government, 2017) and Softopia Japan Foundation (Softopia Japan, 2017) are implementing project-based learning (PBL) type activities called a "Creative Camp Project" through collaboration between companies and high school students. The Creative Camp is a project which started in 2013 with the purpose of fostering future high-level IT human resources. This is a field of PBL practice where high school students majoring in information and its related fields in Gifu Prefecture experience developments of new products and services which are not taught at school while they start to use facilities of Softopia Japan, collaborate with a venture company and create a product in line with the theme.

The Creative Camp Project starts with a two-day and one-night camp (lodging session) held on Saturday and Sunday when they generate ideas and make a prototype, after which they spend about a month creating their product. Each school team works collaboratively with a venture company in charge. They raise issues on their product, work out what the real issues are, generate ideas, design and make a

prototype, and at a mid-term presentation held on the afternoon of the second day are given feedback from an advisor for improving their product. After the camp they continue to work on their product after classes at their school until the presentation day. This is a challenge conducted through industry-university-government collaboration, since a venture company and a teacher work well together in facilitating students' work both at a camp (lodging session) and at school. High school students can acquire experience creating a product together with an IT innovator or an IT creator who is active in society. Meanwhile, a venture company can get tips useful for developing new products or services from high school students' way of thinking. That is to say, the project provides both of them with valuable opportunities.

In this paper, we will introduce our PBL challenge practiced in the 2016 "Creative Camp Project". We will describe the participation of NIT, Gifu College (NIT, Gifu College. 2015) in the "Creative Camp Project" with the support of KAKKO E LLC. (KAKKO E LLC. 2017) Softopia Japan, KAKKO E LLC and NIT, Gifu College, all of them are unique institutions, so we will first mention the outline of respective organizations below and describe the details of our PBL challenge from Chapter 2.

1.1 Softopia Japan

Softopia Japan is aiming to realize "Good Living Gifu" by conducting various kinds of projects related to information technology, while foreseeing and quickly responding to the changing times. The Gifu Prefectural Government, predicting the arrival of an advanced information society, opened "Softopia Japan Center Building" in Ogaki City, Gifu Prefecture in 1996 as a hub for the development, promotion, and accumulation of information industries. This area is packed with the following organizations: Softopia Japan Foundation, Institute of Advanced Media Arts and Sciences (IAMAS) and IT-related companies. They are aiming to realize "Good Living Gifu", where industry, education, welfare, and all other areas are informatized. These challenges are generally referred to as "the Softopia Japan Project". Now the Softopia Japan Area is home to about 150 IT-related companies.

The promotional structure of Softopia Japan projects consists of the Gifu Prefectural Government, Softopia Japan Foundation and designated managers. Specifically, the Gifu Prefectural Government is supervising the project, Softopia Japan Foundation is implementing various projects relevant to the development of the information industry, and also designated managers are maintaining facilities, promoting use of facilities and supporting the companies which have moved into Softopia Japan.

Immediately responding to changes over time, Softopia Japan projects have changed as well. In 2009, when smartphone use began to spread, "GIFU smartphone project" started. In the project, fostering, exchange and accumulation of human resources related to smartphones, as well as business commencements, were promoted, which brought the worldwide applications such as "sekai camera" (literally, "world camera") and "finger piano". Now that the spread of mobile devices including smartphones has made IT more easily available, Softopia Japan Foundation is making a transition to projects conscious of IoT/IoE Era.

1.2 KAKKO E LLC

KAKKO E LLC, a design company, was established in Ogaki City, Gifu Prefecture in March, 2016. The company, started by two graduates of the Institute of Advanced Media Arts and Sciences, is working mainly in advertising and education, covering creating posters, designing leaflets, creating websites and applications, taking moving pictures and still images, and planning, designing and operating workshop for programming and product creation. Considering "designing" not as "drawing a picture" but as "architectonics", KAKKO E LLC is using it as a means for solving problems. For example, responding to a

request from a client to create a poster, we start by asking the client why the poster is needed, not by discussing what kind of poster to create, and try to find out together what the client is really seeking. This kind of approach is important as a foundation of product creation and useful in the educational field as well. These ideas are based on "Design Thinking" advocated by IDEO. (Brown, T. 2009).

As part of our educational programs, KAKKO E LLC is holding "Workshop for experiencing the thinking way necessary for creating products" for volunteer students at GifuKAKAMINO senior highschool (GifuKAKAMINO senior highschool. 2017) and Ogaki Commercial Senior High School (Ogaki Commercial High School. 2017). With regard to programming education, the company is putting emphasis not on the instruction of programming methods but on learning how to use programming. The rapid technological progress in recent years will surely change existing programming methods. Therefore, the company, seeing programming simply as a means, is placing emphasis on acquiring a skill to select an appropriate means and use it. In this context, in the workshop the company is using the approach of "Design Thinking" where a product is developed while repeating or returning to the steps of "understanding", "observation", "discovery", "creating ideas", "prototyping" and "testing", while trying not to lose sight of the original purpose. Through the workshop the company intends to increase the number of young people who have interest in the business of product creation.

1.3 KOSEN (National Institute of Technology)

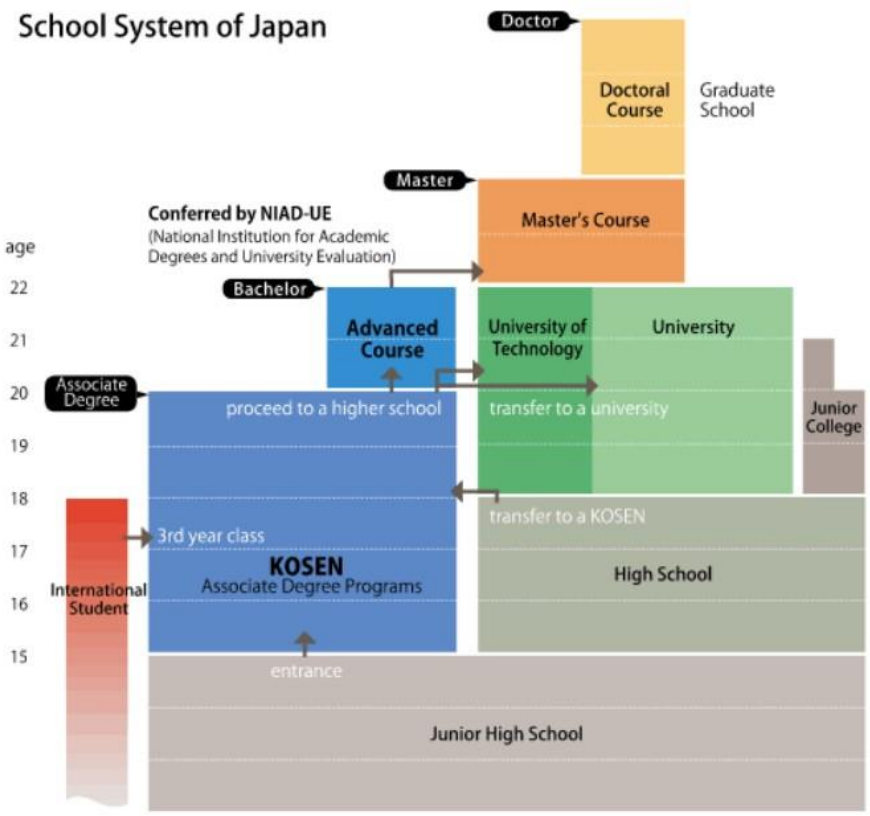

Figure 1: Japanese National Institute of Technology and the other educational institutions

KOSEN, National Institute of Technology (KOSEN, National Institute of Technology. 2009), accept junior high school graduates and provide them with integrated higher education. KOSEN is a unique Japanese

educational system which the Ministry of Education, Culture, Sports, Science and Technology established in the 1960s. (Figure 1) The graduates of a department (5 years) at KOSEN earn an associate degree, and the graduates of an advanced course (2 years) at KOSEN earn a bachelor's degree. It is possible for high school graduates to enter the fourth year of KOSEN. KOSEN is characterized by the provision of practical education incorporating various types of PBL. In Japan one KOSEN campus exists in almost every prefecture across the country. In 2004, the National Institute of Technology (NIT), Japan was inaugurated to manage 55 national KOSEN, which had been separate higher education institutions before that.

Though the Creative Camp Project is a PBL challenge for high school students, the first, second and third year students of NIT, Gifu College corresponding to high school students are allowed to participate in it. In 2016, the third year students at the Department of Architecture, NIT, Gifu College participated in it.

2 About Creative Camp Project

The PBL challenges called "Creative Camp Project" (initially, "autumn camp") started in 2013 under the theme of "Developing smartphone applications". In that year, two schools participated, and four teams created four applications. In 2014, it was held under the theme of "Association with smartphones" in a new way where a venture company takes charge of a team, and four applications were created by using the latest technologies such as Augmented Reality (AR) (Azuma, R. T. 1997, Dörner, R. *et al.*, 2013) and Projection Mapping (Lee, J. et al., 2015, Lange, V *et al.*, 2016). In 2015, the name being changed to "Creative Camp Project", it was held under the theme of "Future items", five digital works were created using the latest technology. (Table 1).

Table 1: Number of participated schools and companies, and theme.

Year	Number of participated schools	Number of companies	Theme
2013	2	3	Developing smartphone applications
2014	3	4	Association with smartphones
2015	4	6	Future items
2016	5	5	Free theme (Digital work)

3 Team Makeup and Schedule of the 2016 Creative Camp Project

In 2016 Creative Camp Project, the camp (lodging session) was held on October 29 and 30, and the presentations, on December 3. Setting a free theme, each team aimed at creating a digital work by PBL using the latest technologies. Also, the created products were exhibited at Ogaki Mini Maker Faire2016 (Ogaki Mini Maker Faire2016. 2016) held on December 3 and 4.

The names of participating schools are shown in Table 2. The team makeup, a combination of a high school and a company, was determined between a high school teacher and a company after they discussed and coordinated the content of a work a high school is trying to create and the technological fields in which a

company excels. The schedule of the camp (lodging session) and the presentation day is shown in Table 3.

Table 2: Team makeup of the 2016 Creative Camp Project.

Team name	School name	Venture company name
SOGO DREAM Labo	GifuSogoGakuenHigh School (GifuSogoGakuenHigh School. 2013)	GOCCO. Co., Ltd. (GOCCO. Co., Ltd. 2014.)
AF3	Ogaki Commercial Senior High School	grasp at the air Co., Ltd. (grasp at the air Co., Ltd. 2017)
Daikou ICT Club	Ogaki Technical High School (Ogaki Technical High School. 2014)	Quantum Information and Communication Technology Co., Ltd. (Quantum Information and Communication Technology Co., Ltd. 2017)
Sahdosuru	GifuKAKAMINO senior highschool	Triggerdevice Ltd. (Triggerdevice Ltd. 2017)
Norucha, POTTI	NIT, Gifu College	KAKKO E LLC

Table 3: PBL schedule of the 2016 Creative Camp Project.

Date	Time	Work
Oct. 29 (Sat)	10:00 - 11:00	Orientation, Introduction of venture companies
	11:00 - 17:00	Teamwork: raising issues, working out what the real issues are, generating ideas, designing a prototype, making a prototype
Oct. 30 (Sun)	8:00 - 12:00	
	13:00 - 14:30	Special lecture
	14:30 - 15:30	Mid-term presentation
	15:30 - 16:00	Teamwork: reviewing a product
Oct. 31 (Mon) – Dec. 2 (Fri)		Making and developing a product at each school
Dec. 3 (Sat)	10:30 - 12:00	Presentation day
	13:00 - 16:00	Exhibition (Ogaki Mini Maker Faire2016)

4 A PBL Challenge between NIT, Gifu College and KAKKO E LLC in the Creative Camp Project

4.1 Activities before the Creative Camp (lodging session) (Oct. 26)

KAKKO E LLC explained to the participating students about how to do PBL in the Creative Camp Project and determined the theme, "electric vehicles running landscape". Most of the participants in the Creative Camp Project are majoring in information at a technical high school, and they usually create a product related to

an application or a service. The participants of NIT, Gifu College major in architecture, so they decided to do a PBL challenge from a viewpoint of our actual life and environment. We thought fitting frequently talked-about “electric vehicles” in the theme would encourage even students majoring in architecture to build a digital work with the latest technology. We also thought they would work with various perspectives as students majoring in architecture, such as performance, design and landscape, through vehicles, our familiar “moving structures”.

After determining the theme, KAKKO E LLC gave the students instructions on how to research electric vehicles so that they could finish it by the day before the Creative Camp (lodging session). They were told to collect basic information such as the history and definition of electric vehicles, the present manufacturers through catalogs, magazines and the Internet, and observe electric vehicles and battery chargers at an automobile dealer.

4.2 Activities of the Day of the Creative Camp (lodging session) (Oct. 29 to 30)

On the days of the Creative Camp (lodging session), on October 29 and 30, the annual school festival was held at NIT, Gifu College. Since the participants of the Creative Camp (lodging session) were engaged in the festival as well, they could not spend two full days for the activities of the Creative Camp (lodging session). Therefore, they took turns to do the work.

A. Orientation (9:00 to 10:00, Oct. 29)

The orientation was performed by connecting the main venue (the second floor of Mobilecore (Mobilecore. 2017) in Softopia Japan) of the Creative Camp (lodging session) and NIT, Gifu College via Skype.

B. Observation and Research (10:00 to 10:30)

About a week's research conducted by the students before the Creative Camp (lodging session) was for collecting various kinds of materials as well as information obtained through authentic voices. They hadn’t taken a test drive in an electric vehicle. Therefore, they actually did. (Figure 2) The test drive helped the students observe and research an electric vehicle centering on how to start it, user interfaces and its actual movements.

Figure 2: Test drive for observing and researching an electric vehicle.

C. Sharing and Organizing Information and Findings (10:30 to 11:30)

Each team organized information collected through preliminary research and a test driving by use of brainstorming and the KJ-method. In the brainstorming session, they wrote down what they felt, thought and knew on sticky notes at first, and next, divided the written information into some groups after putting the sticky notes on a larger sheet.

D. Creating Ideas (11:30 to 14:00)

Based on each team's grouped information, they tried creating ideas under the theme of "electric vehicles running landscape". While doing this, they adopted an "idea sketch technique", a way of sharing ideas based on "Interactive Sketch" (Interactive Sketch. 2015) advocated by Junichi Kanebako et al. Writing ideas, target persons, situations to be used and comments and drawing sketches of ideas themselves in a single A4 sheet, they shared the ideas within a team using the sketch. (Figure 3) Based on the sketches of ideas, the idea of each team was decided as follows:

Team 1: An automatic charging system "Norucha" (literally, "driving")

Team 2: Demonstrating electric vehicles "KAKKO EV" (literally, "cool electric vehicle")

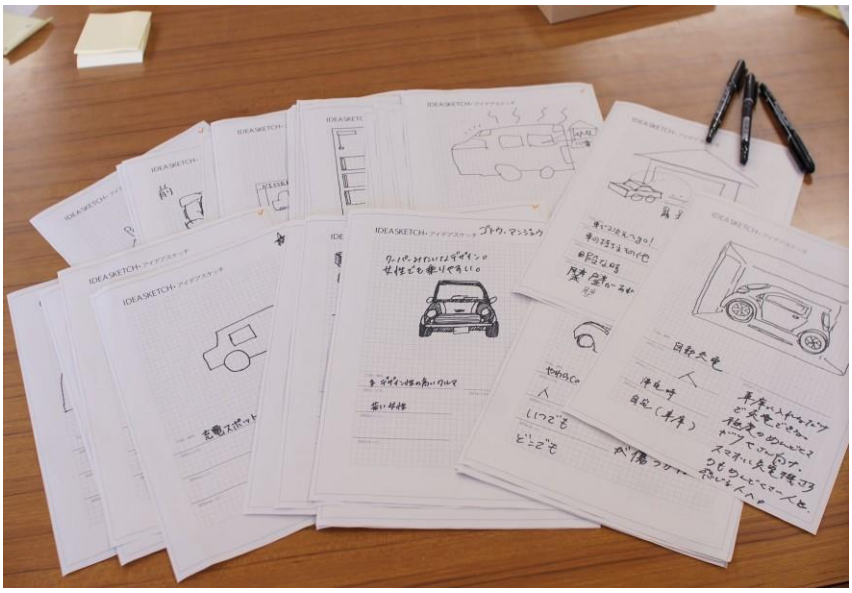

Figure 3: Examples of idea sketchs students created in the PBL challenge of the Creative Camp Project.

E. Instruction on How to Use SONY MESH and Make a Prototype (14:00 to 14:30)

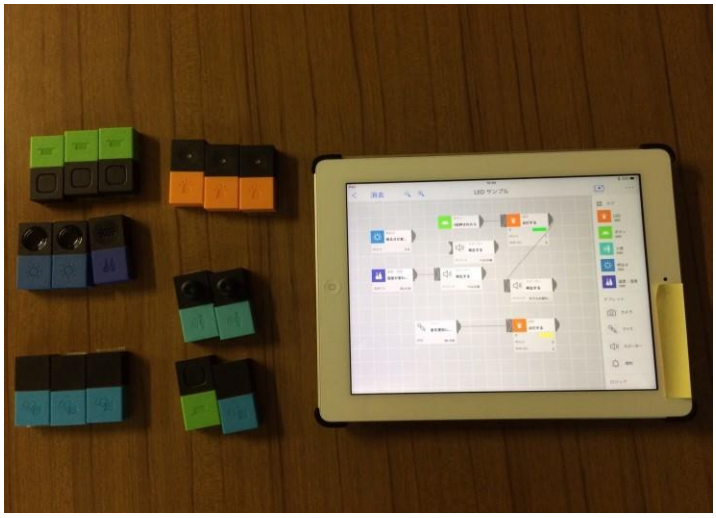

Figure 4: Used MESH tags and iPad.

KAKKO E LLC explained to the students on how to use SONY MESH useful for making a prototype. MESH can connect a small block called a tag which is embedded with a device such as a sensor or an LED to, for example, the functions of a camera, a speaker and email of a tablet, and control them. Therefore, KAKKO E LLC told the students to adopt MESH to make a prototype of an idea where flashing and the sounding timing is important. It is difficult to express them just by a model. For example, a car light is turned on when it gets near to a battery charger, or a car produces a sound when it gets dark. The following kinds of MESH (MESH. 2016) were prepared: four Button tags, four LED tags, four Move tags, two Motion tags, two Brightness tags, a Temperature & Humidity tag and a GPIO tag. (Figure 4).

F. Making a Prototype (14:30 to 9:00, Oct. 30)

Figure 5: Students making a dynamic prototype product using MESH.

Each team was engaged in making a prototype with their ideas from 14:30 to 9:00 of the following day. KAKKO E LLC told the students to make it with the emphasis on properly expressing the essential part of their ideas, rather than its appearance, since the prototype is only used for a presentation. They made a dynamic prototype product using MESH, cardboard, curing tape and a model car. (Figure 5)

G. Preparation for Mid-term Presentation (9:00 to 14:00, Oct.30)

In order to give a sufficient understanding of the system, the "Norucha" team made a 3D model in addition to a prototype product and also created presentation materials using PowerPoint. The "KAKKO EV" team

made a poster according to the form of a poster session. After completing the materials for the presentation, the students practiced for it.

H. Mid-term Presentation (14:30 to 15:30)

Figure 6: Presenting a dynamic prototype product using MESH at mid-term presentations.

The mid-term presentation was performed at the main venue (the second floor of Mobilecore in Softopia Japan) of the Creative Camp (lodging session). The presentation time was about three minutes for one team. Respective presentations were followed by feedback by three guests (President Kumasaka of Softopia Japan Foundation, President Yoshida of Institute of Advanced Media Arts and Sciences (Institute of Advanced Media Arts and Sciences. 2017), and Mr. Kobayashi, CGI director of EVANGELION (EVANGELION. 2009)) and by a final comment on the whole thing by the partner company of respective schools.

The prototype the “KAKKO EV” team showed was a model car with MESH which flashes in time with the movement of the model car. Its mechanism was easy to understand, and it worked all right at the

presentation. The idea the team presented was that part of a road would flash the moment an electric vehicle passes. The speakers themselves had taken a test drive in an electric vehicle and were impressed with it, which motivated them to spread its merits throughout society.

The prototype the "Norucha" team showed was a model car with MESH (Brightness tag and LED tag). Its mechanism was also easy to understand, and it worked without any trouble. The team presented a system where an electric vehicle could be charged just by parking, focusing on "charging", at which an electric vehicle is weak. Existing electric vehicles cannot be charged without connecting to a cable, but the idea could resolve this inconvenience by using the electromagnetic induction principle. (Figure 6) Seeing their work differently from the other high school teams, who made presentations focusing on the content of their ideas, the "Norucha" team made a presentation focusing on physical size and implemented standards rather than mechanisms and ideas.

4.3 Making and Developing a Product at Each School (Oct. 31 to Dec. 2)

The participating students engaged in making and developing a product at each school from October 31 to December 2. Keeping two ideas at the time of the mid-term presentations, the two teams of NIT, Gifu College, the "KAKKO EV" team and the "Norucha" team were reorganized into three teams, the "Machi" (literally, "town") team, the "battery" team and the "Kuruma" (literally, "vehicle") team. The "Machi" team started to cast their ideas into shape based on the ideas created by the "KAKKO EV" team from the viewpoint of "electric vehicles and landscape", the "battery" team, based on the ideas created by the "Norucha" team from the viewpoint of "charging", and the "Kuruma" team, from the viewpoint of the "design of electric vehicles".

4.4 Final Presentation (Dec. 3)

Figure 7: Students' products exhibited at Ogaki Mini Maker Faire2016.

In the final presentation, the "Kuruma" team and the "Machi" team jointly presented a single product, which had been completed by improving the ideas created by the former "KAKKO EV" team. In consideration of demonstrating a running electric vehicle, the two teams suggested a low-center-of-gravity design which would be realized by placing batteries at the entire bottom of a vehicle. Also, they designed a landscape where electric vehicles are naturally mixed in a town by presenting a model of the town where they were running.

The "battery" team offered a presentation on a mobile cover, considering actual mounting and backed by the engineering aspects such as electric energy and size. After the final presentation, the students' products made by PBL were exhibited at Ogaki Mini Maker Faire2016, a festival of product creation, which was held in

Softopia Japan on the same day. (Figure 7)

5 Conclusion

The 2016 Creative Camp Project, which was conducted as a PBL challenge, ended with an exhibition (Ogaki Mini Maker Faire2016) held on December 3. In the past, however, some teams continued to improve their products and succeeded in achieving productization. In this sense, the final presentation is not a goal but a start. Since the Creative Camp is a project conducted through industry-university-government collaboration (the prefectural government, Softopia Japan, schools and venture companies), they cover for each other. This type of collaboration will enhance the prospect for productization. Creativity fostered by PBL will bring social competencies for survival to students. In small-group PBL, specific challenges are solved through the process of insight, observation, dialogue, negotiation, reflection and restructuring of learning. The upward spiral is expected to make the flowers of the seeds of ideas come into bloom as innovative products, and to encourage students to improve thinking power and creativity they have acquired and develop human resources with venture spirit.

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Entrepreneurial Education and Project Based Learning (PBL) Outcomes in Engineering

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Abstract

This article aims to report the entrepreneurial education experience of three professors from the Itabira campus of Itajubá Federal University, who used PBL strategies with the objective to develop entrepreneurial skills in their students. This study focused in the integrated model for entrepreneurial education proposed by Pretorius, Nieman, & Vuuren (2005), and tested the learning outcomes of their entrepreneurial education experiences in an engineering context. Therefore, the question that guided the study is: What impacts, in terms of entrepreneurial learning, project-based learning strategies can generate for the students involved? Through the application of a questionnaire to the students, the impacts of PBL strategies were obtained in terms of the motivation to become an entrepreneur, the learning of entrepreneurial skills (creativity, innovation, and leadership), the learning of business skills (business model development, financial, marketing, and human resources management), and the impact of the facilitator's ability and skills to enhance motivation, entrepreneurial skills, and business skills. The data was statistically analysed and, considering the results, the authors highlighted the following outcome: a) 76% of the students said that the facilitator's ability and skills were effective to motive and transmit knowledge; b) 57% of the students felt motivation to perform in an entrepreneurial manner, c) 51% of the students developed their entrepreneurial skills during the experience; d) 42% of the students developed their business skills during the experience; and d) 67% of the students said that the PBL pedagogical approach was appropriated to its objective. This study showed the importance of the facilitator´s role in the entrepreneurial education. PBL approach proved its value to engage students and to turn learning into an interesting journey for the students. It was possible to point out opportunities of improvement in the practice of the teachers involved, and in the learning strategies used by the teacher (such as the integration of technological and entrepreneurial disciplines, the involvement of external mentors and professionals, and a solid behaviour orientation toward an entrepreneurial mindset).

Keywords: Entrepreneurial Education; Engineering; Project-Based Learning

Type of contribution: research paper.

1 Introduction

New social imperatives have rendered it essential that universities assume a responsible role as trainers of good professionals capable of entering, and thriving in, the workplace. Improving employability is now more than ever a key aspect of education, and one that all universities are obliged to tackle. In engineering fields, university departments should seek to provide students with a broad range of skills and knowledge beyond the merely technical (Ohland, Frillman, Miller, & Carolina, 2004), including good communication skills, expertise in multidisciplinary teamwork, entrepreneurial spirit, global and

multilateral approaches to problem-solving, and sensitivity to the cultural, social and economic environment (Torres, Velez Arocho, & Pabon, 1997).

In face of this context, it can be seen that both entrepreneurship education and the adoption of active learning methodologies have had considerable relevance in the context of engineering education. This is due to the fact that both educational applications aim to provide engineers with entrepreneurial and management skills (Papayannakis, Kastelli, Damigos, & Mavrotas, 2008) that will enhance their profiles in accordance to the new requirements of a knowledge-based economy.

In order to address this matter, this article aims to report the entrepreneurial education experience of three professors from the Itabira campus of Itajubá Federal University, who used project based learning strategies with the objective to develop entrepreneurial skills in their students. This study focused on the integrated model for entrepreneurial education proposed by (Pretorius et al., 2005), and tested the learning results of their entrepreneurial education experiences in an engineering context.

This article contains six parts. This first part is the introduction. The second part is the theoretical framework for understanding the following fundamental concepts of this study: entrepreneurial education, active learning in engineering education, and project based learning. The third part presents the research procedures, consisting of questionnaires answered by the students during 2016's first semester. The fourth part discusses the data. The fifth part contains final considerations about this study and, finally, the sixth part lists the bibliographic references used in this work.

2 Theoretical Framework

2.1 Entrepreneurial Education

The world has been experiencing challenges in the socio-economic area. As a result, entrepreneurship emerges as an alternative through which the generation of new innovative companies can help countries to generate revenue and development. When entrepreneurial development is seen as the main contributor to enhance the creation of new ventures, and hence facilitate economic growth and development, the best possible education model is required. The creation of more entrepreneurs is, at least partially, dependent on the creation and improvement of efficient productive models (Pretorius et al., 2005; Inacio, 2014).

In Brazil, some entities are guiding the incorporation of entrepreneurial education, such as the Law of Innovation (Brazil, 2004), the Law on Guidelines and Bases of Education (Brazil, 1996), the work of the Brazilian System of Small Business Support (SEBRAE), and Endeavor, which have programs to promote entrepreneurial education in the country's universities. This action has been widely used in the authors' university, where teachers have being trained in entrepreneurship education. This training uses the "Bota pra Fazer" platform developed by Endeavor.

In the context of engineering education, there are new imperatives of the knowledge-based society requiring engineering students to equip themselves with a broad range of skills, among which entrepreneurship plays a critical role (Ortiz-Medina et al., 2014). In saying so, the authors realized that there are several different reasons pressing teachers to create an education environment where engineering students feel encouraged to reshape their mindset toward trusting, risk assessment, communication, overcoming social barriers, rejection therapy, and fail training (Sidhu, Singer, Johnsson, & Suoranta, 2015).

Maresch, Harms, Kailer, & Wimmer-Wurm (2016) embrace the concept that entrepreneurial education (EE) is based on the realization that successful entrepreneurship is positively affected by the dispositions, skills, and competences of the founders of an enterprise. Several authors suggest that these dispositions, skills, and competences can be shaped by education (Ortiz-Medina et al., 2014;Lopes, 2014; Pretorius et al., 2005; Inacio, 2014).

Considering the diversity of elements that interfere in a successful entrepreneurial education, Pretorius et al. (2005) have developed a model that compiles all these elements. Understanding the elements and their influences on the development of entrepreneurial potential is crucial to internalize the entrepreneurship theory and to develop and implement policy initiatives that enhance the entrepreneurship education(Pretorius et al., 2005). This model is represented by the following equation:

$$E \quad E/P = \quad \times \quad / \times \quad / \times \quad + \quad / \quad ,$$

where, E for E/P is the education for improved entrepreneurial performance; F is for the facilitator's ability, skills, and experience; M is for motivation; E/S is for the entrepreneurial skills; B/S refers to business skills and knowledge; A is for approaches to learning; B/P is for business plan utilization as an approach; and a to f are constants (0 < constant < 1).

According to this model, Education for E/P is a linear function of the facilitator's ability and skills (aF) to enhance motivation (bM), entrepreneurial skills (cE/S), and business skills (cLB/S) through the creative use of different approaches and, specifically, the business plan. It is important to realize that the constants will have a value ranging between zero and one. For example, a facilitator could have very low skills and abilities that he or she would apply, but it is above absolute zero. The same would be true for the constants of the other constructs that mainly have to do with the learner. The authors said that model serves as a guideline for the compilation of entrepreneurship educational programmes. Understanding the elements and their influences on the development of entrepreneurial potential is crucial to the internalisation of entrepreneurship theory and the development and implementation of policy initiatives to enhance entrepreneurship education.

To summarize Pretorius et al. (2005) findings, it could be stated that the success of entrepreneurial and small business learning overwhelmingly depends on the facilitator construct of the programme despite having the same value as the other constructs in the model. A good facilitator or group of facilitators could, therefore, achieve more with a poor programme content than poor facilitators could achieve with a good programme content. The importance of the facilitator's role in the learning process has been constantly emphasized. It seems that the facilitator is the key construct of the proposed model, while the other constructs serve as tools to achieve a desired outcome.

2.2 Active Learning in Engineering Education

The discussion about active learning (AL) has become increasingly popular among higher education institutions in Brazil and worldwide (Prince, 2004; Fernandes, Flores, & Lima, 2010; Rocha & Lemos, 2014; Nagai & Izeki, 2013). Teachers from various knowledge fields, mostly on medicine and engineering, have successfully experimented with AL methodologies, obtaining valuable results in motivation for learning, social interaction, retention, and other outcomes (Prince, 2004).

The university where the authors work, Itabira campus of UNIFEI, has invested in AL methodologies for teachers, creating a pressing reality for these authors. This investment has been made through

partnerships with Minho University (Portugal) and Delaware University (United States). In addition, UNIFEI participates as an active member of the STHEM (Science, Technology, Humanity, Engineering and Mathematics) consortium, which uses AL methodologies to improve teaching in these areas.

To clarify the increasing importance of AL, Lima, Andersson, & Saalman (2017) made a bibliometric survey by using the Elsevier Scopus search service (https://www.scopus.com/), and found 17,523 published documents in journals related to engineering education, of which 751 are related to AL in engineering education. The most popular techniques were analysed in this survey, where problem based learning and project based learning had an important relevance of 60% in 751 occurrences.

The survey time frame was from 1985 to 2015. The authors could notice that in the last decade, the number of papers on this topic had grown significantly. According to Lima et al. (2017), the active learning topic has an increased importance for the engineering education community. In the first seven months of 2016, 69 documents were already published in indexed journals, it is expected that the total number of published documents in 2016 will be greater than the 98 published documents in 2015 (Lima et al., 2017).

The AL methodology goal is to engage students in the process of knowledge construction (Prince, 2004). The student leaves the passive listener position of a lecture and is invited to absorb the proposed content with the responsibility of seeking new sources and new interpretations about the content that is being discussed. In the scope of active learning, methodologies use several types of strategies that allow the process of knowledge construction to take place inside and outside the classroom.

Problematization and problem based learning methods are based on critical pedagogy, and work with learning problems, valuing the learning to learn (Marin et al., 2010). In these methods, students should seek explanations and propose solutions to the problem. The learning occurs by resolving the situation with a hands-on attitude, an by critically analysing the situation (Marin et al., 2010).

According to Marin et al. (2010), the problematization methodology is based on Paulo Freire's principles and problem based learning is based on John Dewey's Theory of Inquiry. According to this theory, learning occurs from problems or situations that generate doubts or questions.

To Braga, Guedes, Silva, & Vicente (2014), the problematization methodology encorages the development of essential attributes for a future professional life, such as problem solving, creative thinking, teamwork, ability to identify strengths and weaknesses, commitment to learning and continuous improvement, confidence, and initiative. The problematization methodology contributes to the formation of the student in a conceptual and investigative way, allowing the improvement of communication and interpersonal skills, which are necessary qualities in a professional environment.

Further more, these learning activities are designed to engage the students and to call the student's attention to the high value of this knowledge. All of this happens with the objective to make students have a hands-on experience, and develop essential skills to their professional success (Lettenmeier, Autio, & Jänis, 2014).

In this engineering education context, AL becomes very advantageous because of the explicit need for knowledge application. In this context, practical classes, laboratories, simulations, field research, and other techniques already induce the student to apply the theory in practice. In addition to applied science activities, several AL techniques appear in the literature. Table 1 briefly describes these techniques as follows.

Table 1: Name and brief description of most popular active learning strategies

Name	Brief Description
Problem based learning (PBL)	real problems are posed so that students, as a group, can create solutions to the proposed situation (Haryani, Prasetya, & Permanasari, 2014)
Project based learning (PBL)	semi structured problems (often interdisciplinary) are investigated, solved, and shared in the form of a product that can be an experience report or a new product (Rocha & Lemos, 2014)
Peer instruction	interactive teaching technique that promotes classroom interaction to engage students and address difficult aspects of the material (Mazur & Watkins, 2009)
Just in time teaching (JiTT)	students read the material before class and provide feedback so the instructor can tailor the questions to target the student difficulties (Mazur & Watkins, 2009)
Team based learning (TBL)	process involving individual study, test of individual content fixation, group discussion about errors and correctness, group activity to apply the concepts and presentation of the learning results of the groups (Michaelsen & Sweet, 2008).
Case Study	presentation of real dilemmas, where decisions should be made and consequences faced (Mayer, 2012)
Simulation	virtual demonstrations of phenomena or real concepts allowing the interaction of the student with the studied content (Finkelstein et al., 2005)
Flipped classroom	active involvement of students in the teaching process that must be prepared before the classroom encounter (Gilboy, Heinerichs, & Pazzaglia, 2015)

By authors

Among the active learning strategies mentioned in table 1, this study focused on the project based learning that was used in the experiences reported in this work.

2.3 Project Based Learning

Projects are finite endeavours with defined goals that rise from a problem, a necessity, an opportunity or interest of a person, a group, or an organization (Barbosa & Moura, 2013). When this concept is used as a pedagogical resource, project based learning (PBL) rises as an AL strategy that allows a student to learn by applying these ideas and concepts (Krajcik & Blumenfeld, 2006).

The PBL is a form of situational learning based on the constructivist findings where the student gains a profound comprehension when he or she gets involved in their knowledge development (Krajcik &

Blumenfeld, 2006). This strategy has been gaining ground especially in applied science universities due to the student´s necessity to develop several learning skills for the professional environment. It is a technique that provides multifaceted learning experiences as opposed to the traditional teaching method (Lettenmeier et al., 2014).

The idea of working with projects as a pedagogical resource in the knowledge development dates back to the end of the XIX century, based on ideas articulated by John Dewey in 1897 (Krajcik & Blumenfeld, 2006; Barbosa & Moura, 2013). However, the Project Methodology (PM) work dates back to the end of the XVII century in Italy under a vocational education perspective, specifically in Architecture field (Knoll, 1997). Dewey considered that projects developed by students demanded the help of a teacher who could ensure the continuous process of leaning and development (Barbosa & Moura, 2013).

According to Barbosa & Moura (2013), there are three categories for this method: (i) Constructive project: it aims to build something new by introducing innovations or proposing a new solution to a problem or situation. It has a function, form, or process in the inventiveness dimension; (ii) Investigative project: research development on a matter or situation by applying a scientific method; and (iii) Didactic (or explanatory) project: tries to answer questions such as "How does it work?, “What is it for?, and “How was it constructed?". It seeks to explain, to illustrate, and to reveal the scientific principles of functioning of objects, mechanisms, systems, and so on.

To Krajcik & Blumenfeld (2006) , PBL is an overall approach to the design of learning environments. Learning environments that are project-based have the following five key features:

1. They start with a driving question, a problem to be solved; 2. Students explore the driving question by participating in authentic, situated inquiry, which are processes of problem solving that are central to expert performance in the discipline. As students explore the driving question, they learn and apply important ideas in the discipline; 3. Students, teachers, and community members engage in collaborative activities to find solutions to the driving question. This mirrors the complex social situation of expert problem solving; 4. While engaged in the inquiry process, students are exposed to learning technologies that help them participate in activities normally beyond their ability and 5. Students create a set of tangible products that address the driving question. These are shared artefacts, publicly accessible external representations of the class’s learning.

Considering all these PBL characteristics, it is possible to conclude that this strategy is broadly used to obtain learning results. For this to happen, it is believed that the teacher must constantly check whether the students have the appropriate theoretical basis for developing a project. Moreover, it is important that the teacher acts as a tutor by following the intermediary results, and by verifying the progress of the work group. Thus, PBL is presented as an alternative to knowledge development that can be shared internally and externally by the university.

3 Research Procedures

This is a descriptive research (Gonçalves & Meirelles, 2002) that is the most appropriate modality to describe the experiences of entrepreneurial education using the project based learning (PBL) strategy of active learning. In order to know in depth the results of the performed activities, the quantitative strategy was used. According to Gonçalves & Meirelles (2002), this strategy is more adequate for the behaviour quantification and analysis of a given population.

To achieve the objectives of the study, a multiple case study was developed that, as Yin (2005) states, can

be useful for testing theories and elucidating situations. The cases studied were the pedagogical experiences of three professors from the Itabira campus of Itajubá Federal University, who used PBL strategies with the objective to develop entrepreneurial skills in their students.

Data collection was done through the application of a questionnaire that was answered by the students at the end of the course. The questionnaire was composed of 36 closed questions that students were asked to answer on a 5-point scale that indicated how often the situations in the questions occurred, being 1 for never, 2 for rarely, 3 for some times, 4 for most of the times, and 5 always. These questions were elaborated to evaluate the results of entrepreneurship teaching experiences following the theoretical model proposed by Pretorius et al. (2005). Thus, four sets of questions were raised which were: a) perception of effectiveness of facilitator's ability and skills; b) perception of motivation to perform in an entrepreneurial manner; c) perception of development of entrepreneurial skills and business skills during the taught topic and d) perception of effectiveness of the pedagogical approach (project based learning). For data analysis, descriptive statistics were used to determine the percentage of students that fit into each situation described in the questions.

3.1 Description of the activities developed in the disciplines

The selection of disciplines took into account the experience that teachers had already had with the application of AL techniques and the respective learning outcomes of the students. A brief description of these disciplines is describes as follows:

- Discipline 1: The Scientific, Technological, and Entrepreneurship introductory discipline is part of the curriculum for the electrical engineering and production engineering undergraduate courses. The fifth semester's discipline consists of approximately 59 semester hours. The main goal of the discipline was to develop business ideas in the students' knowledge area. According to (Barbosa & Moura, 2013), the project was investigative because the students had to develop and present an executive summary of the business idea formulated by their group. The project was developed by using the "Bota pra Fazer" platform developed by Endeavor.
- Discipline 2: The Introduction to Engineering discipline is part of the curriculum for all undergraduate courses. The first semester's discipline consists of approximately 15 semester hours. The main goal of the discipline was to develop business ideas in the students' knowledge area. (Computer Engineering and Control and Automation Engineering). According to (Barbosa & Moura, 2013), the project was investigative because the students had to develop and present the technical, economical, and commercial viability of the study, along with the social and environmental impacts of the business idea developed by their group.
- Discipline 3: The Industrial Instrumentation discipline is part of the curriculum for the electrical engineering courses and for the control and automation engineering courses. These courses consist of approximately 90 semester hours, with one third of the classes in a specific laboratory. In this discipline, a project was proposed with the main goal to solve a real problem by assembling sensors and conditioning their signals. The students were divided into groups. Each group was managed by a leader, as if they were in a company, with operational rules, roles, and functions. At the end of the course, each group had to present a prototype as if they were presenting a commercial product.
- Discipline 4: The Logistics discipline is part of the curriculum for the Mobility Engineering undergraduate course. The ninth's semester discipline consists of approximately 45 semester

hours, with one third of the classes in a specific laboratory. The main goal of this discipline is to present the logistics and the supply chain management concepts. The PBL was used in hands-on classes, where the students had to build something new, proposing a solution to a problem or a situation in the logistics field. The project was developed by using the "Bota pra Fazer" platform, developed by Endeavor.

3.2 Presentation of Collected Data

As the authors pointed out on the previous session, the students were asked to answer the questions on a 5-point scale that indicated how often the situations in the questions occurred, being 1 for never, 2 for rarely, 3 for some times, 4 for most of the times, and 5 always. Considering the most frequent situations (responses 4 and 5), the authors got the results presented on Tables 3, 4, 5, 6, and 7 which are considered the assessment level of the constructs indicated on the (Pretorius et al., 2005) model.

As shown on Table 2, the effectiveness of facilitator's ability and skills got the highest assessment level. According to the answers, it is possible to see that the facilitators were effective to support the development of the projects. The teacher also acted in an entrepreneurial way, and was effective to motivate the students and to provide the knowledge needed for the project development.

Table 2. Perception of effectiveness of facilitator's ability and skills

Situation	%
The teacher was effective in proposing relevant reflections for the project development.	87,50%
The professional experience of the teacher was sufficient to direct the projects.	83,30%
The teacher acts in an entrepreneurial way.	81,90%
The teacher was effective in leading the learning process.	76,40%
The teacher was effective in transmitting business techniques.	75,00%
The teacher was effective in motivating me to act creatively and innovatively.	70,80%
The teacher was effective in motivating me for entrepreneurship.	66,70%
The teacher was effective in transmitting technological knowledge.	62,50%

Table 3 presents the construct motivation to act in an entrepreneurial way. According to the responses, students felt more motivated to change their attitudes to solve problems and to contribute to economic development (local or global) through new technologies. The same degree was not obtained for the motivation to apply their ideas, to manage, and to open a company. It is believed that this data reflects the risk aversion that some students have. This risk aversion has been reported in some studies about the disposition to entrepreneurship (Inacio, 2014).

Table 3. Perception of motivation to perform in an entrepreneurial manner

Situation	%
I felt motivated to adopt new attitudes to solve problems.	68,10%
I felt motivated to contribute to economic development (local or global) through new technologies.	65,30%
I felt motivated to turn my ideas into reality.	55,50%
I felt motivated to be a manager in a company.	50,00%
I felt motivated to start a business.	45,90%

Table 4 presents the construct development of entrepreneurial skills. During the deployment of the disciplines, students report that they improved their endurance, creativity, critical thinking, planning, and project management. It was noticed in a smaller proportion that the abilities to identify an opportunity, leadership, confrontation of risky situations, and innovation were less developed. Note that the students had difficulties to create innovations based on their own knowledge.

Table 4: Perception of development of entrepreneurial skills during the taught topic

Situation	%
I developed my persistence to achieve goals.	62,50%
I developed my ability to think creatively and critically.	61,10%
I have developed my ability to plan and manage projects to achieve objectives.	61,10%
I developed my ability to identify opportunities to generate new solutions to real problems.	54,20%
I developed my leadership ability.	45,90%
I developed my ability to deal with risky situations.	38,90%
I developed innovative ideas.	34,80%

Business skill development was the construct that obtained the worst evaluation, it is noticed that it has room for improvement for the practices analysed in this article. The indexes were considered low when students were asked whether they had learned management techniques during the deployment of the discipline. 50% of the students reported that they knew financial management techniques; 47% reported that they knew marketing techniques; 44.5% reported they knew operational resource management techniques; and 41.6% reported that they knew techniques of managing people. Knowledge of business legal implications was the worst index, with only 25%. These are very relevant techniques for entrepreneurial activity, which demonstrates a need for improvement in future practices.

Table 5: Perception of development of business skills during the discipline

Situation	%
I have known business financial management techniques.	50,00%
I have known marketing / business communication management techniques.	47,20%
I have known business operational resource management techniques.	44,50%
I have known management techniques of business people.	41,60%
I have known business legal implications.	25,00%

With regard to the construct pedagogical approach, it is considered that the experience was well evaluated. According to the students, the content of the discipline was fully learned. In addition, the teacher / student relationship and the student / student relationship were facilitated. This allowed the students to report that they had learned how to work in groups. Regarding the essential purpose of AL strategies, which enables the student to be permanently active in the learning process, it was reported that 66.7% of the students felt responsible for their learning. 58% of the students reported that the learning was acquired when dealing with actual problems. In a smaller proportion, 48.6% of the students recognized that PBL provided unique learning situations.

Table 6: Perception of effectiveness of the pedagogical approach (project based learning).

Situation	%
The content of the course was fully learned.	90,20%
The teacher / student relationship was facilitated.	77,80%
The student / student relationship was facilitated.	75,00%
I learned to work in a group.	73,65%
I felt like an active agent in your learning process.	70,90%
I felt responsible for my own learning.	66,70%
The learning was acquired when dealing with actual problems.	58,30%
I developed skills that would not be developed by another method	48,60%

4 Data Discussion

This is the question that guided the study: What impacts, in terms of entrepreneurial learning, project-based learning strategies can generate for the students involved?

In general, the application of the active learning strategy PBL had positive impacts on students' learning, who experienced the development of projects that generated solutions to real problems. With regard to the perception of effectiveness of facilitator's abilities and skills, both in the motivational part and in the presentation of the technical contents, the teacher's performance was fundamental for the students to develop the activities throughout the semester and to motivate the students to seek solutions for the proposed projects. Considering the average answers by group of question, the approval of the teacher's performance was 76% according to the students. As advocated by Pretorius et al., (2005) the facilitator plays an important role, and it can be concluded that the facilitator’s performance was decisive to motivate and transmit knowledge in the experiences reported. Regarding the perception of motivation to perform in an entrepreneurial manner, the average response was 57%, a lower percentage when compared to the previous group of questions. It is believed that these data reflect the risk aversion that some students have that has been reported in some studies on entrepreneurship willingness (Inacio, 2014). It is noticed that the students believe that to open their own business it is necessary to have more maturity. This belief makes the entrepreneurial career deferred in relation to the search for a job. The data shows that students find it difficult to take ideas from the paper and visualize innovative technological solutions to solve real problems. While on one hand it is possible that the programme helped students to develop these skills, on the other hand it is possible to state that there is room for improvement on this issue. One element to rethink is the introduction of a strong behavioural orientation for the development of creativity. In addition, it is believed that the integration of technological and entrepreneurship disciplines can help with the development of the students' inventiveness when they can, from the technical knowledge obtained to

generate innovative technologies.

The questions that reflect the perception of development of entrepreneurial skills and business skills during the program averaged 51% and 42%, respectively. In the evaluation of the authors, these numbers can be considered low, which opens important considerations on the opportunities for improvement in the disciplines. Beyond the introduction of a strong behavioural orientation mentioned above, it is believed that it is imperative that during the programme students are invited to reflect on the mindset that governs their behaviour (Sidhu, Singer, Johnsson, & Suoranta, 2015). One of the highlights was the issue related to the development of business skills, with particular emphasis on the legal implications of business. At this point, it is understood that it will be necessary to reformulate the way the information is shared, making use of actions of partnerships with specialized professionals. These findings highlighted the importance of building a solid support network involving a whole range of aspects and roles, and carrying out continuous monitoring.

The last group of questions focused on the perception of effectiveness of the pedagogical approach (PBL). The mean of the responses was 67%, which shows that the students realized how different the application of the adopted pedagogical technique was and how they benefited from it by learning in a different way. This different form of learning involves improving the relationship between the students and the teacher, between the students themselves, and also through the sharing of responsibility in their learning. Students understood that the teacher can facilitate the learning process, but they need to take an active role in developing the activities.

Data showed that those pedagogical experiences were good enough to generate an attitudinal and behavioural modification by the participant after having attended the programme. The authors also noticed, by this research, that this modified attitude will lead to activities associated with business start-ups or entrepreneurship on established enterprises. The survey indicated that the facilitators impacted the participant in such a way that the attitude and behaviour were modified. Nevertheless, the outcomes of start-up creation can only be measured in the future.

Final Consideration

It can be said that the students have been able to reach the dimension of inventiveness, in the function, form, and process of the PBL. The problems identified by the students were solved through the discussion of business concepts, and often presented with innovative solutions. One of the points that attracted attention was the question about the student's motivation who participated in the application of the PBL. PBL is one of the methodologies that help students and teachers build learning environments. With all of PBL´s characteristics, it is possible to development strategies to obtain learning results: they learn and apply important ideas, development collaborative activities to find solutions to "driving question", can learn with technologies and create a set of tangible products. Therefore, PBL can support entrepreneurial education and entrepreneurial activities and it is a function of human, venture and environmental conditions.

It was noted that the motivation could be greater if the formation and pulverization of the entrepreneurial culture was deployed throughout the course, and not only in some disciplines in different periods. Another factor worth highlighting is the cultural issue. Cultural change is also an important factor in this learning process, and the training of both teachers and students needs to begin in elementary and secondary education.

Although the teachers' skills have been well evaluated, it is understood that teachers should constantly seek the updating of techniques and mechanisms to improve the sharing of knowledge with students. Another important aspect to be considered in future experiments is the assessment of knowledge and skills before and after the disciplines. This procedure would allow for more accurate comparisons of the behavioural changes that the program generated.

As possibilities for future studies, the authors aim to compare results among disciplines and to expand this research to the entire campus instead of applying it just to graduates. The purpose of these future studies is to verify the impact of the disciplines in the generation of start-ups post university.

This study showed the importance of the facilitator's role in entrepreneurial education. PBL approach proved its value to engage students and turned the learning experience into an interesting journey to the students. It was possible to point out opportunities for improvement in the practice of involved teachers, such as the integration of technological and entrepreneurial disciplines, the involvement of external mentors and professionals, and a solid behaviour orientation toward an entrepreneurial mindset.

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Experiences of implementing PBL in engineering courses in Southern Chile

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Abstract

In this best practice paper, the experiences with the implementation of the methodology of Problem Based Learning (PBL) in engineering courses at three universities in southern Chile are presented and discussed. In June and August 2016, academics of the University of Strathclyde delivered at the Universidad Católica de Temuco two one-week workshops to 17 teachers. In the first workshop, the teachers experienced the dynamics of learning with the methodology when they were assigned to solve predesigned problems by working in groups. In the second workshop, the teachers were asked to design problems based on given topics. The workshops appeared to be crucial in the cultural change of adapting the active pedagogy, as 11 teachers started to implement the newly incorporated methodology. The workshops provided a series of helpful experiences with practical and design aspects of problems, complemented by an introduction of general concepts of active teaching. This contribution gives an account on the experiences of the following implementation of PBL by four teachers who participated in the workshops. Major identified challenges are the role of the facilitator, the role distribution among the students, and the use of the evaluation rubrics.

Keywords: Problem Based Learning, Best practices

Type of contribution: Best practice paper

1 Introduction: Motivation for PBL implementation

Engineering students need to acquire competences and abilities beyond their expertise in specialized subjects. In order to enable them to address the future needs of the industry efficiently, we need to evaluate strategies to improve the training of these future professionals. Complementary to the familiarization with the necessities of relevant industries early on during their studies, active pedagogies help to acquire key competences. Problem Based Learning is an active pedagogical method, where "real" or realistic problems are raised in order to motivate and guide the learning. Instead of the transmission of isolated materials, it develops critical judgement and integrated knowledge of multiple disciplines (Fernández and Duarte, 2013).

A major challenge in higher education in Chile is the fact that the teachers themselves are the products of a traditional authoritative education. In addition, in their methods, teachers tend to replicate the same patterns they experienced in their own education (Charbonneau-Gowdy, 2015). Complementarily, classroom design infrastructure's, the common content oriented design of study plans and the mind-set of key senior staff members are factors that support traditional teaching setups. Despite of increasing efforts to encourage innovations in education, only a minority of teachers are adapting pertinent methods. A radical change in the formation of professionals can only happen when innovative pedagogical methods are adapted in a massive way.

According to several authors at an international level (Lehmann *et al.*, 2008; Hitt, 2010; Shinde *et al.*, 2013), there is a big discrepancy in engineering between the skills of the engineer needed by the industry and the engineer graduating from the university. These differences are related mainly to the skills expected from a graduate: creativity, collaboration, critical thinking and communication. All these essential skills are not genuinely addressed in the educational field, especially when still approaching a traditional teaching where the teacher is the owner and exclusive transmitter of knowledge.

For the specific case of chemical engineering, the study of Ramírez *et al.* (2016) points out that, because of the challenges in the area during the next ten years, constantly updated academic programmes are mandatory. The aim is to adapt the teaching of theoretical knowledge and practical abilities to the emerging worldwide economic and technological challenges. Under this premise, these authors, among others in the same area, highlight that the education in engineering needs to be centered in guaranteeing that future engineers acquire the minimum abilities to confront new challenges. The abilities to seek information and promote self-learning are most valuable (Ramírez *et al.*, 2016; Hasna, 2008; Miller 2014).

The project "Building Capacity in STEM for enhancing socio-economic development in regional Chile", which was financed by the Newton Fund via the British Council, organized a teacher training on the methodology of Problem Based Learning. The two one-week workshops at the Universidad Católica de Temuco where delivered by staff members of the University of Strathclyde and attended by 17 teachers of various engineering disciplines from several neighboring regional universities. In the first workshop, the teachers experienced the dynamics of learning with the methodology by being exposed to predesigned problems that were assigned to be solved by working in groups. In the second workshop, the teachers were asked to design problems on given topics. The motivation of the participants was to get training in active pedagogies, being aware that cultural change in teaching practices is an ongoing topic. Moreover, in regional universities the new teaching methods arrive delayed and there are few opportunities to receive an adequate training by experts that are familiar with both pedagogical concepts and the subject area.

In the present contribution, we present an account of our experience with the implementations of PBL in engineering courses, which were subsequently offered by the newly trained teachers. The long-term perspective is to replicate the same teacher training in other South American countries as part of a dissemination strategy of PBL.

2 Description of the PBL method

The principal characteristic of the applied PBL method consists of defining a so-called "problem" that generates an open and realistic task which mirrors workplace experiences from a local industry. The identified "problem" consists of a "case" or a "situation", which is transformed such that it can be worked on in the classroom by groups of students. The role of the teacher is to design the problem and to guide the process during the classes, so that the students can formulate their goals and eventually resolve the case. The work in groups is ideally regulated by a formalized "work contract", in which the students codify their commitment in a written form.

In a typical problem design approach, the case is formulated as an internal memo of a company with the information organized in a couple of sections: the presentation of the background and context, the real problem or situation by itself, goals e.g. in terms of costs and variables, and finally the format of the presentation of the results. Since the problem is real, respectively realistic, only a partial information and structure is provided, and there is not only one unique solution.

2.1 Educational models

The different institutions of the workshop participants are all dedicated to the transformation of teaching methods. All promote a student centered educational model, where the goal is to educate students to be self-directed, independent and life-long learners. The teachers take on the role of guiding the students through the learning process, while withdrawing from the traditional model where the teacher is owner and transmitter of the knowledge (Ballerini *et al.*, 2008). This focus change generates the necessity of new classroom strategies that favour an active learning.

Among the active methodologies, Problem Based Learning is defined as a method in which relevant practical problems are introduced at the beginning of an instruction cycle, setting up the context and the student's motivation of the subsequent learning process. The method itself requires guidance from the moderator, and, most importantly, a significant amount of self-learning efforts by the students (Prince, 2004). The methodology of Problem Based Learning initially started in study programmes in the area of health care, but in the past 15 years a growing number of engineering schools have successfully incorporated it in their study plans (Mills *et al.*, 2003; Saptono, 2003; Northwood *et al.*, 2003; Shinde *et al.*, 2013).

2.2 PBL cycle

There are many versions of the PBL cycle, consisting of various step numbers and step labels. Table 1 shows the cycle taught in the workshops by academics from the University of Strathclyde. The cycle is carefully organized into 10 steps, such that the participants can internalize it more easily.

Table 1: Steps of the PBL cycle.

#	Step	Description
1	Case description	What do we understand (or what we do not) from the case description?
2	Brainstorming	What concepts are associated to the case description?
3	Idea categorization	How can we group the ideas of the brainstorming?
4	Previous knowledge	What do we already know?
5	Definition of cases	What do we want to investigate? What do we need to know?
6	Learning outcomes	What do we need to learn? What are our learning outcomes? What resources or tools do we need?
7	Investigation	How can we carry out the investigation through Individual tasks, achieve our learning outcomes and teach our peers?
8	Generalized discussion	How can reflect we on our group learning, share and discuss our recently acquired knowledge and explore alternatives towards the solution?
9	Knowledge application	What can we conclude to solve the case?
10	Assessment	How can we assess our newly acquired knowledge and reinforce our previous knowledge, how did we work as a group and how do we assess the obtained case solution?

This cycle can be separated into three main parts, where two are realized inside the classroom and one outside. Steps 1 to 6 take place inside the classroom with the facilitators present, step 7 can be done outside the classroom without the facilitator's assistance, and steps 8 to 10 are done again inside the

classroom. This generalized process cycle allows the teacher to develop the steps in order to optimally solve the case and obtain learning outcomes.

3 Experiences with the implementation of PBL

In this Section, four teachers that participated in the training workshops give an account of their experiences during a first implementation of the PBL methodology:

Experience 1: At the Universidad de Magallanes, PBL was implemented in the course called Computational Applications in Chemical Engineering during the 2nd year of the Chemical and Environmental Engineering undergraduate programme. In this course the five students learned to apply numerical methods in chemical engineering calculations by programming in Visual Basic Application (VBA) of Microsoft Excel. Two cases were developed inside the classroom with the following tasks: (1) create a program to evaluate a cubic equation of the state of gas (e.g. van der Waals, Peng-Robinson, Redlich-Kwong, etc.) with a numerical method like Newton-Raphson, and, (2) create a user form to calculate the heat capacity of a gas at normal pressure but different temperatures using numerical integration like the Simpson rule.

The contexts for the cases where: (1) A chemical gas company enquires about the estimative gas volume for different temperature and pressure conditions for storing; they consult your assessment group to elaborate and demonstrate the use of a programme for this solution; (2) Susan, your classmate in the Physicochemical course, does not understand the relation between heat capacity and numerical integration. She asks your group to help her in understanding how to calculate the heat capacity and how to determine the necessary parameters to compute it through numerical integration.

The implementation process of PBL consisted in explaining the phases of PBL and its learning objectives. Guidelines were uploaded in the institutional Moodle platform. This material included a visualization of the steps of the PBL cycle, a list of minimum requirements for a “work contract”, where team members specify their commitment, and a guideline for the redaction of session minutes. For each case, the score weightings, rubrics, dates of the classroom and the workflow diagram of the PBL process were provided. At the end of the first case, a survey on the students perceptions was collected.

Experience 2: At the Universidad de Bío-Bío, PBL was implemented in the obligatory course called Bioreactor Design for the 4th year of the Chemical Engineering undergraduate programme. PBL was used as strategy to acquire the first learning outcome of the course which was specified as the ability to “recognize the importance of microorganisms in industrial processes for the manufacturing of various biological products of social and commercial interest”.

The complete activity corresponding to the learning outcome consisted of four cases with the following titles: (1) Microalgae that devour pollutants, (2) Alternatives to the current management of dairy cattle slurry, (3) Obtaining probiotics with a focus on breast cancer prevention, and, (4) Alternatives for the food industry effluents treatment. Cases (2) and (4) were given as memorandum, and cases (1) and (3) as news.

The implementation process of PBL consisted of separating the class of twelve students into two groups of six students. Because this was their first encounter with the methodology of PBL, in the first session an introduction class was given, explaining the methodology and phases of the PBL cycle. The timing of the PBL cycle was arranged as follows:

- Phase 1: 120 minutes duration (Reading the case description, brainstorming, categorization of ideas, previous knowledge, definition of the problem and learning outcomes);

- Phase 2: 180 minutes duration distributed in three days (individual task investigation);
- Phase 3: 120 minutes duration (general group discussion, application of acquired knowledge and final process evaluation).

At the end of phase 1, each team was required to deliver a work record, where they should report among each other on the task distribution and the roles of each student in the group. At the end of phase 3, activities like expositions, reports and debates were realized.

In every activity, evaluation instruments were generated in order to measure the advances of the students at a cognitive and metacognitive level, by rubrics and a KPSI (Knowledge and Prior Study Inventory) test. Additionally, a survey collected the students' views on the methodology.

Experience 3: At the Faculty of Engineering of the Universidad Católica de Temuco, PBL was implemented in the course called Unit Operations I in the 3rd year of the Industrial Engineering undergraduate programme with 46 students separated into groups of around six students. This course aims to deliver tools that enable the students to understand the physicochemical principles which govern unit operations that are employed by the chemical industry.

Applying PBL to an engineering context, three problems with increasing difficulty were developed: (1) Syrup pump system design, (2) Plan distribution for three new manufacturing products from the mining industry, and (3) Energy efficiency study of the heating system and classrooms with thermal insulation.

The implementation process of PBL started with a proficiency test in order to assess the preexisting knowledge so that the students could be separated into equal groups. Because this was the first encounter of the students with PBL, it was implemented in only a few units of the course curriculum. Rubrics were used as an assessment tool to measure the students' progress.

Experience 4: At the Universidad Católica de Temuco, PBL was implemented in the course on Applied Mathematics in the 1st year of Health and Safety Technical Studies with 28 students in an evening school. This studying format gives them the opportunity to work and study at the same time. Students who study in this class tend to optimize time inside the classroom, work online and avoid the passivity of traditional forms such as lectures.

The course was grouped into two groups of five students and three groups of six students. The case problem called "Unreachable Heights" consisted in searching for strategies to find the height of objects in huge elevations that are visible but unreachable for a direct measurement. Proposed objects were the Temuco cathedral, the Villarrica volcano and the university buildings. The main learning outcome was to establish three different strategies that allow the students to obtain the height of these unreachable objects with ancient technology used 3,000 years ago by Egyptians and Babylonians.

The teacher decided to compare the traditional method with PBL. The pedagogical guidelines of the course are defined by the stimulation and development of skills that allow the apprehension and use of the know how and necessary mathematical elements. PBL was incorporated progressively, finalizing with a case study at the end of the course that covered the entire last unit.

4 Obtained results

In this section the results of the experiences are described. The methodology to obtain the results can be described as action research, where the teacher, during in his classroom interactions, simultaneously

performs active observations. This explorative study, where several cases are reported, might be extended in a follow-up study, where possible results are anticipated and classified before the classroom action.

Experience 1: The five participating students worked as a one group in the PBL cycle. The course was divided into lectures and laboratories, with lectures dictated by the main teacher and laboratories by an assistant teacher. For making the PBL cycle work, the role of the facilitator was rotated between the main teacher and the assistant. In the final phase of the PBL cycle a qualitative evaluation was done for the two problems which consisted of a discussion between the group and the teacher. At the end of the first problem, the students were surveyed about their understanding of the PBL method.

While working on the first problem, the group filled the roles of coordinator, time moderator and secretary as outlined in their work contract. In the first session the group started to brainstorm immediately, following the given guidelines. The learning outcomes were easily determined and each individual task was assigned. During the second session, the group members discussed their individual research and partially completed the solution of the problem. Because of the high demands of the course itself, a moderate score was achieved. Even though the group did not obtain a high score, they felt empowered by working as a group following the PBL. They gave feedback to the teacher that this kind of teaching method is adequate for this course. The second problem was more easily and faster solved than the first problem; the students rotated the roles but otherwise made no changes in their contract. They delivered the solution on time and showed a presentation on the created programme.

Experience 2: The methodology worked well in the sense that the students were fully committed to the activity. However, in several groups, one or two group members did not participate actively in the discussion.

Those students that were motivated to collaborate acquired substantial technical knowledge and transversal abilities. In particular, the quality of the conversations and arguments improved significantly as the course advanced during the semester. Role assignations and task distributions presented some challenges at the beginning of PBL cycle. There was some resistance from the students to assume responsibility in a role and task assignation. In addition, few members of the group had to cover more tasks and responsibility than other members.

Experience 3: At the beginning of the course the students were resistant to the proposed methodological change. They questioned the teaching method and refused to work in a more self-responsible and serious way. Because it was their first time working with PBL, they were confronted with many difficulties. It took two classes to make them understand how the PBL cycle works.

In addition, the students did not understand the evaluation instruments such as rubrics, therefore they underestimated their importance in the evaluation phase. During the PBL cycle in the second case, the students were more organized in collecting the necessary data and in finding a better structured solution than during working on the first case. Finally, while working on the third case, the students had a higher level of motivation and obtained the information much more quickly than what was required for resolving the problem. In addition, they consulted the teacher less often and their form of working in a group become more independent.

Experience 4: By implementing PBL progressively, the students learned to work in a group. They assumed different roles during the learning process until arriving at its conclusion when resolving the final big case problem that covered the entire final unit. The implementation was progressive with the intention to

compare the differences that exists between PBL and a traditional class of lecturing with little interaction between the peers.

In the first unit the traditional teaching-learning style was used where lectures were complemented by support material. Subsequently, the team formation and the work contract design were incorporated. In the first phase, the groups searched actively for information and held brainstorming sessions by presenting small problems inside the classroom. In the second phase, the activities continued with the categorization of ideas, the incorporation of new knowledge and the definition of problem and learning outcomes. In the last activity, the PBL cycle was fully incorporated.

Students are typically familiar with traditional learning setups, which generate low motivation and are not perceived as very challenging. The progressive incorporation of the PBL model supported the team cohesion and strengthened role assignment and self-organization.

The use of rubrics during the process turned out to be somehow difficult, because the students did not bother to check the evaluation indicators but instead followed their intuitions. Another difficulty was to understand that the task of the facilitator is to make questions and not to answered them. During the course of the classes the students increased their understanding of the PBL method and mayor discomforts were overcome at the last unit.

5 Lessons learned

Besides the experience of the implementation by the teacher in their classes, we also reflect on the experiences of the teachers during the training workshops, which we refer to as "Experience 0". The identified challenges, lessons learned and future perspectives are composed from individual contributions. They might serve as a precursor for a more systematic follow-up study, where the same experience is carried out for a broader audience; this would allow a quantitative and qualitative validation of the obtained observations.

5.1 Challenges

According to the accounts given below, the teachers identified the following challenges in designing and implementing the PBL cycle, among which we can identify challenges for the teacher, for the students and for the local universities.

Challenges for the teacher:

Problem design: The elaboration of an attractive and interesting problem is a challenge that demands plenty of time. The teacher has to create a problem that contains the learning outcomes according to the unit contents, use keywords, data or background information for the student in order to trigger the brainstorming easily (Experience 1). The problem description should be made more attractive to the students by using different formats like memos, emails, news, among others. With this input the students should be able to understand what is required of them (Experience 2). Eventual design gaps generate a major pressure during the facilitation, where the moderator has to provide solutions for incongruent aspects (Experience 0).

Rubrics: The elaboration of an appropriate evaluation tool or perceptive rubrics consumes a significant amount of time. The teacher has to select adequate criteria that includes the know-how (process) and the final product (Experience 2). It is imperative in PBL to establish appropriate learning outcomes, so that the

teacher can conclude whether the students have achieved them by working on the case and finding a solution as team (Experience 1).

Motivation: A major challenge for the teacher is to convince the students that PBL is a method that helps with the development of transversal skills. Motivating students who encounter PBL for the first time is an especially challenging task which appears hard to solve (Experience 2).

Time management: The teacher has to understand the relationship between the level of difficulty of the created problem and the timing of the sessions. Whereas small projects with small comprehensible solutions can be realized within two sessions, problems calling for complex solutions like programming, interviewing third parties, among others, require more than two sessions. The teacher has to be take into account and give the groups enough time for completing the PBL cycle adequately (Experience 1).

Role of facilitator: The facilitator faces a dilemma regarding the question as to how detailed the intended learning outcomes should be stated and ensured. If the moderator's role is too prominent, the centring on the students gets lost, provoking a reinstatement of to traditional teaching. If the moderator's role is too weak, the students eventually lose their focus. Ideally, the students are able to formulate and meet the learning goals with only a few hints (Experience 0).

For the student:

Work in groups: For the students, a major challenge is to understand how to work in a group. Many problems emerge at the beginning of the PBL cycle when the roles are assigned and tasks distributed. Many students have the erroneous view that the coordinator or the leader of a group should take the largest share of tasks and therefore they get disengaged, shifting both responsibilities and workload to this formal role (Experience 2). If roles are not assigned from the beginning then the overall process turns out to be complicated, because nobody wants to take responsibility (Experience 4).

Responsibility: The students take on responsibilities of their assigned roles, formulate the work contract and follow the group consensus. In this context, a major challenge is that the students understand the formal requirements of the PBL cycle and to follow it (Experience 1). A major challenge is to get responsibilities and workload more equilibrated (Experience 3).

Dealing with frustrations: Under the PBL methodology, one single unsolved problem can have many possible solutions. Therefore, the students have to evaluate various alternative paths and make decisions on how to proceed when resolving the problem. This can be frustrating when working in a group if the assignments are not equally distributed (Experience 2). Another source of frustration is the lack of the students' understanding if they do not adopt an attitude of self-learning and self-regulation (Experience 4).

Peer evaluation: The evaluation of active learning processes naturally includes peer evaluation, self-assessment and group evaluation. For advanced students, who know each other much better, sometimes a scenario of misunderstood "loyalty" occurs, when some students do not evaluate their peers honestly for the fear of causing a negative impact on the final score (Experience 2).

For the local universities:

Learning paradigm: Though all local universities advocate active learning strategies on paper, and try to promote them by training within internal projects, not all teachers apply them and follow best practices. One common goal is to change the paradigm of how students and teachers perceive and handle active learning (Experience 3 and 4). However, there is a competition between different teaching styles, in particular between different active pedagogies with various similar teacher trainings entering the scene. A

teacher interested in innovative methods might get confused: although there is vast experience in the implementation of PBL in careers like medicine, there is less experience in other disciplines (Experience 0).

Active learning strategies: A main challenge for the local universities is to establish the PBL methodology in undergraduate programmes at the department and university level. This can be achieved by training more faculty members in PBL and associated tools (Experience 3). The subsequent obstacle for the trained teacher is to convince the own academic unit and fellow faculty members of the benefits of PBL by inviting more teachers to implement and feedback this active learning strategy (Experience 4).

Course program design: Even though active learning is promoted, the usual course programs adhere to a hybrid methodology, mixing classical and progressive concepts. The stated contents of the program, for example, will follow a traditional pattern, whereas the stated learning outcomes will be formulated according to a progressive pattern. Therefore, there is an ongoing dispute on whether to emphasize more on contents or competences, e.g. whether to skip and ignore classical contents for focusing on competences (Experience 0). For a course following the PBL methodology, the challenge is how to possibly integrate every associate content of the course (Experience 4).

5.2 Lessons learned

According to the described experiences, the teachers reached the following conclusions from designing and implementing the PBL cycle. They are based on the self-assessment of the participating teacher.

Time management: The invested time needs to be managed more efficiently. Teachers typically are overburdened by the time consumption on individual scale and on an institutional scale (Experience 0). Better time management could be achieved by planning PBL sessions at least one semester in advance in order to prevent a considerable loss of time during the execution (Experience 2).

Role of Facilitator: The problem redaction has to be carefully elaborated in coherence with the learning outcomes established by the teacher (Experience 1). The role of the facilitators is not simple when they are also the teachers of the course at the same time because they tend to guide too closely or deliver too much information (Experience 2). The facilitator has to offer the support to follow the PBL process adequately and must not deliver the answers but give hints towards alternative paths (Experience 1). The benefit of PBL for the teachers consists of the opportunity to reach alternative solutions of a problem and to visualize the complete learning process of the students (Experience 0).

Environment: The facilitator's good intentions are not enough if the environment, e.g. in terms of classroom design, remains inappropriate (Experience 0). For the development of PBL sessions, it is necessary to have an adequate classroom infrastructure (Experience 2).

Role assignment: It is necessary to assign the roles before starting the PBL cycle for every student of the group to know his or her role before the group work begins (Experience 2). The PBL process should work if the students are committed to their roles, and if the assigned tasks challenge them to succeed based on their self-motivation (Experience 0 and 1). The work contract signed by every student of the group compels them to be responsible with the task and their learning. By promoting active group work and promoting responsibility, PBL gives confidence to the students (Experience 1).

Learning styles: Before entering university, students have been familiarized in school with different, mainly traditional, pedagogic methods. Because students are more familiar with traditional learning, it is necessary to implement PBL progressively (Experience 4). With all student having their own way of learning, PBL gives them an opportunity to achieve the learning outcomes independently and to reach a deeper understanding

that might even awaken a personal interest (Experience 3). The best moment to introduce a new methodology is during the first year, since later there is a major resistance to the new methods among the more senior students (Experience 0).

Evaluation by rubrics: The evaluation rubric has to be clear and concise if it wants to get acceptance by the students (Experience 3). It is necessary that the students see rubrics as an orientation on how to organize the work, i.e. to read them carefully and use as a reference when consulting with the teacher and peers (Experience 4).

5.3 Future perspectives

In the view of the shared experiences it becomes clear that the PBL methodology is a powerful tool to facilitate active learning strategies. Accordingly, it should be of interest to establish a public policy that encourages undergraduate programmes to introduce this methodology as a desirable component of a professional formation.

While it may be possible to create many cases from diverse engineering disciplines, it is helpful to network with the employers of the future graduates and let the local industries provide the context of realistic problems, which are the cases our future graduates will confront when working. As a consequence, our students are going to feel closer to and identified more with their future role.

The teachers trained within the reported project are acting as multipliers of the PBL methodology. The Universidad de Magallanes has started a reinforcement group of engineering education, composed of teachers from different engineering disciplines (chemical, mechanical, construction, computational engineering) and exact sciences. Their goal is to implement active learning inside the classroom. They have started to integrate problems from local employers in the implementation of PBL in their obligatory courses.

As university teachers need to change their way of teaching from passive to active learning methods, there is a strong request to train more faculty members. The members of this trained group of teachers are networking as PBL experts and sharing their experiences inside the classroom to improve their own methodology.

Evaluation rubrics remains a key issue when evaluating a PBL process. Teachers have to evaluate the learning process and learning results, giving a major emphasis in the process. The goal in PBL is to improve the students' transversal skills and to apply theoretical concepts in activities as working in group.

Recently, a new criterion has been included into the national accreditation process for the undergraduate programmes at Chilean universities, which is called "Formation and Investigation at Faculty Level". This criterion evaluates how the faculty body promotes, manages and verifies the development of studies and papers among their teachers that make a positive impact in the theory and practice of teaching consistent with the university's mission and vision.

6 Conclusion and reflection on the study

The teachers in charge of the reported courses received a formal training from two workshops within the project "Building Capacity in STEM for enhancing socio-economic development in regional Chile", which was funded by the British Council via the Newton Fund and delivered by staff members of the University of Strathclyde in the Universidad Católica de Temuco.

Comparing the experiences there are lots of similarities such as (a) the first encounter of the students with the PBL methodology; (b) active classes centered in teamwork; (c) the need for the students to be familiar with the PBL process for its to be implemented correctly; (d) the increase in complexity and difficulty of the cases as the course advanced; (e) the use of evaluation rubrics adapted to the PBL process; and (f) the drafting of a work contract for the group organization and the role distribution.

PBL was introduced into courses with type and size varied significantly. In two occasions, PBL was implemented in courses with large numbers of students. The two courses from Universidad Católica de Temuco were composed of 46 senior year students and 28 first year students, respectively. The major problems were related to the role of the facilitator and the students' comprehension of the evaluation rubrics. However, with the help of the teacher the students began to understand the steps better as the sessions passed by, which resulted in a successful implementation of PBL.

PBL was also implemented in small courses. At the Universidad de Bío-Bío, twelve senior year students participated in the course, while only five second year students had enrolled in the course at Universidad de Magallanes. The course taught at the Universidad de Bío-Bío had major problems in the role distribution during the first session and a lack of motivation on part of some members of the group. In the course offered at the Universidad de Magallanes, the course structure caused the only problem; here, the role of facilitator had to alternate according between the main and the assistant teacher.

Although some teachers had had previous experiences with active methods, it was the first time that they had used the PBL methodology. The teachers followed the PBL cycle as a guideline, while adjusting it to their own preferences and timings.

The teachers trained by the workshops are networking with each other, forming a community of PBL experts, sharing their experiences and being multipliers in their own universities. The perspective is to gradually extend the network. As PBL is one of the most effective learning methods, we would like to replicate the workshops in more Southern American countries, where PBL is slowly been introduced.

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Activities leading towards implementation of PBL at faculty level in Polish university

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Abstract

The way leading to implementation of PBL at the Faculty of Machines and Transport, Poznan University of Technology was complicated. The beginning of this way was the will of faculty dean to reach following goals: to improve the quality of students' practical knowledge and to deepen relations with the industry. Several initiatives were undertaken, like introduction of the course on innovatory entrepreneurship into curriculum or establishing of sustainability-oriented specialization, called 'Eco-engineering'. But the most promising tool towards reaching these goals is the project called "International summer school of solving technical problems in mechanics, material sciences and transportation". As a one week project, gathering the graduate students from Faculty of Machines and Transport and the students from foreign universities cooperating with faculty, this event focuses on solving practical technical tasks from everyday life of companies, which propose to solve them. The event has become a successful undertaking. It is very popular with the best students, which really can familiarize with practical problems. In many times the project's problems are an inspiration for proposing master or even doctoral thesis subjects. Companies are very interested in participation in this project, too. The benefits for the university are also very important and they constitute the further step of quality improvement of educational program at the Faculty of Machines and Transport, towards PBL and strengthening the co-operation with industry.

Keywords: engineering, sustainability, product, industry

Type of contribution: best practice paper

1 Problem-based learning in engineering education

Problem-based learning (PBL) is perhaps the most innovative instructional method conceived in the history of education, originally designed to respond to the criticism that traditional teaching and learning methods fail to prepare students for solving (practical) problems. Instead of requiring that students study content knowledge and then practice context-free problems, PBL embeds students' learning processes in real-life problems (Hung et al., 2008).

The engineering profession and academics are more familiar with the concepts of projects in their professional practice, than with the concepts of problem-based learning. Most case based learning strategies use cases as a means for testing one's understanding. The case is presented after the topic is covered in order to help test understanding and support synthesis. In contrast, in PBL, all of the learning arises out of consideration of the problem. From the start, the learning is synthesized and organized in the context of the problem (Savery & Duffy, 1995). During the problem solving process, students construct content knowledge and develop problem-solving skills as well as self-directed learning skills while working toward a solution to the problem (Hung et al., 2008).

There are at least two key issues that go to the heart of all of these approaches to learning through problem solving. First, all the approaches emphasize that learners are actively constructing knowledge in collaborative groups. Second, the roles of the student and teacher are transformed. The teacher is no longer considered the main repository of knowledge; he/she is the facilitator of collaborative learning (Hmelo-Silver, 2004).

Professional problem-solving skills in engineering require the ability to reach a solution using data that is usually incomplete, whilst attempting to satisfy demands from clients, government and the general public that will usually be in conflict, minimising the impacts of any solution on the social and physical environment and doing all this for the least cost possible (Mills & Treagust, 2003).

Engineers need more than just factual technical knowledge to be successful in an ill-structured and complex environment, problem-based learning seems well suited to prepare future engineers. Problem-based learning in engineering is a natural fit since it espouses developing students' ability to solve ill-defined problems, increasing critical thinking skills, and broadening their communication skills (Yadav et al., 2011).

As presented in paper by Williams & Williams (Williams & Williams 1997), PBL and engineering have in common:

- Large number of phases or stages through which to pass during the project or problem,
- Starting with an identified problem or situation which directs the students' area or context of study,
- Student initiated research is relied upon for the student to progress through the project as well as for their own learning,
- Requirement of high levels of student initiative, students need to develop motivation and organisation skills,
- Effective use over a longer time frame, as is usually associated with technology projects,
- Open ended with regard to outcomes, allowing the student the opportunity to choose, after appropriate research an outcome that interests them,
- Observational skills are identified as having a high priority, especially in the initial stages during identification of the problem,
- Student reflection is an important aspect of both models, the student is encouraged to evaluate fully the outcome they have achieved,
- Group work reliance.

Hence it would appear to be a logical extension of design education in engineering to implement problem-based learning (Mills & Treagust, 2003).

2 Sustainability as the common theme

The idea of sustainable development includes meeting the needs of the present without compromising the ability of the future generations to meet their own needs. The reference to the future is there in educational process, because of the effects of teaching at any level relate to the future. Higher education institutions no longer concentrate on the marketplace and economy, as they compete for students and resources. Students demand competition, as they are interested in more flexible programmes and more interesting curricula. New fields of study play an important role in winning students. Programs need to

develop more awareness amongst students of the social, environmental, economic and legal issues that are part of the reality of modern engineering practice (Mills & Treagust, 2003).

Boks (Boks et al., 2006) , Jeswiet (Jeswiet, 2006) and Nobels (Nobels et al., 2006) give the examples that universities offer one or more courses, which are focused on sustainability issues. The scope of engagement in introducing these important aspects varies. The authors show the broader attitude towards placing environmental issues in design education, with the aim of creating awareness among students about the role played by sustainability in industrial product development processes.

Reasons for sustainability issues being reflected in the study program at the Faculty of Machines and Transport include:

- Modern object-oriented engineering education, with the exemplary "machine", "mechanism" or "device" being the central point of analysis and development requires inclusion of sustainability-related criteria for design, operation and end-of-life scenarios,
- Creation of a framework in which life cycle management and life cycle assessment of technical objects is possible, leading to introduction of product related policies, like extended producer responsibility, integrated product policy, eco-labeling programs etc.,
- Ability to think in life cycle constraints, which enables product innovations further behind effectiveness, reliability or technological aspects.

The concept of sustainable development does not only refer to environmental issues, but it also includes a wide range of important policy areas, containing links to world's development. Consequently, education in all its forms will have to integrate the principles of sustainable development. In this context, universities and other higher education institutions must play an important role in promoting the objectives of sustainable development.

3 Faculty of Machines and Transport – history and present day

In the year 1919 The State Higher School of Mechanical Engineering was founded in Poznan. The Higher School was given the status of a university in 1945. Finally, during a number of transformations the university received the present name in 1955. At the beginning, Poznan University of Technology had 3 faculties: Electrical, Civil Engineering and Mechanical. Those faculties were transformed and the last one was split in 1953 and one of faculties that had arisen was the Faculty of Agricultural Mechanization. The research was dedicated to agricultural machinery. Within the years this faculty was changing its profile considerably and the name change reflected that. In the year 1967 it was renamed as the Faculty of Machines and Vehicles and its present name – the Faculty of Machines and Transport - was given in 2000. The fields of study which students can study are 'Mechanics and Mechanical Engineering', and 'Transport'. The education lasts seven semesters to reach Bachelor of Science in Engineering and three extra semesters to reach Master of Science in Engineering.

A growing number of students interested in studying at the FMT have been observed. At the beginning of 90's the number was about 600 and today there are around 2200 students at FMT. This tendency remains stable for the whole Poznan University of Technology.

To make the FMT more attractive some initiatives and serial events for students are organized. Within the years some of them became obliged, i.e. a summer practice. The main idea was to bring students closer to

industry and practical aspects of their knowledge. Students participate in this project after the 2nd, 3rd and 4th year of studies, during summer holidays.

The first above mentioned summer practice lasts 3 weeks. Students are delegated to industrial companies where they are introduced to mechanical technologies. Those who finished 3rd year of studies have an opportunity to visit industrial or trade companies or services. The profile of the company they choose depends on their interest. This practice lasts one month. Its major goal is to familiarize with an organizational structure of the company, its management methods, etc. The last one summer practice is connected with the subject of a student's master thesis. It lasts one month. A very helpful person is a supervisor. He or she is a person responsible for the contact with a company and controls the course of a particular practice.

Some activities are obligatory, like four week internship, while others are not, like "International Summer School of solving technical problems in mechanics, material sciences and transport" (ISS). These are dedicated for different group of students because of their specific education profiles. They are also highly related with companies, e.g. the main objective of ISS is the improvement of products and technologies by solving complex problems presented by companies.

The benefits for the university are also very important. The popularity of these initiatives among the students confirms the need for their continuation. On the basis of these experiences, the FMT has taken next steps to improve the learning process. New forms of instructions have been introduced like common university-industry cooperative projects with the substantial students' participation. They lead students mostly to preparation of their master theses'. Another activity had started to increase the number of lectures and exercises with the participation of industry representatives. The details of a completely new initiative are presented in the paper and the possible implementations of this initiative in the education process are considered.

The authors' focus in this paper results in describing the origins, features and the role of sustainability-related and problem-based learning-oriented programs at the FMT:

- Eco-Engineering
- Product Engineering
- International Summer School

4 Eco-Engineering

Representatives of mechanical engineering faculties at Poznan University of Technology, working on the areas closely related to problems of sustainable development, jointed their efforts to cooperate on the project leading to establishing a specialization "Eco-Engineering" (the name "Industrial Ecology" had been also considered). The shared concept was to introduce environmental issues into the education of mechanical engineering students.

The first step was to identify a professional profile of a graduate of the Eco-Engineering. This specialization was placed within the framework of the field: Management and Engineering of Production, at the Faculty of Mechanical Engineering and Management. Earlier statement put in a description of a profile of a Management and Engineering of Production graduate, that "he/she is aware of environmental conclusions of technological or constructional solutions created by him/her", was broadened to "he/she is actively introducing pro-environmental solutions to new technologies or constructions". Graduates of Eco-Engineering are prepared to solve interdisciplinary problems oriented towards environmental aspects.

The education process leads to prepare future engineers of Eco-Engineering for independent and creative work with all aspects of information technology supporting research, concerning complex technical and organizational problems. The syllabus assures a combination of theoretical and professional knowledge in design of structures and technological processes, on the basis of general and specialized disciplines. General disciplines play an important role in the educational process, allowing students to gain necessary skills in theoretical analysis and synthesis of phenomena and processes in technical systems. Specialized courses contribute, in turn, to a mechanical engineer's professional skills and knowledge. The educational process is enriched by courses in economics, necessary in today's market economy.

The graduate of Eco-Engineering gains the ability of identifying ecological potential of existing and created technical objects, technologies and skills, in order to apply this knowledge to designing and managing objects and processes. Students widen their horizons in following issues: recycling of technical objects, environment-friendly drives, material and energy efficient technologies, proecological infrastructure of production, environment-friendly materials, eco-products, LCA analyses of technical objects and processes.

The total span of study in Engineering leading to a master degree in Poznan University of Technology is planned for 5 years. A system of so called fields (directions) of study, which, after three years of joint program study, splits into several so called specializations, is offered. Eco-Engineering is one of these specializations, with a 2 year program of study and it starts with the shared level of knowledge and skills offered to every student of a given field of study. In the case of two mechanical engineering oriented faculties, the following areas of study as a basis had been considered: Mechanical Technology, Transport Technology, Production Engineering and Management and, after thorough analysis, the last one was chosen. It means that Eco-Engineering is a specialization developed on the academic foundation of Production Engineering and Management.

The shared 3 year program of study consists of several groups of subjects, such as: Humanities, with 390 teaching hours span; Sciences with elements of mathematics, physics and chemistry with the span of 300 teaching hours; Foundation of Economy and Management with 195 hours of classes. It gives in total 885 hours of basic subjects, and on that basis we are now delivering the basis of Engineering Education at 660 teaching hours, consisting of the elements of mechanical engineering, strengths of materials, machine design and automation, manufacturing technology, manufacturing systems and processes, metrology, ecology, systems engineering, engineering applications of information technology: CAD, CAM, CAE. The next group of subjects is focused on production engineering and management, with 375 hours of teaching, and encompasses all subjects related to engineering accounting, management and marketing, giving the students some knowledge and skills regarding finding oneself space and operating on the contemporary market. The last portion of base engineering education (825 hours) provides students of previous engineering subjects with more advanced knowledge and skills, including some new ones, such as Total Quality Management and logistics. This is given in the form of laboratories, projects and seminars, as well as the industry training. Such is the core education for the specialization Eco-Engineering which, in total, consists of same 3200 teaching hours, leading to the Diploma of Master in Engineering.

The interest of students to study eco-engineering confirm the need for education of newly profiled engineers, who can face the challenges of eco- or green business. The OECD defines the eco-industries as those which produce goods and services to measure, minimize or correct environmental damages.

Experiences connected with performing first diploma works show that connecting the knowledge from different areas is not an easy task. Therefore the thematic fields of diploma works are still limited, but the

new elements appear, i.e. the application of LCA methodology to evaluate the environmental consequences of different technical objects' life cycles.

The popularity of Eco-Engineering specialization among students (it opens on yearly basis with complete or nearly complete coverage) encourages continuing the efforts to improve the study programme. The further development of curricula should lead to creation of newly profiled engineers, who could face the challenges of green business. Markets in developing and emerging economies of Central and Eastern Europe are growing fast. So, the perspectives for employment in this field are optimistic. It is a strong signal for encouraging secondary schools graduates to start studying at the Poznan University of Technology, and becoming Masters in Eco-Engineering.

5 Product Engineering

At the FMT, to meet contemporary and complex problems of industrial companies, among Mechanical Engineering specializations a new one has been established: Product Engineering. It gives an opportunity to develop knowledge and skills of in the field of life cycle-oriented technical products design and management and it is a chance to become a specialist for whom there will be a growing demand in the market, an engineer for the future needs of industry and economy. Today one of the main issues on the market is the "product". It is defined as an item that ideally satisfies a market's wants or needs or is described as a deliverable or set of deliverables that contribute to a business solution. In economics and commerce, products belong to a broader category of goods.

Product engineering refers to the process of designing and developing a device, assembly, or system such that it can be produced as an item for sale through production process. Product engineering usually entails activity dealing with issues of cost, quality, performance, reliability, serviceability and user features. These product characteristics are generally all sought in the attempt to make the resulting product attractive to its intended market and a successful contributor to the business of the organization that intends to offer the product to that market. It includes design, development and transitioning to manufacturing of the product. The term encompasses developing a concept of the product and a design and development of its mechanical, electronics and software components. In its broadest scope, product engineering comprises of the process of innovating, designing, developing, testing and deploying a product.

A product engineer is a person that can design, develop, and manage new product ideas for corporations. Being an engineer is not always required, but the person must be familiar with all phases of the product development cycle and keep up with the latest technologies. Also, the product engineer has to combine technical knowledge, human factors, and creativity in order to make a product successful in the marketplace.

Product engineering (PE) is a master cycle course extending over 930 hours of lectures, desk and laboratory exercises, project sessions and seminars. Most of it is concentrated in the first two semesters, while the third (and last) one is devoted mainly to the preparation of students' master theses.

First semester starts with introduction to marketing aspects of product management, showing students the complex process of preparing, executing and communicating the value to potential customers. This lecture is also important as an entry point for quality management, stressing out the importance of proper customer requirements analysis. Foundations of innovation explain the central role of innovation process in developing new products and services. Two subjects: Ecotechnologies and Ecological Evaluation Tools address the environmental aspect of sustainable development, the latter being conducted as a course to

teach Life Cycle Assessment (LCA) theory and practice. Students learn how to provide ecological evaluation using SimaPro software. Computer aided realization of mechanics and flow issues is also performed on different other subjects: Programming Languages, Technical Thermodynamics, Strength of Mechanical Constructions and Surface Engineering. The education on the first semester of PE is complemented with analytical mechanics, applied mathematics and review on newest achievements in physics.

Second semester introduces Life Cycle Management, a practical implementation of sustainable development issues on a product level, presenting an integrated concept of product management. Services Engineering extends students' knowledge on how to manage the market outcomes of 'tertiary sector of industry', nowadays accounting for about 70% of GDP in most developed economies. Ecodesign, Computer Aided Design (CAD), Machine Technology, Modern Engineering Materials and Fluid Mechanics are all subjects introduced into the PE program for extending qualifications of students in their major – Mechanics and Mechanical Engineering. Quality Engineering introduces important aspects of products' conformance to customer and/or user requirements, while Intellectual Property and Customer Protection explains the role of legal aspects of product development and manufacturer's responsibilities.

Subjects taught on the last semester of the PE program focus on implementation of gained knowledge into everyday business practice. Modern Management Systems presents how and why should various system-based management frameworks (quality, environment, health & safety) be introduced and how they contribute to product management. Project Management puts students' expertise of New Product Development (NPD) process into practice, while Corporate Culture and Communication explains how the information and knowledge disseminates in companies. There is also a complementary course on Life Cycle Costing (LCC) methodology, useful for students who want to base their thesis on LCM of chosen product. On the third semester vocational lectures can also be chosen, in the previous PE editions these covered the tribology, fuels and lubricants issues. Finally, there is the diploma seminar, which helps the master level candidates refine their scientific writing skills.

After three editions of PE (the 3rd at its finish in June 2017) it can be safely assumed that students find the program and courses interesting and useful for their future careers. The number of candidates is increasing on a yearly basis: there were 7 students in the 1st edition, next year there were 13, and the 3rd edition gathered 21 persons. It is to be noted that the final status of the group is heavily dependent on the decisions of Polish embassies and consular offices across the world, especially when it comes to candidates from no-EU or non-OECD countries. The students don't seem to have major problems with strictly technical subjects (mechanics, design, and thermodynamics) and they seem to grasp the life cycle thinking and its practical approach (LCM, LCA, ecodesign etc.) very well.

Popular diploma topics among PE students from the 1st and 2nd PE editions include LCA of selected objects for the need of setting ecodesign criteria, use of quality-oriented tools and methodologies for product development and in some cases students' own propositions coming from own interests' or previous education (first cycle studies).

6 International Summer School

The idea of the International Summer School (ISS) is concentrated on cooperation between students and different companies from Poland. It is a particular mixture of a theory and practice. The main objective is a quality improvement of different areas of those companies. Moreover, students - engineers in the future

defined as "problem solvers" (Hills & Tedford, 2003) – have an opportunity to solve complex problems using their knowledge and working capabilities.

This annual 5-days workshop is organized in the middle of September. It focuses an attention on more than 30-40 students from Poland, Hungary, Czech Republic and Slovakia, Germany and Portugal each year. Of those, circa 60% are PUT students from different faculties and fields of study (mainly mechanical engineering, transport, electrical engineering, industrial management). The companies represent different branches of industry. Some of them such as a producer of household equipment or a producer of precise measurement devices take a part in this innovation since the beginning. The problems they present are always real and up-to-date.

The organization of the workshop starts at the beginning of the calendar year. It is a time when an organizing committee is formed. The inviting letters are prepared, sent to companies and to the scientific committee members. It is vital that the cooperation with companies starts before the budgeting planning process starts, as they need to secure funds for supporting initiatives as ISS. If too late, it typically results in limited cooperation forms, and as of now is the biggest threat to the ISS continuity. Then the information about the workshop is distributed to students, also in form of posters and leaflets. Participants can visit ISS website with detailed information about the International Summer School with registration form.

The workshop always starts on Monday with the students' registration. The participants receive a work package including a detailed schedule of the ISS, technical drawings, companies' prospects, description of the problem to solve and other informational materials. After a registration, the opening ceremony begins, including introductory lecture. The representatives of the companies present problems to group of students. Problems are related to the major fields of the workshop i.e. mechanics, materials engineering and transport.

Students are devoted into the groups of 3 or 4. Each problem is solved by two teams that compete with each other. This is the time for discussions. Groups of students can of course cooperate each other, but the proposed solutions must be different and unique. It is also possible that one group is working on more than one solution of a problem, indicating advantages and disadvantages of each.

Within the following days students visit companies (usually on Tuesday), especially those located in Poznan or nearby, learning more about them and their major problems. Students can also consult their ideas with PUT scientists. Not only companies and students are participants of this undertaking. Important role is played by the professors, who are supervisors in finding the best solutions of delivered problems. Students can consult their ideas from Tuesday until Thursday. Thursday is also the last day of their work. In the evening they are obliged to prepare and present a report for the Organizing Committee. This is a formal document, which finally goes to the companies.

Finally, students present the results of their projects in the last day of the workshop (Friday). The time for each presentation is limited to 20 minutes with 5 minutes for discussion. The number of presenters and the form of presentation is not defined. Each project is judged by a jury, i.e. the representatives of the university and companies. One of the most important features is its objectiveness (Osiecka, 1996). The members of the commission are not directly engaged in projects. The jury meets after all presentations and notes for each group are given. The marking scheme goes beyond simply marking a presentation. Similarly as in the case presented by T.D. Short, J.A. Garside and E. Appleton (Short et al., 2003) the factors that are taken into account are as follows: creativeness (initiative and ideas), undertaken effort, understanding the problem and level of project realization. The maximum note a group can receive equals 10 points. The

quality of the presentation is also marked and the notes are as follows: -1, 0 and 1. All those marks are collected in the form and the final opinion is delivered.

The final notes are presented during the closing ceremony. The most advanced and interesting solutions are rewarded. All students also receive certificates of participation. This document includes information about the note they get. The closing ceremony finishes the official part of the workshop. All the concluding remarks are taken into account during the organization of the ISS next year.

7 Conclusion – FMT initiatives as PBL examples

Initiatives undertaken at FMT to include problem-based learning and sustainability awareness in study program can be viewed through disctinctive characteristics of PBL, as presented by (Hung et al., 2008). They are:

- Problem focused – students are addresing authentic, ill-structured problems, provided by the companies cooperating with the University with selected educational endeavours; this stimulates knowledge building process, which has a profound effect for the education of freshman and sophomore year students,
- Student centered – significant aspect of the International Summer School – the participation, role-taking and problem solving approach are voluntary, the role of the Faculty is to provide conditions (rooms, equipment, knowledge, organizational issues) under which students solve problems,
- Self-directed – stated objectives relate only to the provision of solutions (ISS) or expected educational results (expert, knowledge and social skills – Eco-Engineering, Product Engineering), students are provided with necessary material means and knowledge, while the path they will take is more or less up to them,
- Self-reflective – adjustment of learning and problem-solving strategies remains mostly in the hands of students, assessment of progress and understanding is performed with the help of academic staff,
- Tutor-facilitated – facilitate group processes and interpersonal dynamics, especially in the multi-national groups of students (typical in ISS and Product Engineering), probing students' knowledge (periodic assessment, consultations).

Improving the quality of students' practical knowledge and deepening relations with the industry as the third party included in the universtity education was the main reason to include PBL approach at the Faculty of Machines and Transport, which – until now – has taken several forms, like the extended education programs (Eco-Engineering and Product Engineering) or extra-curricular workshops (International Summer School). The need to continually improve the educational offer of the Faculty and the University as a whole determines creation and refinenement of new ideas.

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CHALLENGES IN IMPLEMENTING THE PBL MODEL IN EFL (ENGLISH AS A FOREIGN LANGUAGE) CLASSES

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Abstract

Unlike with other disciplines, implementing the PBL (Problem-Based Learning) model in EFL (English as a Foreign Language) classes is not always that easy. This is because there are no universal or uniform problem tracks or project themes for English language practices or English literature topics. Most of the time, the most recognized benefit brought about by PBL to EFL classes is its Active Learning tactics. However, this should not be the only purpose for PBL adoption. In order to identify major challenges usually run into by our faculty members and students in EFL classes, a mix of research surveys and interviews were carried out with 200 Vietnamese English-majored students and 20 Vietnamese English teachers from the Faculty of Foreign Languages at Duy Tan University (DTU). The ultimate expectation of this study is that by recognizing major categories of challenges in EFL classes, we may be able to categorize the problem tracks and project themes for our EFL classes. Major challenges as identified by our study for EFL classes include fluctuation in the learning styles of different English skills, differences in the roles and approach of various English teachers, requirement of interdisciplinary knowledge for cross-culture learning, and the lack of motivation for critical thinking and teamwork collaboration in EFL classes. To add more to the complexity of each of these above challenges, English classes with a large number of students are quite popular at DTU. A number of EFL problem tracks and project themes were suggested based on the findings above, and while the validity of these themes and tracks would need to be assessed in some future study, their suggestions have brought about the requirements for prompt action in transforming our English teachers' role and restructuring our English assignment design for different English skills, particularly in the freshman- and sophomore-level EFL classes. Specific recommendations and proposals from these requirements will be helpful for EFL teachers around the world, who seek to improve on the process of learning English by their local students.

***Key words*:** Problem-Based Learning (PBL), English as a Foreign Language (EFL), challenges interdisciplinary learning, learner-centered, problem-centered, Active Learning

Type of contribution: Research paper

1 Introduction

Undoubtedly, learners will always grasp the knowledge better when they have the chance to engage in learning by doing to certain extent with the subject at hand. Learners today, in particular, would need strong English language proficiency besides other technical and soft skills to catch up with constant advances of the global knowledge economy. In the past, the passive learning model was typical in many schools with students sitting in class for hours listening to one-way lectures and taking lengthy notes. Those outdated teaching and learning methods can no longer fulfill the needs and demands of modern learners in the 21st century.

Unfortunately, a major part of the higher-education system in Vietnam still relies on the requirement of materials memorization for its assessment. Students often get higher marks in quizzes and exams by memorizing their textbooks page by page, if not word by word. We realized that this teacher-centered approach and memorization-based assessment system are a huge shortcoming and obstacle in the social, technological and educational development of our students. Taking up the challenge of renovating our learning and assessment methodologies in the new era, Problem-Based Learning (PBL) was adopted at Duy Tan University in the teaching of English as a foreign language (EFL) with the aim to enhance learners' performance and achievement.

Generally speaking, with PBL, learners have appeared to become more involved in relevant intellectual inquiries, and they also actively try to acquire knowledge from different real-world situations and scenarios. According to Simpson (2011), the PBL approach opens up the door to: communicative competence, authentic learning, intellectual autonomy, collaborative learning, additional language proficiency, and ultimately, enhanced self-efficacy, self-esteem and self-actualization. With the combination of these skills, students easily become the 'master' of their learning process. The role of teachers, as a result, also becomes more of providing guidance and facilitation. As for the adoption of PBL in EFL, PBL appears to bring about a great number of benefits for teaching EFL at the tertiary level. Specifically, its most recognized benefit to EFL classes is its Active Learning tactics. Students generally become more enthusiastic and interested in PBL language assignments. They can also manage the pace and progress in their whole learning process. Furthermore, positive improvements have been seen in the students' oral performance, in particular. PBL generally fosters students' motivation and ability in learning and using vocabulary in context.

The lack of research literature in Vietnam on the experiences of teachers and learnings using PBL in EFL classes, however, raised a concern about the recognized effectiveness of PBL for EFL. In general, there are very few studies exploring the challenges that teachers and learners are facing with PBL for EFL in their in-class interactions. Thus, this research will focus on identifying major categories of teaching and learning challenges with PBL in EFL classes, particularly in the freshman- and sophomore-level EFL classes at Duy Tan University in Danang, Vietnam. Detailed recommendations and proposals presented in this paper will be helpful for EFL teachers around the world, who are seeking for ways to improve on the process of learning English of their students.

The following research questions are raised by this study:

1) What are the challenges in implementing the PBL model in EFL classes to the teachers?
2) What are the challenges in implementing the PBL model in EFL classes to the learners (or students)?
3) In what ways do teachers and learners (or students) in EFL classes currently respond to the above identified challenges?

2 Theoretical Background

2.1 Problem-Based Learning (PBL)

Problem-Based Learning (PBL) is rooted from John Dewey's project-based pedagogy of the 20th century (Dewey, 1938). It is an approach that has been around for more than half a century, and it generally uses real-world situations and scenarios as the basis for the development of knowledge and problem-solving

skills of students. It helps students build essential reasoning and communication skills required for their future career success (Duch et al., 2001). A study by Weissinger (2004) also confirms that not only does PBL encourage students to develop critical-thinking skills in learning, but also it helps develop students' problem-solving skills which they can make use of throughout their lifetime. Furthermore, Problem-Based Learning also provides teachers with a variety of opportunities for new knowledge, acknowledges their personal beliefs and experiences, and expands their knowledge and skills as they engage themselves in learning (Levin, 2001). The classroom setting of PBL is usually under the format of small group interaction or focus group discussion. Hence, learners or students can always work together, share their knowledge, and learn from each other's experiences, under the guidance of their teachers. Similarly, PBL was defined by Howard Barrows (1996) as a learning methodology which involves student-centered learning in small groups lead by a tutor or "expert", rather than teaching using traditional lecture approach. The role of the tutor is to guide the students toward discovering answers on their own rather than to simply provide the correct answers. Through the guiding process the tutor will stimulate the students' cognitive learning process and problem-solving skills with self-directed learning.

Within the scope of foreign language learning and teaching, PBL aligns with approaches in which students learn the target language by using it, rather than being presented and then trying to practice predetermined language structures. In other words, PBL helps engage language students in learning how to learn both the language and its contents at the same time. This approach aims to take language learning one-step further by enabling students to transfer their language learning into real-world contexts and situations and to use the knowledge of that language itself in their own performance or problem-solving scenarios (Barron & Darling Hammond, 2008).

2.2 Implementation of PBL to EFL Classrooms at Duy Tan University (DTU)

The skillset and capabilities required of language learners in the 21st century now even include cross-cultural understanding, corporate ethics and responsibility, critical thinking and decision-making capability, and even, creativity besides personal and interpersonal skillset, as usual (Partnership for 21st Century Learning, 2007). The PBL pedagogy appears to be able to satisfy most of those requirements. And that was the reason, it was chosen as a mainstay teaching and learning approach by the Faculty of Foreign Languages of Duy Tan University.

In particular, the PBL approach has been applied at the freshman- and sophomore-level EFL courses for English skills in reading, writing, listening, and speaking. It used to be usually very hard for EFL teachers to make their classes an effective learning environment and at the same time, an enjoyable place to be. In PBL classes, multi-skills activities focus on topics or themes rather than on specific language targets. The activities provide students with opportunities to recycle known language and skills in a relatively natural context. (Haines, 1989). The teacher needs to act as coaches or facilitators for activities that students themselves will carry out. They no longer only present students with the new lessons or knowledge and directly control the pace of learning in class. Instead, teachers will provide students with case-study problems for each English language skill, and assist students through the process of presenting, brainstorming, and solving such case-study problems. After that, teachers will give necessary feedback and support to students as well as to evaluate on students' performance and problem-solving skill concerning their English literacy and proficiency. These, however, seem to be a great deal of work to handle the PBL-structured classes successfully.

In order to conduct a successful PBL class in EFL, more specifically, teachers need to systematically follow through four stages of work (Albion & Gibson, 1998). But before any of those stages, the teacher needs to

make sure that students understand the goals and benefits of PBL for language learning. The importance of using PBL activities in learning English should be well emphasized to the students.

Then, starting by presenting the PBL problem(s) and English vocabulary that goes along with each problem should be essential in the first stage. The teacher can use pictures, videos, and games to warm up class atmosphere and to set the tone for presenting PBL case studies and problems. Students should be asked to use the vocabulary provided to represent those problems. The teacher then will let students brainstorm on possible solutions for each PBL problem using their previous personal experience related to the problem.

In the second stage, students should be assigned to groups of preferably from 4 to 7 members and discuss their various solutions. It should be reminded that the teacher needs to point out to their students that there is no single correct solution for the case-study problems at hand, and it is more important that they discuss with each other, arguing for their solutions, and arriving at the most reasonable and explainable solution(s). In the process, students should be allowed for access to data resources such as the Internet, books, newspapers, magazines, television, etc.

For the third stage, observing and supporting students through their problem-solving process will be its focus. The teacher will observe and provide support as need, but not attempting to direct their guidance or controlling the scope of students' creativity toward any predetermined solutions. While observing, the teacher can also take notes and provides feedback on the language handling capability of their students.

During the fourth or final stage of work, progress evaluation and assessment as well as later follow-ups should be actively provided by the teacher. Students will have the opportunity to present and share the results of their work. They can also make any adjustment based on the follow-ups provided from the teacher's continuous observation. The teacher will assess and grade students' participation, performance and presentation, subsequently.

3 Research Objectives

This study aimed to recognize major categories of challenges in EFL classes and categorize the problem tracks and project themes for our EFL classes at Duy Tan University (DTU). It is expected that specific recommendations and proposals will be helpful for EFL teachers around the world, who seek to improve on the process of learning English by their local students.

4 Research Methodology

The study is designed to capture data from teachers as they relate to their perceptions about the implementation of problem-based learning. The study utilized open-ended interview questions designed to gather data on the perceptions of EFL teachers and English-majored students. The interviews were recorded, transcribed and analyzed by the authors of this paper. It is a descriptive study in that it seeks to produce information about what is happening in relation to the objectives of the research. Furthermore, a survey questionnaire was later distributed to English-majored students at the freshman and sophomore levels, asking them on a number of definitive questions regarding their views, negative or positive, on certain aspects of problem-based learning for EFL.

5 Data Collection and Analysis

The research samples included 200 Vietnamese students of English major from six different classes and 20 Vietnamese English teachers of the Faculty of Foreign Languages at Duy Tan University. All of the students are freshmen and sophomores. The choice for freshman and sophomore students came from the fact that PBL has only been adopted at the Faculty of Foreign Languages for the last two years. Of the 20 teachers, two teachers had the most direct experience with problem-based learning for at least 10 years. The challenges to the teachers as mentioned in the interviews were identified through the selected literature by Bender (2012) and Markham et al. (2003). Also, students' challenges in survey questionnaires were listed in regard to the essential 21st Century skills for learners (Partnership for 21st Century Learning, 2007). In addition to the text fields in the interviews and survey questionnaires capturing data specific to each perceived challenge, both teachers and students in this study had the opportunity to add in additional information about how they had responded to each challenge in implementing project-based learning through their "suggestions" or "statements of challenge" or "comments" about the context of PBL adoption at their faculty (e.g., with scheduling or other responsibilities) or through their academic assessment practices (e.g., in an effort to meet certain testing requirements).

6 Findings and Discussion

The initial results from the interviews collected in this study reflect the tension EFL teachers and students at Duy Tan University usually experienced with the adoption of problem-based learning in their EFL classes. Further results from the survey questionnaires implicate certain interesting facts concerning these challenges from the opinions of students, as inexperienced PBL learners.

6.1 Challenges in PBL Implementation on Students' Work

Considering the list of learning objectives that we have redesigned based on PBL, students perceived the most challenging items in their contact with problem-based learning for EFL classes as "Critical thinking & Problem solving" and "English background".

Table 1 - Perceived Challenges in Implementing Problem-based Learning for EFL

No.	Challenges	1 never	2 seldom	3 sometimes	4 often	5 always	Total Responses
1	Creativity & Innovation	28	39	73	26	34	200
2	Work arrangement	50	46	56	28	20	200
3	Time management	19	51	55	51	24	200
4	Collaborating with other students	22	54	66	38	20	200
5	Technology literacy	28	56	52	44	20	200
6	Critical thinking & Problem solving	20	38	44	60	38	200

7	English background	14	42	49	58	37	200
8	Initiatives & Self-direction	25	45	58	46	26	200

Of the 200 respondents, 98 identified "Critical thinking & Problem solving" as a usually perceived challenge. Closely following this item was "English background" while "Collaborating with other students" and "Work arrangement" were the least challenging items perceived.

Due to the differences in students' learning styles, "Critical thinking & Problem solving" was considered as the most challenging skill to be acquired by students. Vietnam is a collectivist culture in which the group values are always preferred. As a result, students usually try to avoid arguments and controversies whenever they work with each other. Also, the role of teachers is very much different from that in Western countries. In Vietnam, teachers are considered to be the most reliable source of knowledge and guidance. Students are taught to respect their teachers as much as they do for their parents. As a result, they dare not ask teacher questions they have problem on but rather trying to ask their friends those questions instead.

According to the findings in this study, approximately 50% of the students admitted that they are not confident when they speak or listen to English. The reason may come from the EFL training focusing mostly on grammar and writing skills from the secondary school. Many students who had seven years of learning English before still cannot make small talks with a foreigner. In the past, they learnt English with the major aim of passing tests and exams or getting through the national college entrance exam. They only focused on grammar and writing skills instead of the other skills, especially listening and speaking. When discussing with their group members in their EFL classes, they also tend to speak Vietnamese rather than English.

Many students said they felt really nervous when standing in front of their classmates. They simply tried to read out whatever English phrases that they remembered rather than really speaking English. They tried to memorize the English words and phrases mostly. That made their English communication ineffective. Another reason for their failure in their English communication is the accent that they may have. They are usually afraid of being laughed at by their friends, and as a result, would not try to speak English at all. On the other hand, most of students don't have much trouble working with the others as a requirement of the PBL approach.

In addition, nearly 40% of the students complained that they didn't have sufficient time to read through all other students' English write-ups and give comments on those in EFL writing classes with group presentations. The standard time period for each class is around two hours. Students normally have to work independently for at least 60 minutes, then another 60 minutes for group discussion before the 10-minute presentation, which is already over the two-hour limit. The usually big sizes of the group (of around 6 to 8 students) make it harder for fruitful and timely discussion or English practice in groups.

Another challenge for students in EFL classes at Duy Tan University as interviewed is the number of students in class and the classroom facilities being used. In many PBL classes, the number of students is up to forty. That makes students feel uncomfortable when they have to practice English in groups of 6 to 8 students. If the teams are assigned to have 3 to 5 students, then they would feel inconvenient having to share small space in the classroom with many other teams with similar activities being carried out at the same time. It would become noisy to practice English in such conditions.

6.2 Challenges of PBL Implementation on Teachers' Work

Table 2 – Number of Years of Teaching Experience by EFL teachers at DTU

No.	Years' Experience	Number of Responses	Percentage
1	1 – 5	3	15%
2	6 – 10	8	40%
3	11- 15	7	35%
4	16 – 20	2	10%
5	Total	20	100%

Most of the EFL teachers in this study have been teaching English for 6-10 years (40%). This category was slightly higher than that for 11-15 years of teaching experience (35%), and was much higher than the 1-5 and 16-20 years of teaching experience categories, which accounted for 15% and 10% respectively. In short, most EFL teachers at DTU generally have 6 to 15 years of teaching experience - this can be considered to be a significant amount of experience with EFL.

Table 3- Perceived Challenges of EFL teachers at DTU

No.	Challenges
1	Collaboration
2	Creating the project (for EFL)
3	Planning and Implementing Class session
4	Use of Updated resources
5	Role change
6	Observing & Taking notes
7	Managing Work groups of students
8	Mentoring
9	Finding extra time
10	Giving feedback
11	Assessment

Table 3 above listed the teachers' perceived challenges in applying PBL approach for EFL classes for the freshman and sophomore students. All of the challenges were mentioned and elaborated in the interviews.

The most challenging item when implementing problem-based learning was "Planning and Implementing Class session". "Finding extra time" was another emerging difficult task which was related to the use of scheduled class time for all the necessary EFL activities or the need to add in additional time for lesson plan discussion with other teachers. All the teachers being interviewed proposed the use of "flexible schedule"

for their problem-based learning implementation. It was difficult for them to find enough time to implement PBL within the currently assigned class schedules.

Assessment of the project results and teamwork collaboration to assign a grade is an extremely difficult job in EFL classes. This includes "grading rubrics" and the grading of individual contribution within teamwork results. In most instances, the EFL teachers indicated how they had approached their assessment of the problem-based experience or reasoned for why they set up certain individual or group grading criteria. In many cases, teachers find it difficult to give one single score for a group project. Thus, they had tried various ways to assess individual and group progress in those projects.

Also, according to the teachers, "Creating the project (for EFL)" consumed a great amount of their time. To design an interesting project for EFL, they had to search through a great deal of resources from textbooks and reference books to the Internet to their colleagues.

Amongst the interview responses, "Role change" was also a major obstacle to many EFL teachers: Giving up a certain amount of direct control in class was nerve-wracking. Shifting from delivering the instructions to facilitating discussion and group work was a big problem for those who had been very much familiar with the teacher-centered mode of teaching.

"Use of Updated resources" is another obstacle, especially for old teachers. Using available resources of other teachers may pose the risk of teaching material ownership and improper approach for unfamiliar teaching materials. In any case, a study project designed for EFL should focus not only on improving students' language skills but also equipping them with essential skills such as teamwork skills, technical skills, critical-thinking skills, so on and so forth. Other teachers also indicated a need to focus on unique elements in a PBL lesson plan like establishing a good driving question or sustaining a rigorous inquiry on the lesson topics.

Furthermore, it is necessary to continuously adjust the project design to meet certain PBL standards. Though through the interviews, EFL teachers gave interesting proposals on how to satisfy certain standards in a problem-based learning experience, often, these proposals were not definitive and were coupled with frequent expressions of how difficult it is to carry them out. Before implementing a project in EFL, teachers should help students identify specific goals for their work group. That makes "Managing Work groups of students" a very important item.

Table 4 - General Opinion about Problem-based Learning

General Opinion	Number of Responses	Percentage
Very positive	33	15%
Generally positive	115	52.3%
Equally positive and negative	62	28.2%
Generally negative	10	4.5%
Very negative	0	0%
Total	220	100%

Last but not least, one of the objectives of this study was to gather information on the general perceptions of teachers and students about the adoption of problem-based learning for EFL classes. Table 4 presents this general perception with the scales ranging from "Very positive" to "Very negative", providing a fruitful insight into the use of PBL for EFL classes. Generally speaking, more than half of the teachers and students consider the adoption of the PBL approach positive: 15% thought PBL adoption was very positive, and 52.3% took it as generally positive. 28.2% were neutral in their consideration of PBL for EFL. Only 4.5% indicated that PBL was a generally negative. No one had any extremely negative feeling of PBL, however.

7 Discussion and Implications

This research deals with PBL for EFL, which is still a "relatively new" concept to many people in the higher education system of Vietnam. PBL is a practical teaching and learning approach which provides the opportunity for the students to work under the guidance and mentoring of their teachers who facilitate for their self-search for new knowledge rather than pointing them to any predetermined learning outcomes. The role of teachers under PBL is quite different to that in the traditional classroom settings. Teachers play the role of more of a facilitator, a guide, a co-learner, or even a co-worker, who creates a supportive learning environment for students. At the same time, the role of students has also changed to become more of an active learner or a meaning maker/searcher. The traditional lecture classroom setting would be transformed into a simulated workplace with sufficient space for students to perform interactive and interdisciplinary activities. Even though there are many challenges in adopting PBL given the conditions in Vietnam, PBL can still be successfully implemented by managing the necessary prerequisites and requirements given sufficient resources and skillful personnel.

Through the implementation of PBL, a great number of students preferred the use of games and competitions to have more classroom interactions; however, they did not show much interest in providing feedbacks to their teachers or doing peer reviews for other students. It should be recognized that not only teachers but also students need to be trained in providing feedbacks and reviews in PBL implementation so as to enhance the effectiveness of overall PBL assessment. Collaboration and teamwork skills, as a result, are also an important component to go along with.

Even though there are lots of challenges in successful implementation of the problem-based learning model for EFL in the context of Duy Tan University in Vietnam, step-by-step approach can be adopted to ensure the effectiveness of PBL for EFL to certain extent:

- First, the teachers need to fully understand their facilitator's role in teaching a new language. And at times, they also need to take a step outside of their facilitation role to provide definitive and direct instructions to students about what is right or wrong in the practice of English. This is especially important since most students here are at the freshman or sophomore levels.
- Second, EFL teachers should consider that using simple and clear instructions in teaching a new language is necessary. Speaking English at a slower rate would ensure that every student can understand and is motivated that they can one way or another learn the new language. Teachers need to constantly check whether students understand the assigned PBL activities or tasks. And learning resources like useful books and websites should be provided to students while the PBL projects for EFL can be localized to the conditions available in Vietnam.
- Third, DTU leadership should continually provide support for the implementation of PBL projects for EFL. This should create enough motivation for EFL teachers to move ahead with PBL even within

the limited time schedule of EFL classes currently at DTU. For inexperienced teachers, the time settings in PBL implementation may get out of their control, but it is essential to remind them not to interrupt students' PBL work if they run out of time in class. Homework or language practices outside the classroom can still be effectively assigned.

- Fourth, for EFL classes with a big number of students, co-teaching should be a choice when one teacher may not be able to handle all the PBL groups and group projects. Ideally, one inexperienced EFL teacher should be assigned to work with one experienced ELF teacher in such classes. They may take turn doing the teaching as well as observing and monitoring the class. Together, they may also prepare more interactive teaching materials with pictures, video clips, animations, etc. They may also become more objective in collectively evaluating the feedbacks coming their way.
- Fifth, with respect to assessment methodologies, the Faculty of Foreign Languages of Duy Tan University should create an online/offline forum for teachers to share their experience. The immediate objective would be to call for teachers to increase the level of engagement and interaction of their students in their EFL classes. At times, some competitions should be carried out amongst the teachers as so who is the best one in implementing PBL for EFL, for example. The longer term objective would be to successfully foster an environment of English-spoken within each EFL classes. This would be no easy tasks to any one individual teacher; rather, it is a collective task of the whole Faculty of Foreign Languages, which requires resources, motivation, encouragement, and even a sense of collective responsibility.
- Sixth, with PBL for EFL, it is in essence still about the learning of a new language. Yet, teachers and students need to move beyond that to realize the equivalent importance of other "soft" skills and cultural knowledge in the overall education of a new language.

8 Conclusion

"*Tell me and I forget. Show me and I remember. Involve me and I understand.*"

As a Chinese proverb goes, it is widely accepted idea that students learn better when they are engaged in real life learning situation or experiential learning. The PBL method trained the students to learn through a problem-solving process which was facilitated and monitored by the teacher. The learning process in PBL classes for EFL proved positive in developing the students' touch for a new language besides other skills of critical thinking, building social and cooperative ties, or promoting reviews and feedbacks. Group work in EFL is also a very essential contribution of PBL: Students get the opportunity to practice English in team, which helps them to develop interactive, communicative and collaborative skills for a new language all at the same time. In the long run, group work helps elevate students' level of confidence in their use of English for formal and informal communication besides professional use of English in certain technical fields.

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Implementation of the procedure model Ten Step Method in the MINT-lab (STEM-lab)

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Abstract

As a technically oriented university, our focus is on engineering science. From this technical point of view, solving problems is a systematic process, like a project, which changes an undesirable, unsolved situation to the desired state, insisting on finding an appropriate solution. This ideal approach of an engineering thinking is in conflict with realistic projects, because of the uncertain objectives or special conditions.

Although the approach of Problem-Based Learning by using the Seven Step Method is significantly more application-oriented, we have combined it with project-oriented learning for students of engineering. With PBL and the Seven Step Method, students learn to structure and to analyse a problem and are supposed to be able to identify problem areas by autonomous incorporation and reflection.

An alternative model has been acquired within the MINT-lab at the University Kaiserslautern/Germany which combines PBL and project orientated learning. The MINT-lab experiments defined as projects cover mathematics, computer science and technology. Students do not receive straightforward instructions to the experiments but are confronted with the experiments as problems and projects forcing them to solve it. As an individual process model for the MINT-lab, a logistic team and a student project team extended the Seven Step Method to the Ten Step Method. In condition to that tutors make a process model available to students, which can be used for any experiment of the MINT-lab and leads the way to spot and solve technical problems.

The aim of this concept is to teach students how to be flexible and to adapt to unfamiliar problems immediately, which PBL can certainly achieve. On the other hand, the MINT-projects must be completed with limited time and resources. Currently, this project-orientation is requested by most companies and to have these competencies is necessary for graduates.

Keywords: review, PLB in engineering, project orientation, MINT-lab, process, Seven Step Method

Type of contribution: Review/conceptual paper.

1 Introduction

Problem-solving competencies are the main objectives in the training of engineers at universities. Engineers are supposed to be able to solve tasks and problems effectively with limited time and resources. Regarding the conflict between effectiveness and the shortage of resources, efficiency becomes the central measure of activities. The employment market requires additional competencies such as high flexibility, project management or team skills from the graduates (Wölker, 2012).

If Problem-Based Learning promotes the individual problem-solving processes, the question is how do the problems for engineers have to be designed to support this process and is there a need for specific approach? At an early stage in their study, prospective engineers are expected to learn that on the one hand obvious problems in professional practice are often not the underlying real problems. On the other hand, the first obvious solutions do not necessarily solve the underlying real problems (Matthiesen S. et al., 2013). This awareness is eminently important, but it is not much anchored in traditional engineering understanding.

For engineers this means to recognize deeper problems and to solve them in a targeted manner is a more creative, open-minded process (Norman et al., 1992). Having the awareness of the major difference between a causal, a final and discursive approach, the problem-based method is an appropriate tool in order to let students discover the subjective controversy while recognizing and solving problems as a creative, individual process. In this context, "discursive" means that rules are not known.

While the engineering curricula mainly provides professional and methodical knowledge and audits the ability to accumulate new knowledge in a short time, the engineer profession demands the ability to uncover problems and to deduce dependencies in dynamic systems. Only then tasks which differ from problems in economic science can be derived. Therefore, new forms of teaching in the engineering sciences claim to overcome the deficit of problem-solving competence (Heitmann, 1994).

The need for alternate forms of teaching in the logistics study has been detected through the awareness of a discrepancy between the requirements of industry and the educational goals of universities. The design of the MINT-lab, which addresses this issue, is an important topic in the logistics academic education at the University of Applied Science Kaiserslautern. In order to unite the procedural comprehension of a problem and the project-oriented alignment, the course of studies "Logistics –Diagnostics and Design" at the University of Applied Science Kaiserslautern offers a STEM-lab, the "MINT-lab". Laboratory experience is usually part of the logistics curricula, but in the traditional definition of laboratories, it is not sufficient to gain problem-solving competence.

Traditionally laboratory experiments should train the students to become scientists (Winter, 2011). Precise instructions are given to the students, which restrict an individual creative approach. Scientific experiments are conducted for tutorial purposes in the meaning of scaling, monitoring, evaluating, analysing, micro scoping, preparing and programming (Boldt, 2005). The traditional understanding of the technical scientists and engineers is "having a problem, solving a problem", which shows a thinking of causality and logic. In addition to the advantages, this form of learning also promotes undesired knowledge.

2 Defining a Problem

"Among the issues of PBL research, problem difficulty has received little attention. Most often, teachers or instructional designers use their best judgment to determine an appropriate difficulty level based mainly on their experiences or intuition" (Jonassen et al., 2008). Determining that an exact definition of a problem is influential for the problem-based approach in logistics requires closer consideration. It means a precise definition of the problems is necessary to create an innovative lab. Problems and their solving are in the context of the person who subjectively addresses the problem. "A problem arises when a creature has a goal and does not "know" how to achieve it. Wherever the given state cannot be transformed into the desired state by mere action (carrying out self-evident operations), thinking is needed" (Duncker, 1966). In

this regard, a problem is considered subjective and to deal with it represents an individual process. This approach constitutes the impulse for a new form of the MINT-lab.

A problem situation differs from a task, in the sense that a task (as in the case of traditional experiment instructions) only requires reproductive thinking with well-known understanding. In the approached experiments by defining a problem, a new process for the executors is created (Dörner, 1976). This makes individual competencies such as problem-solving competency stable.

Providing students with problems requires a simulated setting that creates a complex environment. In contrast to exercises, goals shall be described to the students to make them able to discover problems, deduce tasks autonomously and to solve the problems. Thereby solving the tasks is no longer in the foreground, but especially the process of discovering the problem, splitting tasks, bringing together pieces of evidence and designing possible solutions. Engineers are mainly concerned with processes and their optimisation. To illustrate processes and to adapt them, engineers adhere strictly to norms. Even the concept of a process is standardised. According to DIN IEC60050, a process is defined as a sequence of steps (DIN IEC60050, 2014). In this context it is anticipated, that an understanding for problem-solving in terms of a process model has to be established.

The entire study of logistics at the University of Applied Science Kaiserslautern is based on the approach of engineers characterised by process and project thinking. At Universities of Applied Science project-based learning highlights projects in teaching, in which students work autonomously on issues, are responsible for their own time management, apply science-based knowledge and are coached by tutors (Heitmann, 1996). The simulated projects in the MINT-lab are limited through their default handling time of two weeks, which is in place for limited resources.

3 The MINT-lab at the University of Applied Science Kaiserslautern

The MINT-lab, as a problem-based course, distinguishes from other classical courses in the focus on a long-term learning curve that is composed of autonomous appropriation of knowledge through Problem-Based Learning methods. The experiment execution covers two semesters and is designed with twelve experiments from fields of mathematics, IT, physics, engineering, and logistics. The MINT-lab is the German analogy to STEM. In addition to the subject-specific contents, the MINT-lab also trains students to manage projects and to work in teams. Each experiment is designed as a project. Experiments are given and explained in a professional manner, and subsequently, the students carry out and record them (Wölker, 2016).

The MINT-lab is different from other classic laboratory experiments by the fact that the approach does not include a step by step instruction for the experiment. The students elaborate the essential theoretical fundamentals by use of problem-based approach, achieved partly in self-study and partly through input from the tutor. Although students create an awareness of the problem, it is indispensable that the students operate in a scientific correct manner. This signifies the identification of the problem enabling them to hypothesize, test the hypotheses in experiments, evaluate the results and make an error analysis. Thereby they work on a variety of logistical problems and their solutions in teams. Only a limited time of two weeks is available and the students have to present their results and procedure in the form of a record at the end of the project. Regular presentations encourage students and strengthen their assurance to present their results not only to improve literacy but also to consolidate basics for scientific work.

The following figure 1 illustrates the chosen combination of problem-based teaching and learning and traditional teaching. This model was developed especially for the MINT-lab in cooperation with social scientists and engineers and serves as a basis for the students to understand the individual process of recognizing and solving problems.

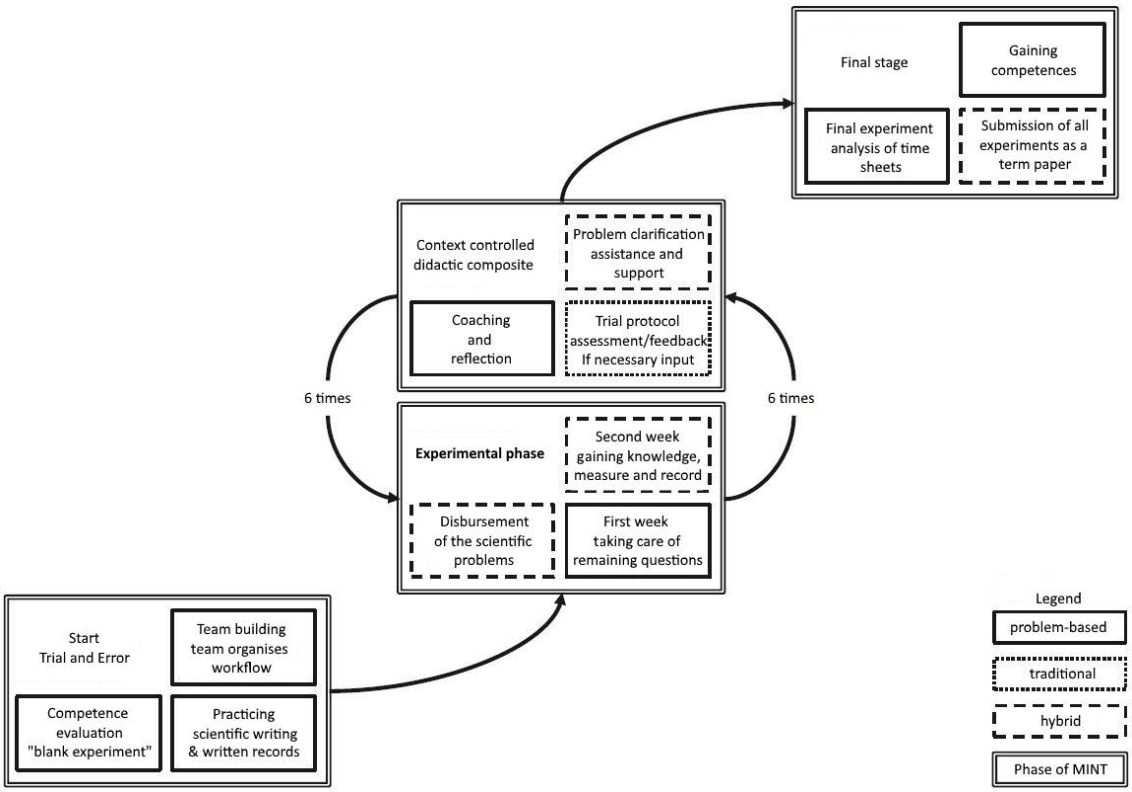

Figure 1: Procedure of the MINT-lab at the University of Applied Science Kaiserslautern (Wölker, et al., 2016)

A students' project conducted interviews with students in the MINT-lab in order to identify students' difficulties during the project processing and to develop suggestions for further improvements. In addition, a monitoring of MINT-teams was deployed to improve the implementation of the Seven Step Method and to question its applicability. As a result of this monitoring, it was evaluated that the MINT-lab is undoubtedly effective, which is shown by the outcome of the students in the form of records. Whereas the efficiency still has the potential for optimization, which corresponds with the result orientation of engineers. Whilst the classic Seven Step Method was integrated into the MINT-lab, the majority of the students did not use this problem-solving procedure.

The classic Seven Step Method was designed by H.G. Schmidt to support the problem-solving abilities of medical students, which is suitable for realistic case studies (H.G. Schmidt, Problem-based learning: rationale and description Medical Education, 1983, 17, 11-16). The seven steps contain the collection of essential information as well as the theoretical practice for solving the case. The fact that the Seven Step Method ends with the exchange of information in the team reflects the hypothetical fundamental idea of medical education. The ability to cure real-life patients is in the charge of professional doctor, not of not

graduated students. This reveals the discrepancy of medical problems and the problems at the MINT-Lab, which are created to perform the experiments practically. The rising need for the adjustment of the procedure model is the subject of research for the logistic team consisting of MINT-tutors and the module manager at the University of Applied Science Kaiserslautern (M. Wölker et al., unpublished).

4 Adjustment of the Seven Step Method for the MINT-lab

The Ten Step Method (Table 1) developed by the student project team (M. Weber et al., unpublished) is based on the Maastricht Seven Step Method (Schmidt, 1987). The development of the Ten Step Method took place during the winter semester 2016/2017. Therefore its implementation and evaluation are still in progress during summer semester 2017. The Ten Step Method is exclusively designed for the handling of problems in the MINT-lab containing practical experiments in contrast to hypothetical approaches.

The adaptation is not a complete absorption of already existing models such as the "triple jump" by the McMaster University (Blake, 1999) or the Ten Step (Guilbert, 1987) since the stipulated requirements for the processing of scientific and technical problem definitions differ from those of medical ones.

Table 1: Individual steps of the Ten Step Method in the MINT-lab
at the University of Applied Science Kaiserslautern

1. Step: Reading the chapter of the manual	At the beginning of the experiment it is necessary for each and every team member to read the relevant chapter in the MINT-lab Guide carefully and to mark unclear terms.
2. Step: Clarifying the unknown terms	Exchange of unclear terms by each team member to clarify them by prior knowledge of the other team members. Is this not possible terms must be defined with the help of further literature.
3. Step: Defining the problem understandably	Defining core problem and sub problems and formulating questions understandably. Starting the record.
4. Step: Creation of hypotheses	Recorded brainstorming to find the solutions of the problems. All members can express themselves equally. Exchanging ideas and expanding personal vision. Forming joint hypothesis.
5. Step: Systematic absorption of the problem	Structuring ideas systematically. Finding connections and linking them. A written documentation is essential.
6. Step: Defining the narrow learning goals	Ordering ideas according to their priority. Framing 3-5 learning objectives depending on the problem to be solved.
7. Step: Dividing the tasks for self-study	Distribution of the learning objectives to the various team members is recorded; a learning goal can be edited by several team members. In the following self-study, the students are supposed to work on their tasks, to use information from different sources and to be able to illustrate the problems to the other members of the team.
8. Step: Knowledge sharing and discussion	Presenting the results of the self-study in the team, explaining and dealing with learning objectives.
9. Step: Experimental procedure	Correct execution and documentation of the entire experiment. In this step, it is important that all team members cooperate constructively. If new and almost irresolvable problems arise, external help is needed to avoid incorrect operations.
10. Step: Evaluation	Evaluation of the experiment execution, processing of the generated

and recording writing	data and a return to the previously determined hypothesis. Preparation of the recording.

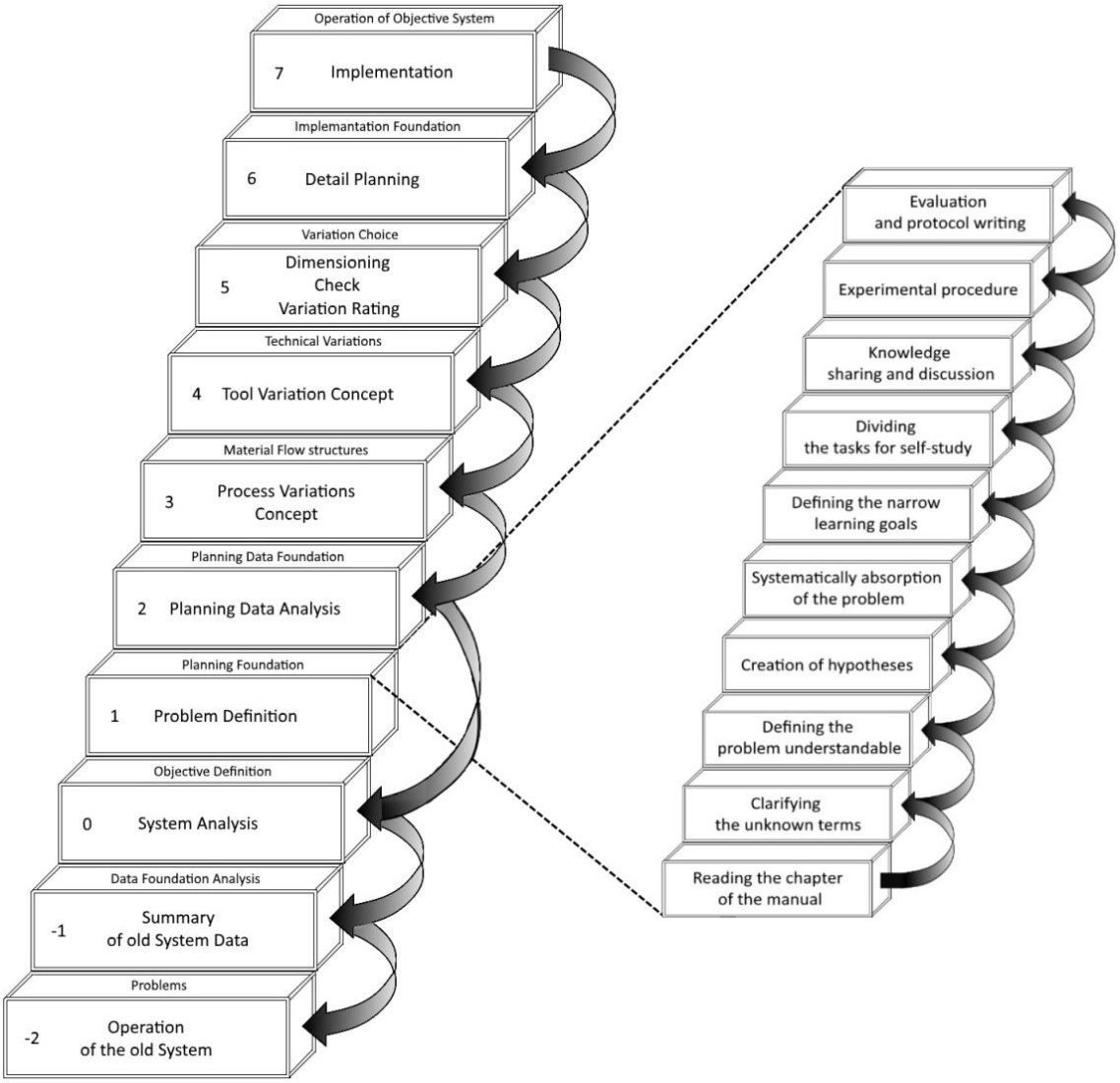

Figure 2: Implementation of the Ten Step Method in the MINT-lab in the advanced approach model of the planning (Wölker, 2000) in place of the "Problem Definition" step in order to fill the gap for planning projects. In face of that, the Ten Step Method is a component of logistical planning projects, which graduates use in the engineer profession.

Case studies in the medical field are based on medical records, complaints or symptoms and a list of diagnosis (Medizinische Universität Wien, 2011). In the medical field, complete solutions for case studies are not given because unlike technical problems requiring facts and formulas to solve them, medical problems need consideration of unclear biological parameters. In the case of medical questions, however, the problems to be examined can be based on various causes (Weber, 2007).

The recognition of these causes, in combination with the treatment method to be selected, characterizes the end of the Seven Step Method for medical problems. In contrast to this, the MINT-lab requires not only knowledge about the experiment, but also practical application through the experiment and a scientific

background by recording (Wölker, 2016). Only then the independent approach for solving technical problems is completed. This combines PBL with the execution of a project.

The adjustment of the Seven Step Method in the MINT-lab allows the implementation of a tried and tested model for approaching and solving problems in logistics studies. The conceived Ten Step Method clearly delineates the steps, which include the documentation of data and their return to an initial hypothesis. A problem is differentiated and offers an orientation to the students for working in projects in a defined process in the MINT-lab. They learn about the structured approach for projects and problems. Through the necessary documentation, a step-by-step approach is verifiable and an intensive view to a problem is ensured.

The starting point for logistics experts to work is usually a system state in which the logistic order cannot be met satisfactorily, as shown in Figure 2. In most cases, the task is to plan a system while it is irrelevant whether the projects involve new planning or optimization. Although there is an analysis phase in this model, it is assumed that the problem is already clear (Wölker, 2000). This model is applied in the planning of logistical projects. Compared to the logistic planning model on the left, the Ten Step Method (on the right) focusses on problem definition.

It is also illustrated that the logistics expert is often involved when the problem is already defined. One of the authors (Wölker) has extended the classical approach of the planning of material flow systems (Jünemann, 1989) to reduce uncertainties by prior system analysis. At that phase (stage 0), the task is not defined as a problem. The model also shows that there is no feedback with the stage of problem definition (stage 1). This stage is exactly addressed by the procedure model of the Ten Step Method. After giving students a target in the MINT-lab, they search for the problem in the system independently. In this respect, the Ten Step Method can be integrated into the advanced approach model of the planning for real projects.

5 Conclusion

Often, logistics are involved in projects, when problems are already defined and they are expected to work on tasks for problem-solving. They are usually unable to assess whether the identified change measures solve the "real" problems. They, therefore, work on tasks devoting a vast amount of time whilst no improvement occurs. Processing the tasks is rarely a problem as engineers are familiar with processing and the analysis of process chains. It remains open if completed tasks solve the real problems.

The MINT-lab represents a course in which the execution of realistic projects is simulated. The students receive several small projects with technical contents and work on them for two weeks in small teams. They should spot problems, carry out experiments and present their results in these projects. In order to identify the problems, the students were introduced to the Seven Step Method. Unfortunately, the students were not able to use this method effectively. Since the identification of problems is an important step at the beginning of the projects, the logistical work group has identified a need for adaptation.

The expansion of the Seven Step Method was carried out by a student project group under the supervision of the logistic team. The Ten Step Method is precisely tailored to the MINT-lab and integrates further steps, which help them to recognize problems. The method not only improves student performance but also prepares students for everyday work. Since engineers are familiar with process models, the Ten Step Method is presented to the students in order to make them able to capture technical input and to highlight the problems. In many small projects, an approach is developed that can be used by the graduates for a life time.

In the following semesters, the Ten Step Method will be tested in the MINT-lab modules and its efficiency will be critically questioned. The success of the implementation is, therefore, difficult to determine, since the higher goal of the introduction is not the improvement of the outcomes of the students in the module. Instead, the students are supposed to train an approach easing the handling of information and formulate problems. Since the Ten Step Method is used only in the MINT-lab, it remains open whether the duration of the training is sufficient to firmly anchor the procedure for problem analysis. For this reason, it is important to integrate the Ten Step Method into other modules and hence show students the universal applicability of the procedure model in technical contexts.

For the intention of integrating the Ten Step Method into other modules and evaluating the consequences of the implementation in the MINT-lab, the good cooperation with student project teams will be continued. The close cooperation promotes the correct scientific work of the students and gives interesting input to the logistic team from the perspective of the students.

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Factors affecting the implementation of a PBL-based strategy aimed at developing the skills of ninth grade students of an educational institution of Cundinamarca

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Abstract

The teaching and learning strategies, aimed at fostering a more proactive role by the students during their learning processes, have acquired a significant importance over the last years. Thus, the methodologies like inquiry-based learning, problem-based learning and project-based learning have been gradually incorporated into different educational levels. Even though these kinds of methodologies are known as methodologies that enable the approach to curricular elements and that encourage the development of transversal skills, there are also some elements that negatively affect the implementation of these kinds of strategies. Some of these elements include: the time at the teachers' disposal for planning and implementing the PBL, the lack of motivation of students, and the command of interdisciplinary topics by teachers. Identifying and analyzing the factors that influence the development of project-based and problem-based learning strategies could be considered as an important area of study to understand the aspects that favor or hinder the implementation of these methodologies.

Within the framework of the implementation of a didactic strategy based on PBL – aimed at strengthening soft and basic skills of ninth grade students of a public educational institution of Cundinamarca (Colombia) – the factors that could affect the implementation of the strategy were identified. The proposed didactic strategy implied that the students had to develop a project focused on the water conservation within their context. The strategy was implemented during six weeks and the language, mathematics, sciences and technology teachers were involved in the development of the strategy. The teachers filled in questionnaires that were designed to identify the factors that affected the implementation of this strategy. According to the results, the factors related to the didactic resources used, the students' motivation and the pedagogical management processes are the ones that most affect the implementation of the strategy.

Keywords: soft skills, high school education, PBL implementation, ICT

Type of contribution: best practice paper.

1 Introduction

For many decades, the methodologies that articulate knowledge areas and collaborative work – to address subjects related to the students' context and reality – have become a valuable pedagogical option to address contents and to develop skills. Approaches such as problem-based, inquiry-based and project-based learning constitute some of the methodologies aimed at fostering the interdisciplinary work and the development of skills. Within the Colombian educational context, these methodologies have been implemented more frequently in higher education, and even though they have been gradually integrated into basic and middle school, normally each subject (e. g. science, mathematics, language) addresses the

topics independently. In this way, few efforts have been made by public educational institutions to propose real scenarios of curricular articulation.

Generally speaking, according to different authors and experiences related to the implementation of methodologies like PBL, the relevance of incorporating these kinds of approaches into teaching and learning processes relates to: a higher motivation of the students to approach the curricular contents through activities based on a real problem or an interesting topic; the integrated development of learning processes and skills through an interdisciplinary work that articulates curricular topics; the strengthening of soft skills such as collaborative work, self-regulation, creativity, communication, among others.

Despite the positive aspects related to the implementation of methodologies like PBL, some factors or elements that hinder their implementation have also been identified (such as the time at the teachers' disposal for planning and implementing the PBL, students motivation and difficulties related to topics articulation). Some of these difficulties can be overcome if the teachers are accompanied throughout the formulation of the PBL-based strategy, or by providing them with structured strategies that articulate with the curricular contents and that could save time in the planning process. In accordance with this last proposal, a didactic strategy was designed aimed at fostering an articulated development of skills of ninth grade students. The strategy was implemented during an academic term and the factors that affected its implementation were identified.

This article presents the results of the identification process through the following sections: literature review, methodology, data analysis, results and conclusions. The literature review section addresses some theoretical references concerning inductive learning methodologies and in particular, project-based learning. The next section describes briefly the characteristics of the didactic strategy proposed, the methodology employed to identify the factors that influenced its implementation and the population involved in the implementation of the strategy. Then, the fourth section describes the procedure developed in order to analyze the data collected through the designed instruments. The fifth section corresponds to the results, where the main analyses and findings are presented with respect to the factors that hindered or favored the strategy development. Finally, the last section of the document discusses the conclusions and presents some considerations for further researches.

2 Literature Review

2.1 Project-based learning

There are different approaches related to the categorization of educational methods to teach students, Prince and Fleder suggest two main categories: deductive methods and inductive methods (Prince & Felder, 2007). The first are methods in which the teacher (knowledge transmitter) is the center of the teaching-learning processes (Prince & Felder, 2006). As for the inductive methods, they allow the student to assume a more active role in their learning process and in knowledge building, taking into account their needs and interests (Froschl, 2005). The inductive teaching-learning methodologies include: inquiry-based learning, problem-based learning, project-based learning, case-based learning, among others (Prince & Felder, 2007).

The Project-Based Learning (PBL) emerged during the nineties as a didactic strategy in which the student learning processes are generated through the formulation and development of projects. Projects can be considered as complex tasks based on the identification of problems and where the student gets involve in making decisions regarding the solution of such problem, the design and development of products associated to the solution, and their socialization (Thomas, 2000). Different experiences related to the PBL

implementation stand out within the positive aspects associated to this methodology the possibility of working around curricular contents and soft skills during the formulation and development of projects (Thomas, 2000; Stefanou et al. 2013; Blumenfeld et al, 2011; Bell, 2010; Musa et al. 2011). Likewise, PBL is considered as a strategy in which the student assumes a more active role during their learning process, generating significant learning through the resolution of problems within the context and encouraging collaborative work in class (Thomas, 2000).

Some researches related to the implementation of PBL strategies were conducted in the context of basic and middle education. Kokotsaki et al. (2016) conducted a review about different experiences that involved project-based learning in countries such as United States, Israel, Great Britain, Kenya, among others. The strategies proposed within the framework of these experiences sought to address elements from mathematics, sciences and technology in different grades (Kokotsaki et al., 2016). According to the results reported in different studies, it is evident that the students that participated in these kinds of strategies improved their performance (usually in relation to groups of students that addressed the same topics through a traditional methodology). Additionally, most of the studies concluded that implementing a strategy with a PBL approach encourages the development of additional skills related to creative thinking and teamwork (Kokotsaki et al., 2016).

On the other hand, despite of the positive elements around the implementation of these strategies, some factors or elements that could negatively affect the development of this type of methodology have also been found (Thomas, 2000). Among these factors are: the time at the teachers' disposal for planning and implementing the PBL, the mastery of interdisciplinary topics by teachers, difficulties in monitoring and evaluating the students during the development of projects, difficulties in articulating the curricular contents with the projects and situations within the students context, among others (Thomas, 2000).

2.2 General information on soft skills

There are diverse definitions related to the concept of skill (Tedesco et al., 2013). Tobón addresses this concept from a wider perspective that integrates elements from different definitions made by other authors: "skills are complex processes of achievement with qualification in certain contexts, integrating different kinds of knowledge (knowing to be, knowing to do, knowing to know and knowing to co-live), in order to carry out activities and/or solve problems as a challenge, motivation, flexibility, creativity, understanding and undertaking, within a perspective of meta-cognitive processing, on-going improvement and ethical commitment, aiming at contributing to personal development, construction and strengthening of the social network, the permanent search of a sustained economic-entrepreneurial development, and the concern and protection of the environment and the living species" (Tedesco et al., 2013).

The different categorizations of skills include soft, social-emotional or non-cognitive skills. Teamwork, resilience, creativity, self-regulation and management are some examples of these kinds of skills. According to different authors, it is important to foster the development of soft skills in order to encourage economical welfare, social development, access to employment, physical and mental well-being (Chen et al., 2013; Viviers et al., 2012; Tan & Neo, 2016; Kautz et al., 2014).

Considering a few programs and initiatives focused on different population groups (from early childhood to young adults), Kautz et al. (2014) summarized the empirical evidence on the development of soft, social-emotional or non-cognitive skills. This study analyses the influence of different initiatives on variables associated to academic performance, educational level, mental and physical well-being, income level, etc. The results of this study suggest that the program participants that developed non-cognitive skills tend to

present a good academic performance, continue accessing to higher education, keep their distance from addictions and perform well in social and occupational contexts.

3 Methodology

In order to identify the factors that have influence on the implementation of a strategy based on PBL –aimed at developing the skills in students of ninth grade–, an accompaniment to the implementation of the strategy was carried out during an academic term. The next sub-sections briefly describe the strategy proposed for the articulated development of skills, the instruments built to identify factors and the population involved in the strategy implementation.

3.1 Didactic strategy for the development of skills

A PBL based strategy was proposed to be implemented during an academic term with ninth grade students, for the purpose of fostering the articulated development of soft skills (management, teamwork, self-regulation, creativity) and skills related to mathematics, language, sciences. The strategy proposed consists of five stages that define different activities to develop skills: formulation, assessment of possible solutions, design, development and implementation, and socialization. In this way, the project integrates the contents from mathematics, sciences and language through a question regarding water conservation, which is formulated in a way it is being addressed from the specific context of certain educational institution. Moreover, some activities to approach the defined soft skills were proposed during the project stages. A set of digital educational resources (DER) was created in order to support the development of the project and to lead the work around the proposed skills. Likewise, a platform was developed including functions related to project management, digital educational resources repositories and communication channels. An offline version of the platform was developed to facilitate its use in the educational institutions with limited access to Internet.

3.2 Instruments for the identification of factors

A questionnaire for the teachers and a focus group were designed in order to collect information regarding the factors that influence the implementation of the didactic strategy proposed. The questionnaire was preferred (over other types of instruments) since it was necessary to count with an instrument to collect structured information, and which the teachers could apply without requiring investigators presence (Cohen, 2013). Additionally, this type of instrument allows predefine the categories of information analysis through close-ended questions, which are designed according to the dimensions of interest (Cohen, 2013). Also, the focus group was proposed as an instrument to collect additional information to deepen about the questionnaire results and identifying emerging variables.

The instruments were design considering dimensions or categories associated to internal or external factors that could affect the implementation of the strategy. These factors were defined based on some basis elements reported in literature (Thomas, 2000) and on the previous experience of the research group in the implementation of similar strategies. In this way, the elements related to the proposed strategy were defined as internal factors (methodology proposed, digital educational resources related, platform available). Likewise, the external factors were associated to the particular characteristics of the institution that could influence on the strategy implementation (e.g. technological infrastructure, physical spaces for the development of teaching-learning activities, class hours for the subjects involved, development of extracurricular activities).

Taking into account the internal and external factors that could affect the implementation of the didactic strategy proposed, a questionnaire with 27 items was designed. The items proposed in the questionnaire had to be assessed by the participant teachers according to the following rating scale: favored, hindered and not applicable. The Table 1 shows some examples of these items categorized as internal and external factors.

Table 1: Examples of items in the teachers' questionnaire about the factors influencing the strategy implementation.

Aspect	Item
External factors	Events, cultural and sports activities, pedagogical workshops, among others.
	Participation and institutional support for the strategy implementation from the directors and coordinators.
	Access to technological resources in the institution (PC, video beam, etc.) to develop the strategy.
Internal factors	PBL as the methodological approach in which the strategy is based on.
	Use of the resources from "Contenidos para aprender" in mathematics, sciences and language.
	Interdisciplinary support (work with other teachers) in the preparation of activities related to the strategy.

Some open-ended questions were included in the final section of the questionnaire in order to identify the most determinant factors in implementing the strategy and to collect additional comments from the teachers with respect to the projects development. As a complementary source of information, a focus group guide was designed to apply it after concluding the strategy implementation and to deepen about the findings of the survey.

3.3 Participant population

The didactic strategy proposed was implemented during the last academic term of 2016, with ninth grade students of the school Institución Educativa Departamental Bagazal, in Villeta (Cundinamarca). About 30 students participated in the implementation of the strategy and the teachers of mathematics, language, sciences, technology and entrepreneurship were also involved.

3.4 Data collection

The strategy implementation was carried out during the mathematics, language, sciences, technology and entrepreneurship classes, and it counted on the accompaniment of one of the experts that participated in the pedagogical design of the strategy. During the implementation of the strategy (approximately 2 months), the participating teachers filled in the questionnaire on a weekly basis in order to identify the factors that affected the projects development. Likewise, once strategy implementation concluded, a focus group was conducted with the teachers of the subjects involved in the strategy with the purpose of collecting additional comments on the aspects that could affect or favor the development of the didactic strategy.

4 Data analysis

In order to analyze the results obtained from the questionnaire about factors influencing the implementation of the didactic strategy proposed, the score given to each item in different stages was processed according to the following conversion structure: favored = 1, not applicable = 0, hindered = -1. Then, the favorability index (I_i) was calculated for each item as the average of the total score given to the item by all teachers. In this way, a favorability index close to 1 would suggest that the factor analyzed favors the development of the strategy, while an index close to -1 would enable to determine that such factor was one of the elements that hindered the implementation. Additionally, the mode related to each item was calculated as an element of further analysis. The Table 2 presents the favorability indexes and the modes for each item included in the questionnaire.

Table 2: Favorability index and mode calculated for the items in the questionnaire

Factor	Mode	I_i
External accompaniment during the strategy planning.	1	0.75
Institutional accompaniment during the strategy planning.	1	0.5625
Time for preparing and planning the strategy activities.	1	0.6875
Connectivity in the educational institution.	0	0.125
Environmental and geographical conditions of the institution.	0	0.3125
Institutional events and cultural or sports activities.	0	-0.1875
Meetings between the teachers involved in the project.	0	0
Participation and institutional support from the directors and coordinators for the development of the strategy.	1	0.1875
Articulation between the strategy and the institutional education project.	0	0.375
Access to technological resources in the institution (PC, video beam, etc.).	1	0.4375
Quantity of technological resources in the institution (pc, tablets, etc.).	1	0.6875
Quality of the physical space for the implementation of the strategy.	1	0.9375
Acceptance of the strategy by the participant teachers.	1	0.8125
The agreements made between the teachers, the institution and researchers to develop the project.	1	0.125
Articulation between the strategy and the curricular plans of 9th grade.	1	0.875
Time allocated by the teachers to plan the sessions.	-1 and 1	0
Interdisciplinary support (work with other teachers) in planning the activities related to the strategy.	1	0.4375
Participation of different teachers in the development of the project.	1	0.6875
Attitude of the students towards the activities proposed.	1	0.6875
Knowledge and adoption of the strategy.	1	0.875
Characteristics of the class (class hours, group size, etc.)	1	0.6875
Experience of the teacher with methodologies related (PBL).	1	0.6875
PBL as the methodological approach in which the strategy is based on.	1	0.875
Use of the resources from “Contenidos para aprender” in mathematics, sciences and language.	1	0.6875

Use of DERs to develop soft skills.	1	0.75
Handbooks available for teachers and students.	1	0.8125
The platform proposed to support the strategy development.	1	0.375

5 Results

According to the results showed in Table 2, it is possible to observe that the teachers perceived "institutional events, cultural, sports activities, pedagogical workshops or other extra-curricular activities of the educational institution" as a factor that hindered the strategy implementation, with a favorability index close to -0.2. In this context, during the focus group the teachers said the external accompaniment to plan the strategy was appropriate (which coincides with a positive favorability index related to that factor), but they also indicated that there were contingencies that disrupted the compliance with the schedule. Furthermore, the factor regarding the time available to plan the class sessions related to the strategy was perceived as a problem for some teachers. This is evidenced in the favorability index (0) and the modes related to the assessment of such factor (-1 and 1).

Generally speaking, the conditions to perform the planning activities internally seem to be factors that do not favor entirely the implementation of the PBL based strategy. This can also be observed when analyzing the item "planning and monitoring meetings between the teachers involved in the strategy implementation", which had a favorability index of 0 and a mode of 0. In this regard, during the focus group the teachers alleged that it was not possible to consolidate interdisciplinarity as a distinctive factor within the strategy development, since no teacher knew of the activities that were being developed in the other subjects involved in the strategy. The teachers said that the time available to develop the monitoring and planning meetings is a crucial factor in most of the public institutions. Some of these elements can be evidenced in the following comment made by a teacher that participated in the focus group:

> *"…We all work hard, but each acting on his own, and then someone ask 'what did you do? Really? ' They went to catch worms because we never had time to meet and it is because we don't have enough time. It is not about demotivation, but about the lack of time! We have a lot of things to do and in the afternoon each has their own activities, so it has been difficult for that reason. So, it is important to provide us a space, maybe during classes, to plan the interdisciplinary activities weekly or bimonthly [Mmm] so everyone know what we are doing… And to feedback, right? On everything that has been done, because if we don't do this you get lost, and what he is saying is true: this demotivates the children involved because they say 'they are disarticulated' or think… 'We have to work on interdisciplinarity but each teacher is on his own'…"* **Teacher participation in the focus group.**

On the other hand, the aspects that most favored the strategy implementation were the factors related to infrastructure, methodology and resources proposed. Accordingly, the factors with the highest favorability index include: "Quality of the physical space (classrooms, computer classrooms, etc.) available for the implementation of the strategy" with an index of 0.937, "PBL as the methodological approach in which the strategy is based on" with an index of 0.875, "Articulation between the strategy and the curricular plans of ninth grade" and "Knowledge and adoption of the strategy by teachers", both with a favorability index of 0.875. In the focus group, the teachers emphasized the importance of PBL as a methodology for developing skills articulately and to address contents from mathematics, language and sciences. In this respect, they

mentioned valuable elements such as the handbooks created to guide the strategy development and the DERs proposed to address the contents of different areas.

6 Conclusions

A didactic strategy based on the PBL methodology was designed in order to favor the articulated development of skills in ninth grade students. The strategy was implemented during an academic term in a public institution of Cundinamarca and involved teachers of mathematics, language, sciences, technology and entrepreneurship. During the implementation, the internal and external factors that could influence the strategy development were identified.

According to the results obtained regarding the internal factors, the PBL was identified as one of the strengths related to the strategy proposed. Likewise, the participating teachers considered that the handbooks, DERs developed and the articulation between the strategy proposed and the curricular plans of ninth grade were factors that favored the implementation of the didactic strategy. With regard to the external factors, most of the teachers considered that the quality of the physical space available in the educational institution to implement the strategy was a factor that favored the projects execution.

On the other hand, most of the aspects that hindered the strategy implementation were external factors. The development of extra-curricular activities, the time available for planning the sessions associated to the strategy, and the lack of meetings between the teachers to monitor the project were identified as factors that affected negatively the project development. In relation to this finding, it is important to emphasize that even though the accompaniment made by the researchers during the planning and monitoring of the strategy was a point that favored the development of this project, this factor could also explain the disarticulation among teachers. One possible hypothesis is that because of the accompaniment made through the planning and implementation process, the teachers did not consider that it was necessary to find other spaces to discuss the project progress, since each area had a structured plan with contents and activities. It is clear that, for further implementations of the strategy, it will be important to create activities that encourage the interaction between teachers out of the classroom, thereby favoring the interdisciplinarity and monitoring of the project activities.

Finally, the results of this experience allowed us to evidence and corroborate that the extracurricular activities and the limited time available to plan new activities, frequently interfere with the implementation of new methodologies. Additionally, these elements seem to be particular susceptible when it comes to address strategies that link or integrate different areas or subjects, as happens in project-based learning and problem-based learning. Therefore, consider these kinds of variables (external) when designing strategies related to PBL could serve as an interesting challenge for further researches.

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Implementation of a Problem Based Learning Environment for First Year Engineering Mathematics

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Abstract

In this work we present the outcome of implementing a problem based learning (PBL) environment in a first year engineering mathematics course focusing on the principles and applications of integral calculus. The PBL experiment was performed with a group of 94 students (split into two sections). To determine the effect of this experiment, a control group of 112 students (split into two groups of equal strength) were also involved in the study. The control group was taught the same contents using the traditional lecturing approach. The experimental group was taught the material using PBL principles. The problems designed for the PBL environment integrated three key themes, namely reinforcement, spacing, and instant feedback. By employing these themes in the PBL environment, the students were required to continuously recall several concepts taught in the previous weeks. This exercise was spaced over the entire duration of the course, and enabled us to reinforce the concepts. A qualified teaching assistant, selected after an interview process, and the instructor were available during the PBL sessions to provide immediate feedback and enable students to rectify their conceptual misunderstandings. The effect of the experiment was assessed using two term tests and a comprehensive final exam. It was found that the students in the experimental sections performed nearly two letter grades better than their peers in the control section. This indicates that the PBL environment provided a superior learning environment. Further, within each group, the performance of the students decreased as the course progressed. This was attributed to the increasing level of difficulty in the course as well as a possibility that the students are optimizing their time to maximize their gains in other subjects.

Keywords: PBL, calculus, reinforcement, spacing, feedback

Type of contribution:– Research paper.

1 Introduction

University/college educational practices have evolved over several generations introducing the best teaching practices that enable student learning and retention. This evolution has resulted in several teaching techniques that can be applied inside the classroom. Researchers have prescribed a variety of classroom practices, namely, co-operative and small group learning (Springer et al. 1999; Hake 1998; Wage et al. 2005; Buck & Wage 2005; Prince 2004; Terenzini et al. 2001), problem based learning (Capon & Kuhn 2004; Dochy et al. 2003; Gijbels et al. 2005; Kolb 2015; Prince & Felder 2006), active learning (Beichner et al. 2007; Burrowes 2003; Cummings et al. 1999; Freeman et al. 2007; Hoellwarth et al. 2005; Knight & Wood 2005; Redish et al. 1997), inquiry-based learning (Farrell et al. 1999; Lewis & Lewis 2005; Prince & Felder 2006), challenge-based learning (Roselli & Brophy 2006), peer-led team learning (McCreary et al. 2006), and

undergraduate research-based learning (Hunter et al. 2007).

The development of such a variety of classroom practices is attributed to the fact that many instructors consider the traditional lecturing approach to be a suboptimal method of delivering the content. In fact, in a traditional lecturing approach only 20% of the material is mastered successfully by the students (Wage et al., 2005). Further, given that each student is different in his/her learning ability, adopting a teaching style is dependent upon the course topics as well as the particular cohort. Put differently, there is no standard or superior way of conducting the classroom sessions that is equally applicable for all courses and all students.

At McMaster's School of Engineering Practice and Technology, the undergraduate degree programs are quite applied in nature and are marketed as such to target students who have an aptitude for active-learning and excel with hands-on applied approaches to learning, rather than the traditional engineering degree programs. As a consequence, over the years, we have found that such students naturally struggle in a teaching environment that is based purely on traditional lecturing methods. In order to overcome this struggle and to facilitate better learning and retention, we have included an active learning strategy in the classroom, enabling students to perform better even in foundational engineering courses like integral calculus. In this work, we present our active learning strategies that have evolved over a span of three years. This evolution has resulted in an increased performance of the students, assessed via periodic term tests and a comprehensive exam.

2 Methods

The study was conducted in an undergraduate course on Integral Calculus that is taught over a period of one term. The control group had an enrolment of 112 students, split over two sections. This split was based on the individual student's schedule and was done by the registrar's office. The students in the control section were taught using the traditional lecturing format. The experimental group where the active learning strategies were employed had an enrolment of 94 students, again split into two sections by the registrar's office based on their individual time-table. For this group, the topics were delivered using an active learning strategy. The specifics of the course design, the content of the course, and the evaluation process are discussed in the ensuing subsections. The control as well as the experimental sections were taught by the same instructor.

2.1 Course Design

For both groups, the material was taught over a period of 13 weeks. Further, in each week the class met for a duration of 4 hours, split into two 2-hour lectures. Learning in the two groups was assessed via two term tests and a comprehensive final exam. The term tests were scheduled immediately after the predetermined set of topics for the respective tests were taught in the class. The cumulative final exam was scheduled by the university at the end of the term along with the other courses.

Each week the control group had two lecture sessions, while the experimental group had a lecture interlaced with periodic breakout sessions. In these breakout sessions, the students in groups of 3-5 would solve pre-assigned problems. A qualified TA is available for assisting the faculty member in evaluating the solutions inside the classroom.

By design, the problem solving sessions integrated the three key themes: *Reinforcement*; *Spacing;* and *Feedback*. The motivation behind the integration of these principles in the intervention strategy is their positive effect on learning and long-term retention of the material, as follows:

a) *Reinforcement*: by repeatedly recalling the concepts from the memory, the information is more permanently stored in the memory.

b) *Spacing*: to aid the retention of the material for a longer duration of time, the material is practiced over a longer span of time.

c) *Instant Feedback*: an immediate corrective feedback can help in better understanding of the material more effectively.

While the same problems were available for the control group, they were assigned just as practice questions, and students were regularly encouraged to meet with the instructor during office hours or make appointments to get additional help. It must be noted that given the busy schedule of the students, the office hours were not availed intensively up until the last few days of the test.

2.2 Materials

The students in the control group as well as the experimental group were taught the same material. The specific topics include:

1) Definite and indefinite integrals and the techniques of integration,

2) Fundamental theorem of calculus,

3) Applications of integral calculus (Velocity and net change, Finding plane areas between curves, volume of solids of revolution, arc length, area of surface of revolution, work done, moments and center of mass), double and triple integrals, and

4) Integral theorems (Gauss, Green and Stoke theorem).

The topics covered in the two term tests included:

Test 1: Covered items 1 and 2 in the list above.

Test 2: Focussed on the applications of integrals, velocity and net change, finding plane areas between curves, volume of solids of revolution, and arc length.

All the other topics were covered only in the final exam. Each test was for a duration of 1 hour and 45 minutes. The final exam was comprehensive and was for a duration of 2.5 hours. There were about 10 questions, some with multiple parts.

2.3 Procedure

For the students of the control group, during the in-class instruction period, the course topics were taught by explaining the concepts and solving a few example problems on the white board. Specifically, each lecture begins with the objective of the topic, and an explanation of the underlying concept, followed by several examples that are solved on the board. At the end of each topic, the students were provided with problem sets for practice outside the classroom. For assistance with the questions, the students could either visit the instructor during the posted office hours, or make an appointment at a time of mutual convenience.

In the experimental section, following a short introduction to the topic and a few solved examples, the students were divided into random groups of 3-5 students. They were assigned a problem set each week to

solve as a group. The students were encouraged to discuss the solutions among themselves and work as a team to derive the solutions. Additionally, the instructor and a qualified teaching assistant were also available in the classroom for the groups to seek clarifications or intermittent feedback. Through the lecture period, the instructor and the teaching assistant would interact on a one-on-one basis with each group checking their progress/understanding and helping identify any shortcomings in their grasp of the concepts. This one-on-one interaction enabled to clarify and fortify the concepts in the students' mind. This exercise enabled the students in the class to obtain the correct solution and had a good understanding of the solution methodology. In addition to this, often due to lack of time, the students were also asked to pursue some of the unsolved problems at home and return to the classroom with the solutions. The fact that the students were able to solve several problems in class encouraged them to pursue the remaining problems outside the classroom, and most students returned with solutions to other questions.

The questions themselves were chosen such that concepts taught in the prior weeks had to be recalled to solve them, thereby *reinforcing* the concepts. The questions in a particular topic would typically be spanning over 2-3 weeks and this *spacing* meant that the concepts had to be repeatedly recalled, aiding in the *reinforcement* process. Finally, the immediate feedback inside the classroom enables us to resolve any misunderstandings of the concepts before the wrong concepts take deep roots in the minds of the students. The integrations of these three themes, namely, reinforcement, spacing and instantaneous feedback, has been found to be useful in aiding learning in the students (Deslauriers *et al*. 2011; Butler *et al*. 2014).

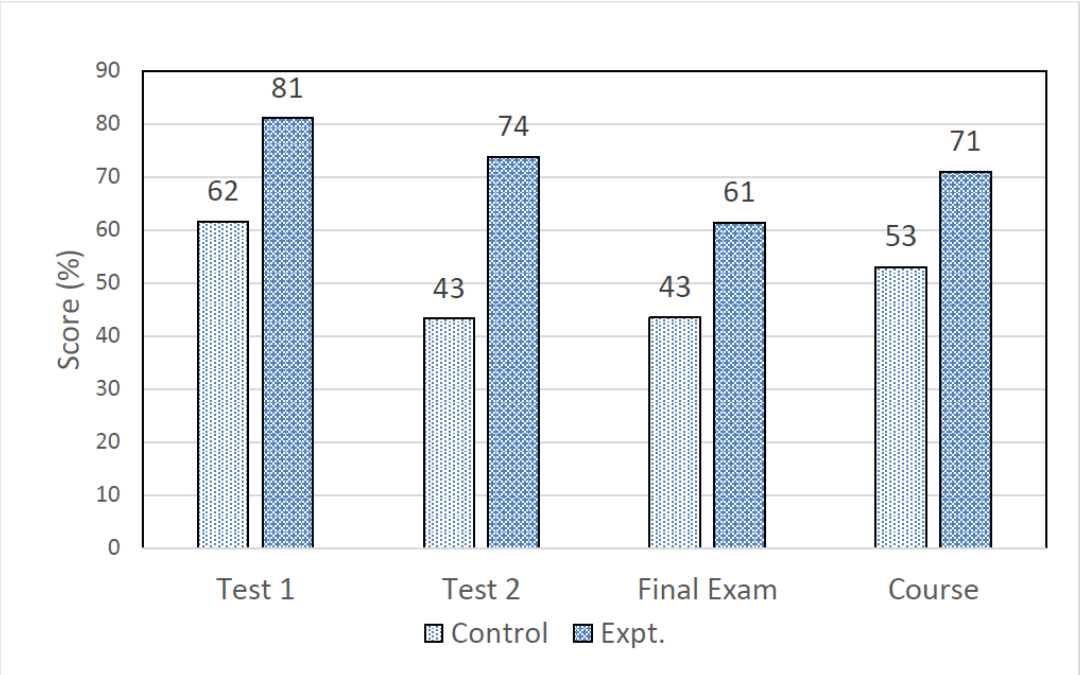

Figure 1: Performance of the students in the two term tests, final exam, and the overall course grade.

3 Results & Discussion

3.1 Tests & Final Exam

The average scores of the students in the experimental group and the control group on the three assessments are presented in Fig. 1. On comparing the performance of the two groups with eachother, we see that the

experimental group performs significantly better than the control group. We believe that the fact that students enrolled in this program are naturally disposed to active learning, coupled with the intervention strategies that aid retention, have contributed to this significantly better performance of this group. At the same time, we would also like to mention that, since the population is not the same in the two groups, there is a possible contribution of this variation in the performance. However, we believe that this variation by itself cannot be a major factor in the improved results that we observe with the experimental group. In other words, we believe that almost all of the gains that we see in the experimental group can be directly attributed to the active learning strategy integrated in the PBL environment that we have employed inside the classroom.

Another observation that can be made from Fig. 1 is that for both groups, there is a decline in the performance of the students between test 1 and test 2. More precisely, the control group's average score falls sharply by nearly 19% from the test 1 to test 2. On the other hand, the performance of the experimental group sees a moderate decline by about 7% from test 1 to test 2. This indicates that the reinforcement and spacing themes employed with the experimental group helps reduce the fall of grades by enhancing retention of the techniques of integration that are relevant for test 2. The 7% decline in the scores can be explained by the fact that the material on test 2 was based on advanced concepts, namely applications of integration, that is more challenging than the topics of test 1. As expected, without such intervention strategies, the performance of the control group sharply declines.

Table 1: Average performance of the class in the various assessments.

Assessment	Control	Expt.	% Change	Cohen's d Effect Size	
Test 1 (%)	62	81	19	0.99	**Avg. = 1.17**
Test 2 (%)	43	74	31	1.44	
Final Exam (%)	43	61	18	1.07	
Course Grade (%)	**53**	**71**	**18**	**1.11**	

3.2 Final Exam & Course Grade

The final exam was comprehensive and had about 13 questions for both groups, some of the questions with multiple parts. The performance of the students in the final exam and the overall course grade are also summarized in Table 1 and shown in Fig. 1

A comparison of the final exam scores between the two sections indicates that the students in the experimental section performed nearly 20% better than the students in the control section. This is approximately 2 letter grades higher than the control section. As a result of the better averages in the three assessment components, the final course grade of the students in the experimental group was nearly 5 letter grades higher on McMaster University's grading scale, changing from D to B-.

Overall, in both groups, the performance of the students progressively decreases, falling by about 20% from test 1 to the final exam. As mentioned above, this is expected because as in any other subject, the materials become increasingly challenging. The lowest score on the final exam is due to the fact that final exam is comprehensive and held along with a host of other courses that the students take. As postulated by Love and Kotchen (2010), the students tend to optimize their performance by splitting their time between several courses to strike a balance and in the process perform a bit lower than their average in the term tests. In fact,

due to the average failing grade in Test 2, the students perhaps invested more time in this course arresting the further fall of the average on the final exam. On the other hand, the experimental group perhaps invested their time in other courses, leading to a further drop of about 13% from their average test 2 score.

3.3 Effect Size

To obtain a quantitative estimate of the influence of the intervention themes in the experimental section, an effect size is calculated as

$$d = \frac{\overline{x_1} - \overline{x_2}}{s} \tag{1}$$

where d is the effect size, $\overline{x_1}$ and $\overline{x_2}$ are the average of the test score in the control and experimental section, respectively; s is the pooled standard deviation that is calculated as

$$s = \sqrt{\frac{(n_1-1)s_1^2 - (n_2-1)s_2^2}{n_1 + n_2 - 2}}, \tag{2}$$

where n_i and s_i are the number of and the standard deviation of the ith section, respectively.

Table 1 summarizes the effect sizes for the three assessments and the overall course grade. As seen in this table, on an average, the effect size is around 1.17 in the three assessments spanning the entire range of topics covered in the course. This clearly indicates that the three themes integrated into the active learning environment produce a significant improvement in the performance of the students through the course. It must be noted that this average value of 1.17 reported in Table 1 matches closely with the findings of Bloom (1984) in which the author reported that an effect size of about 1.20 can be obtained when strategies to reinforce concepts are used inside the classroom.

4 Summary & Conclusions

In this study, the outcome of employing a problem-based learning strategy in a first year undergraduate engineering mathematics course is presented. The course in which this strategy has been employed focuses on integral calculus and its applications, and was delivered over a single term (13 weeks). Each week, the class met twice for two hours.

In conducting this study, a group of over 200 students were divided into four sections of comparable size. Two sections were part of the *control group* and the other two sections were the *experimental group*, all handled by the same instructor. The control group were taught the material using traditional lecturing format. The experimental group learnt the same material using a problem based learning approach. Specifically, for the latter group, following a short discussion on the main concept, the students in each section were subdivided into groups of 3-5 students. These students were then assigned problems to solve inside the classroom. A qualified teaching assistant and the instructor were available for the students to discuss their solutions. By design, the problems incorporated three key themes, namely, *Reinforcement*, *Spacing* and *Instant Feedback*. Each week, the designed problems were designed such that several of the earlier concepts had to be recalled and applied in order to solve the problems. This enabled us to reinforce the concepts. Further, by ensuring that key concepts had to be employed in problems over

several successive weeks, the spacing aided the reinforcement process. Finally, by immediately providing the feedback to the students inside the classroom, potential misunderstandings were quickly resolved.

The outcome of the experiment was measured via three key assessments, namely, two term tests and one comprehensive final exam. The key findings were:

(i) On average, the experimental group performed about 20% better than the control group. The overall final course grade improved from D to B- from the control to the experimental sections.

(ii) Within each group, the performance for the students declined from the test 1 to the final exam. This is expected and attributed to two factors: (a) the course gets progressively difficult. (b) with other courses to focus on during the final exam, the students optimize their time to maximize gains in all the courses (Love & Kotchen, 2010).

(iii) The assessments indicate an average effect size of 1.17, that is consistent with the postulates of Bloom (1984) who indicates that an effect size of 1.20 is possible with reinforcement strategies inside the classroom.

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Project-based learning: Practical experience in Statics courses

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Abstract

This article presents an experience in the implementation of a PBL (Project Based Learning) methodology in Statics courses in the third semester of a Civil and Agricultural Engineering program.

The students worked in groups of two or three and had the possibility to decide what kind of project they wanted to do. In most of the cases the project had a social component and covered a necessity of the community related to at least one member of the group. For example: The sports centre for the town where he/she lives, the milk production centre for the farm of her/his parents, the bridge in a rural area that connect the town where he/she comes from.

With this project, the students were able to understand the applications of what was learnt in the course as equilibrium of particles and rigid body, centroids, inertia, trusses, beams, frames. They also managed to work in groups and sometimes in teams, when all members were engaged in the project.

The members of the group interviewed owners, professionals and people in general. Besides, they read papers and codes; and get plans of areas. The result is that they learnt how to learn by themselves.

The students integrated the previous knowledge they had with the recent knowledge acquired in the class.

For the reasons exposed above, the activity has brought more advantages than disadvantages.

Keywords: Project based learning, Static course, Civil Engineering programs, teamwork, social component

Type of contribution: best practice paper.

1 Introduction

For the post conflict in Colombia after the peace agreement, it is necessary to carry out some work to improve the quality of life of the rural and urban population. For this reason, the universities have the responsibility to educate integral engineers and leaders with enough knowledge, skills for working in groups, initiative and capacity of analysis, solution and decision. According with these expected competences, the main and the formation objectives of the Civil Engineering program at the Universidad Nacional de Colombia are formulated. The main objective is *"the formation of a Civil Engineer with a solid analytical capacity and with a special knowledge of the practices of the profession and the context in which his work is carried out. In this way, the program graduates will be able to undertake research and the generation of new knowledge, and to conceive, design and build the infrastructure required by society."*[1](Universidad Nacional[a], 2016*).*

Some of the formation objectives are usually taken into account in the courses, as the solution in basic sciences applied to engineering problems; the formulation of methodology; the evaluation and design of

[1] All translations are mine.

components or processes; and the analysis and solution of problems of design and construction processes. However, there are others formation objectives, sometimes forgotten, like: "*Recognize the importance of the social, economic, institutional and environmental context in identifying, formulating and solving civil engineering problems and analysing their socio-environmental impact"; "Develop communicative skills to express ideas and concepts towards a technical and non-technical audience"; "Participate effectively in multidisciplinary groups, organize and direct their efforts*"; "*Develop skills for autonomous learning"* and *"Integrate knowledge learned to apply them in the creation, formulation, management and control of projects and companies*". These are forgotten because most of the courses are lectured, focusing in the transmission of the knowledge to the students leaving beside the development of students' competences needed to achieve the formation objectives.

In the lecture classes, the teachers do the task that corresponds to the students and the students choose the easy way, which is, not participating actively in their own learning process, preferring receiving than contributing. Mason (2009) wrote "*Some learners sit in rows waiting to be told what mathematical or scientific procedures and facts they need to know. They naturally want to minimise their investment of energy, particularly when the 'subject' is peripheral or seen as at best a necessary tool rather than as a central element of their discipline. They are in a transition phase waiting to acquire a 'license to practise' in their discipline in the world beyond education. They assent to what they are given and asked to do, but have no thought to take initiative or to do more than requested".*

The knowledge acquired in this way is quickly forgotten until the student finds an application of it. In the words of Felder & Brent "*If you simply lecture on those things and you're a good lecturer, the students may leave class thinking that they understood everything, but when they get to the assignments they soon learn otherwise".*

If the purpose is to achieve the objectives of the engineering programs, the lecture classes are not enough. It is necessary to encourage active learning looking for the students to think by their own, asking questions about the things and situations around them, finding the solutions of problems and learning how to work in groups.

It is possible to use different methods where the students construct their own knowledge. One of the approaches is the Project Based Learning (PBL). According with Felder & Brent (2006), in some evaluations of PBL engineering programs it was found that "*students who participate in project-based learning are more motivated, demonstrate better communication and teamwork skills, and have a better understanding of issues of professional practice and how to apply their learning to realistic problems"*

In some courses of the Civil Engineering program at the Universidad Nacional de Colombia, especially in, the last semesters of the career, the students develop projects of application as the design of a steel structure roof, a pedestrian bridge or a building, in order to make the students analyse, apply, reinforced and finally understand the themes. Maybe, with this kind of projects, it is not possible to reach all the formation objectives but they help to be close. With the project, the students increase their capacity to work in groups, relate their environment with the projects they are working at, apply and integrate their knowledge in the project and develop competences to study by themselves. Besides, they get engage with their career. Not only in the Universidad Nacional, but also in other universities, the development of projects in last semesters is implemented (Gavin, K., 2011).

In contrast, most of the first semesters subjects are lectured and complemented with some students activities as classes exercises and homework without contemplating the development of a project. These

subjects are usually seen as courses needed to get the knowledge for other posteriors. Nevertheless, one of the ways of motivating first-years students could be introducing them to a Project-Based Learning and design thinking approach. The paper "Engineering Design Thinking, Teaching, and Learning" (Dym et al, 2005) mentions that "*first-year students can do reasonable conceptual design without the detailed technical knowledge they acquire only later in the curriculum*" and that cornerstone courses in the first year "*enhance student interest in engineering, enhance student retention in engineering programs*" and gives some examples where the retention rate improved with this practice as in the Universities of Alabama, Texas and Florida and the Gateway Coalition of Eight Schools (Columbia, Cooper Union, Drexel, NJIT, Ohio State, Polytechnic, South Carolina and USC).

Also, if it is pretended to participate in the formation of the integral engineers needed by the society, the entire curriculum, since the beginning, should be planned to get it. The education should be centred in the student, not in the teacher and focused in the process, not in the content (categories C and D of Fraser and Bosanquet, 2006). As Graaff & Kolmos (2014) wrote "*PBL is a very comprehensive system of organizing the content in new ways and students' collaborative learning, enabling them to achieve diverse sets of knowledge, skills, and competences. As already stated, there is an increasing demand for competences that goes beyond the technical field and reaches into process competences and integrative personal competences such as collaborative and creative knowledge processes. This means that education can no longer address only the cognitive part; it is necessary to think in broader terms".*

Having in mind the previous paragraphs, a PBL methodology was implemented in two groups of Statics courses in the third semester of a Civil and Agricultural Engineering program.

In this context, the following questions arises:

How do students describe their experience developing a project in an Statics course?

What was the perception of teachers who attended the socialization of the students projects?

How was the work in group?

This paper describes the experience of a practice of PBL approach in two Statics (Mechanics) courses, the methodology, the perceptions of the students and attendant teachers, results and conclusions of the practice.

2 Static subject

The Civil Engineering program offered by the Universidad Nacional has three Basic Components (Universidad Nacional [b], 2016):

Fundament, related with sciences subjects, where the engineer is enable to *"use the mathematical language of the methods of analysis to quantify the responses of structures and systems"* and "*construct his conceptualizations, his models and his theories for the complete understanding of the phenomena".*

Disciplinary professional, addressed to "*the applications on which knowledge of materials is based, and the prediction of their behaviour as an integral part of a civil construction, when are subjected to the forces produced by the loads they will be exposed. The subjects of this component also deal with the methods of analysis, design procedures and technologies of construction*"

Free electives component, related to human and economic sciences and *"those subjects that help to obtain a vision of the context in which the engineer carries out his work"*, looking for the understanding of the role of the Civil Engineering in the society.

Static is a third semester disciplinary professional subject, and has as prerequisite subjects: lineal algebra and physics. In this semester, the students start to take disciplinary professional subjects, and statics is one of them. It is pretended with this course that the student, through his learning process, could: establish the conditions of static equilibrium of the elements and structural systems under external loads; calculate the internal actions of a rigid body and the reactions of the supports; and study the geometric properties of the cross sections of the structural elements. Usually, there are near 30 students per course most of them from the Civil Engineering Program and few from Agricultural Engineering Program. Statics is one of the most important subjects because the students start to learn the disciplinary subjects in both careers and also because the acquired knowledge in this course is basic for other subjects not only of the structures area, also of the hydraulics and geotechnical fields.

3 Experience of a project in the course of static

In two courses of statics, the students worked in a course project in groups of 2 or 3.

The objectives of this practice of PBL were:

- To increase the students motivation in the subject
- To improve the students capacity to apply static knowledge in real life.
- To develop skills for autonomous learning
- To enhance the team work skills

3.1 Goals and methodology

The project was established in the first month of the course of four months. In the project they had to apply their acquired knowledge in the course, framed in a general project. The students defined the kind of building, structure or construction related with the general project.

The students had to contextualize the general project. One of the aims of the course project was that the students could achieve more knowledge related with the general project but behind this, increase their initiative, their research capacity, their self study, the skills for work in groups and their engagement with the society and environment.

The students had to look for applications of the themes learnt in the course. Then, they had to enunciate an exercise of each theme and solve it. With these activities they could see the connexion between the real life and the course, but also, they were building their own knowledge formulating an exercise of static, asking questions and finally solving it.

At the end of the course they presented their projects to the rest of the class.

3.2 Evaluation of the project

In order to promote the self-regulation and the peer evaluation, the course project had four grades: The first one, named "Auto-evaluation" corresponded to the evaluation that each student did to his/her own work. The second, "co-evaluation inside each group", corresponded to the grade that each student

assigned to each member of his/her group. The third, "evaluation of all projects", is the grade that each student thinks that corresponds to each project presented. The last one was the evaluation of the teacher. The percentages corresponding to each component was agreed between all. The first two qualifications are more related with the work and participation of each member of the group and the last two grades also included the content and quality of the project in general, the final report, and the presentation. At the beginning of the presentations the different aspects to be evaluated and guidelines to evaluate were mentioned.

3.3 Description of the projects

Although at the beginning the groups were supposed to be of three members, the 50% of the projects were developed by groups of two members.

The general projects selected by the groups were different according with their interest. There were social housing, community library, stables, fitness centre, cellars, materials deposits, bamboo bridge, sport centre, greenhouses, suspension bridge, construction development projects, equine exhibition hall, barns among others. Also it could be said that these were closed to the interest of at least one student. For examplethe community centre for the town where he lives, the milk production centre for the farm of her parents and the bridge in a rural area of the town where he comes from.

Besides the visible objective of the project, that was the reinforcement of the knowledge of the themes learnt in class, some groups wrote down other objectives related with the solution of the necessity of the community, the importance of the environment, the solution of engineering's problems and the application of the knowledge toward the evaluation and creation of projects.

Most of the groups presented localization plans, figures and diagrams, building plans and some groups also showed render and videos of the general project made with Sketch Up.

In each project the groups identified how to apply the static knowledge. Framed in the general project, the groups enunciate and solve different exercises of equilibrium in particles and rigid bodies, centroids, inertia, analysis of trusses, cables, beams and frames and diagrams of shear and moment.

3.4 Perception of the students about the activity

The students were asked to write down their commentaries about the activity in the same format where they grade the auto-evaluation, co-evaluation and evaluation of the groups. In this first attempt of application, there was no survey only a blank space for open opinions. In this section some of these opinions are presented, they were selected because they represent different aspects about the learning process. Not all opinions are posed because in some cases several students' commentaries convey the same basic idea.

The students were made aware that what they write about the activity would not affect the qualification of the project and the subject. 28 of 64 students in total (44%) wrote their thoughts and perceptions of the results of the realization of this kind of project. All the commentaries about the results were positive although for some students (according with their commentaries) the activity was not clear enough at the beginning.

In the commentaries of the students it is possible to perceive the following advantages of the realization of the project:

- They increased their self-confidence about their capacities, "*My classmates surprised me by their ingenious, and I also surprised myself"* (Students, 2016)
- They perceived that they have better understanding of the themes, *"Through the final project for this subject, it was possible to put into practice and assimilate in a better way all the concepts learnt in class…"* (Students, 2016)
- They noticed the necessity to integrate different knowledge areas, *"The project was very interesting and encouraging, since we could not only better understand and apply the issues seen in class, but also we had to devise, investigate and learn many other areas that would greatly influence our training"*. (Students, 2016)
- They realized about the advantages of this type of learning "*Indeed I learned and consolidated better the concepts of static through this project. I believe that learning from projects is something that forms us a lot ..."* (Students, 2016)

And also, they thought further in the curriculum *"… I think it is extremely important that this kind of activity be repeated in this and all other subjects, because it is through practice and application, that the importance of what is learned, is finally understood..."* (Students, 2016), "*It should be promoted not only in all static courses, also in the other disciplinary subjects of each curriculum. It helps to see in a more tangible and clear way, how to apply all the issues seen"* (Students, 2016).

Considering that it was the first time that the students followed and also the supervisor applied this learning methodology, initially the students felt confused *"At the beginning of the semester I did not see clearly the final project"* (Students, 2016); for that reason some of them recommended some guidelines and specifications of the project "*I must say that at first we were confused, or rather, we were not clear what should be done in this project. Therefore, despite achieving the objective, I want to recommend to the teacher for the next courses, to provide a document with the guidelines and specifications of the project".* (Students, 2016).

3.5 Peer evaluation

Some colleagues of the Faculty assisted to the presentation of the Static course projects. They went to different sessions of presentations and saw different projects. Some commentaries received by the colleagues show that the activity allowed students to:

- Integrate knowledge learned in the course with applied problems of real life, *"In general, observed projects motivate students to identify problems in which they must perform static calculations"*, *"It is a very interesting experience for students because it helps to reduce the gap between theoretical concepts and the concepts needed in the work environment", "There are different cases of application of structures in the project with their associated calculations"* and *"Integration of all acquired knowledge or problems of society".* (Professors, 2016).
- Increase their motivation and enhance the understanding, "*when working with real cases, students are motivated and have a better understanding of concepts, and it is evident in the security with which they spoke", "It is also interesting that the project makes them examine some topics not considered in the basic content of the course, thus motivating them to give a context of real applications to the content they are learning"* and *"During the development of the exhibitions students are interested and ask several questions".* (Professors, 2016).

But also some of them observed that in some cases there were division of labours, *"In some presentations it was noticed that there was no good teamwork. Each member of the group was in charge of doing a part of the calculations and in the end each one exposed his part".* (Professors, 2016).

4 Results

With the realization of the project, some results were observed in the students, in their skills and in the acquired knowledge.

Related with the students themselves, the project enhances their self-confidence, motivation and their social and environment responsibility as engineers.

With respect to their skills, the development of the project strengthened their autonomous learning: they interviewed owners, professionals and people in general; read papers and codes; and learnt how to use software that they did not know before. Also they improved their communicative skills and it is reflected in the way and the security that they did the presentation. However is necessary to work more on the group work skills. Some of the groups were conformed by only two students and also, in some groups it was seen the division of labours of the members of the group.

About the knowledge, the students could integrate the themes learned in the course with applied problems of real life.

Thinking in the implementation of the activity, in order to avoid the students' confusions and misunderstandings, it is important to define the goals and scopes of the project clearly and give some guidelines. The auto-evaluation and co-evaluation methodology was assertive because, in general terms, it was possible to see which member of the group worked more and who worked less. Also the grades assigned by the students to the projects coincided approximately with the supervisor's grades.

Related with the PBL approach, some students identified the positive aspects of PBL in the course and some of them also recognized the advantages of the implementation of PBL in the curriculum. Besides, some students and peers identified the necessity of interdisciplinary work to manage global projects.

5 Conclusions

Notwithstanding that it was an experience of only one semester, the application of the PBL approach shows positives results in the learning process of the students as the enhancement of competences skills as the autonomous and communicative learning. Apparently, it also reduces the gap between the concepts learnt in the academy and the necessities of the external world and gives raise to deeper learning. Moreover, the development of the projects improved the motivation and self-confidence of the students. In this way, most of the proposed outcomes of this activity were reached.

In spite of the advantages mentioned in the former paragraph, there is still one proposed outcome that has not been reached yet: enhance the teamwork skills. Thus, it is important to carry out some studies that analyse the possible interventions to improve this aspect and the effectiveness of them.

In order to conclude if the implementation of this active learning approach improves the students achievement levels and enhances their competences skills, it is recommended to perform quantitative and qualitative researches. This paper only presents some qualitative results of the application of a project in two Static courses, but the preliminary observed results show that the response to this type of learning approach could be positive.

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Experiencias en aprendizaje basado en proyectos de un curso integrado en ingeniería

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Abstract

Son muchos los autores y organizaciones que ven con preocupación la formación de los ingenieros, teniendo en cuenta las necesidades de la ingeniería del siglo XX, los ingenieros deben ser técnicamente competentes, globalmente sofisticados, culturalmente conscientes, innovadores, emprendedores, despiertos, flexibles y móviles. El modelo lineal de currículo, común en escuelas de ingeniería, no permite satisfacer estos requerimientos haciendo necesario nuevos enfoques y paradigmas en la educación en ingeniería. Varios autores han llegado a la conclusión que se requiere un modelo de currículo en red con un enfoque holístico desde la educación para la sustentabilidad abordando las necesidades sociales en términos culturales, ambientales, económicos, legales y políticos, basado en la integración de las ciencias naturales, la tecnología y las ciencias sociales, orientadas a la práctica profesional.

El Aprendizaje Basado en Proyectos (ABP) se reconoce como una iniciativa que involucra el trabajo en equipo, reactivando los conocimientos previos, fomentando el trabajo colaborativo y permitiendo la adquisición de competencias. El curso Taller de Proyectos Interdisciplinarios de la Facultad de Ingeniería de la Universidad Nacional de Colombia, con un enfoque de ABP, es una iniciativa curricular que pretende solventar entre otras, las dificultades de los egresados de la Facultad de Ingeniería al momento de enfrentarse a circunstancias profesionales donde deben interactuar con otras ramas del saber, poniendo en función las habilidades adquiridas en torno a un objetivo común. El curso tiene 350 estudiantes de las carreras de ingeniería, diseño industrial y de medicina, con alrededor de 25 profesores que desarrollan 50 proyectos que, en el marco de la formulación y ejecución proyectos, buscan lasolución de problemas específicos. Son diversas las experiencias y conocimientos que ha proporcionado este curso, como por ejemplo el reconocimiento del conocimiento local, por lo que se hace interesante revisar sus resultados y conclusiones, y cómo éstos aportan en la formación de los nuevos ingenieros.

En el presente artículo se muestran los principales resultados de la experiencia, en algunas de las diferentes dimensiones que interactúan con el curso y la percepción de algunos de los clientes de dichos proyectos, contrastándolos con los requerimientos de la formación en la ingeniería actual.

Keywords: Aprendizaje Basado en Proyectos, Diseño Curricular, Educación para la Sustentabilidad

Type of contribution: best practice paper.

1 La educación en ingeniería

Internet, aceleró las relaciones entre los países, las instituciones, las empresas, los grupos y la gente. Con su poder de interacción, mediado por su disponibilidad en todas partes del mundo, con muy pocas excepciones, brinda la oportunidad de un intercambio cercano de información, de entendimiento de

algunos problemas de las diferentes culturas y de conocimiento de varios temas. Volvió nuestro mundo un mundo interdependiente. Lo que sucede en cualquier lugar del mundo nos afecta en mayor o menor grado. Las ideas, los productos y los servicios, se volvieron ubicuos, superaron las barreras de razas, etnias, países, lenguas y culturas. Es el comercio el que ahora se enseñorea por el mundo ofreciendo productos y servicios con las tecnologías más avanzadas en una competencia sin precedentes, en muchos casos amparado por el poder económico y militar de los países.

Esto ha llevado a que nuestro tiempo, nuestra cultura, nuestra civilización, se definen por el vertiginoso desarrollo tecnológico, que está cambiando nuestras vidas de la misma vertiginosa manera. Lo importante aquí, es que son los ingenieros quienes están en el centro de ese crecimiento, son loshacedores de la cultura y de los cambios en nuestra forma de vida. Evidentemente enmarcados dentrode la estricta disciplina de los negocios y de sus beneficios económicos. A pesar de esto, son losingenieros quienes diseñan y construyen la mayoría de los bienes y servicios de los que nos beneficiamos. De esta manera, es la ingeniería la profesión central de nuestra civilización.

Hoy en día la ingeniería no es una profesión local, cerrada, con problemas completamente definidos, eminentemente técnica. Se volvió una profesión abierta, interactuante con diversidad de disciplinas y profesiones y culturas, para llegar a la definición de un problema dentro de un contexto, planteardiversas alternativas, hacer la escogencia de la mejor y llegar a su solución apropiada; ahora es una profesión social. Esta es la definición de las Naciones Unidas de esta profesión:

“La ingeniería es el campo, disciplina, práctica, profesión y arte que está relacionada con el desarrollado, adquisición y aplicación de conocimiento técnico, científico y matemático para la comprensión, diseño, desarrollo, invención, innovación y uso de materiales, máquinas estructuras, sistemas y procesos para propósitos específicos “ (United Nations, 2010 p. 24).

Analicemos un poco la definición con el fin de tener una mayor claridad sobre esta. Según Duderstadt (2008) la ingeniería:

1. Es una disciplina (como la física o las matemáticas), que posiblemente tiene su lugar entre las “artes liberales”, que caracterizan la sociedad del siglo XXI controlada por la tecnología.
2. Profesión, que aborda tanto las necesidades urgentes como los grandes retos que encara nuestra sociedad.
3. Con una base de conocimiento: que apoya la innovación, el emprendimiento y la creación de valor en una economía del conocimiento.

De manera que de acuerdo con Sheppard, Colby, Macatangay, y Sullivan (2006), el trabajo de ingeniería se enfoca en solucionar una condición indeseable a través de la aplicación de tecnologías. Las tecnologías involucradas pueden estar bien establecidas, nacientes, o como ahora no imaginadas. Por lo tanto, una actividad central (sino la central), del trabajo en ingeniería es la solución de problemas.

Y continua Sheppard et. al. (2006) la actividad central del trabajo en ingeniería es la solución de problemas. Implícito en este enunciado es que la intencionalidad del trabajo de ingeniería es afectar el cambio en el mundo, modificando procesos, procedimientos o introduciendo nuevos productos., tecnologías o conocimiento. Estos cambios constituyen la solución.

Con respecto a la intencionalidad del trabajo de ingeniería, los propósitos específicos, nos lleva directamente a la tecnología. Los métodos y aparatos productos de la tecnología siempre tienen un

propósito; se innovan, se inventan, se producen con un propósito específico, como solución concreta que produce la ingeniería.

Veamos un par de características de la tecnología: todas tienen un propósito y todas utilizan uno, o generalmente más fenómenos naturales, encapsulados para sus propósitos específicos. El hecho de utilizar los fenómenos naturales para producir tecnologías es lo que obliga a que en la ingeniería seestudie de manera detallada, laboriosa y dedicada las ciencias naturales, tomando un subconjunto de estos temas para aprenderlos y utilizarlos en una especialidad de la ingeniería (Arthur, 2009).

Pero la práctica de la ingeniería no es simplemente un proceso de solución de problemas a través de conocimiento especializado, requiere otros procesos y conocimientos para llegar a la tecnología. La ingeniería es compleja, es una integración pensada e intencional de estos conocimientos para un fin significativo. Por ejemplo, cuando se generan soluciones candidatas para un problema determinado, los ingenieros buscan experiencias relacionadas a las situaciones en estudio para encontrar conocimiento que se sabe que es útil.

Entonces podemos ver un producto tecnológico, la solución, como un dispositivo o un proceso, como una estructura en la que internamente está lo central que maneja el fenómeno encapsulado que usamos, rodeado de una serie de restricciones y ajustes, además de situaciones contextuales. Figura 1.

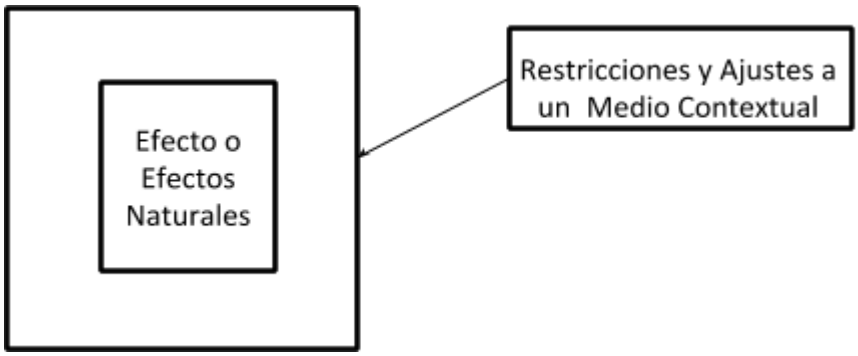

Figura 1. Estructura general de una tecnología, producto final de un proceso de ingeniería, para la solución de un problema.

Para la parte central utilizamos el conocimiento científico, matemático y de ciencias de la ingeniería, que nos permite llegar a la solución analítica. Rodeada de un conocimiento del contexto donde se va a usar esa tecnología, que le permite realmente ser la solución, una solución "social".Otra forma de ver la estructura anterior, es examinar el conocimiento que utiliza en la captura del fenómeno o fenómenos físicos y en el análisis de las restricciones y ajustes al medio contextual:

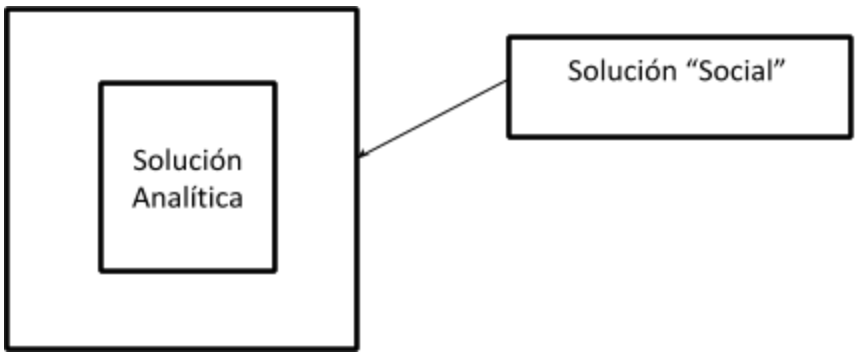

Figura 2. Conocimientos requeridos: modelos analíticos, modelos físicos, ciencias naturales, matemáticas. Solución "social": Conocimientos y destrezas en comunicación, ética, medio ambiente, cultura, instituciones, etc.

Otra forma de ver la estructura anterior, es examinar el conocimiento que se utiliza en la captura del fenómeno o fenómenos físicos y en el análisis de las restricciones y ajustes al medio contextual. Dentro de la solución analítica se encuentran: las ciencias naturales, las matemáticas, las ciencias de la ingeniería, los modelos físicos, los modelos de simulación. Con respecto al conocimiento social se encuentran: habilidades de comunicación, colaboración, ética, sostenibilidad, historia y otros.

Sin embargo, en los currículos de formación de los ingenieros, esta relación entre lo "hard" y los "soft", como se presenta en algunas discusiones, la mayor parte del currículo está dedicada a la parte "hard", dejando lo "soft", como cursos inconexos de humanidades, muy bajos en número. En la gráfica 3, se presenta el porcentaje de estos dos tipos de cursos de diversos currículos vigentes en Ingeniería Eléctrica. Los datos se tomaron de las páginas de las universidades que se muestran abajo, del currículo de Ingeniería Eléctrica.

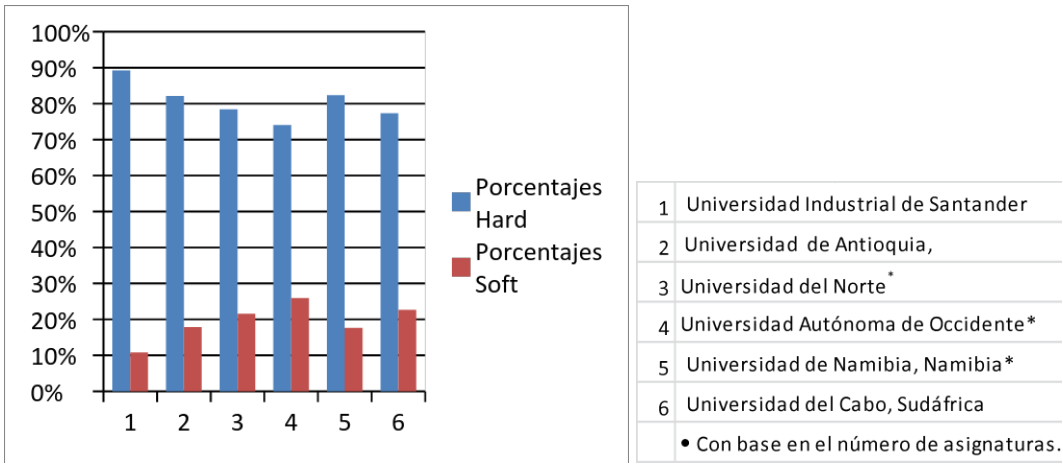

Figura 3. Relación de cursos "soft" y "Hard", programas de Ingeniería Eléctrica de diferentes universidades.

De lo anterior se puede observar que los programas actuales de formación de ingenieros no son suficientes para satisfacer los requerimientos actuales de formación y se deben buscar alternativas. Una de las alternativas que más se ha trabajado es el Aprendizaje Basado en Problemas y Proyectos.

2 Aprendizaje Basado en Problemas y Proyectos

El Aprendizaje Basado en Problemas (PBL) es una de las estrategias de aprendizaje utilizadas paraintegrar el desarrollo sostenible y para abordar los desafíos de la educación en ingeniería. En PBL, elproceso de aprendizaje comienza con el análisis y la formulación de un problema, a partir de escenarios de problemas reales y mal estructurados. PBL se basa en principios de aprendizaje tales como el aprendizaje contextual, autodirigido, experiencial y colaborativo. Estos principios permiten a los estudiantes desarrollar habilidades de razonamiento alto (por ejemplo, conocimiento metacognitivo), pensamiento crítico, conocimiento interdisciplinario, habilidades de resolución de problemas y habilidades de comunicación (Guerra, 2014). El PBL permite el desarrollo de habilidades como la creatividad (Porto 2008). De la misma forma, Guerra (2014) afirma que el PBL también es interdisciplinario, y relaciona la teoría con la práctica. Mediante el uso de problemas reales, los límites disciplinarios se borrosa que permite a los estudiantes a desarrollar conocimientos de varias disciplinas.

De Graaff & Ravesteijn (2001) sostienen que los aspectos no técnicos de la educación deben tenerse en cuenta en la educación superior, en particular, aspectos relacionados con:

- Responsabilidad social (por ejemplo, ética, sostenibilidad)
- Habilidades sociales (por ejemplo, comunicación, colaboración)
- Humanidades y ciencias sociales (por ejemplo, historia, psicología, etc.)

El aprendizaje basado en proyectos y en problemas requiere que el estudiante desarrolle competencias, entendidas como el resultado de procesos evaluativos que miden conocimientos, habilidades y actitudes (Villardón, 2006).

De modo tal, el PBL puede apoyar la integración de la educación para el desarrollo sustentable en la educación de ingeniería mediante: fomentar el pensamiento sistémico y la colaboración interdisciplinaria, fomentar un enfoque transformador holístico de resolución de problemas, mejorar las relaciones entre la teoría y la práctica para el desarrollo sustentable (Guerra 2014).

3 El Taller de Proyectos Interdisciplinarios de la Universidad Nacional de Colombia

La asignatura de Taller de Proyectos Interdisciplinarios TPI, nace desde el año 2008 con el propósito de desarrollar las habilidades de trabajo en equipo, comunicación a los estudiantes de la facultad de ingeniería de la universidad Nacional de Colombia mediante el trabajo interdisciplinar alrededor de un proyecto. Se ofrece en los últimos semestres de los nueve programas de la facultad (industrial, sistemas, mecánica, mecatrónica, civil, agrícola, química, eléctrica, electrónica). Inicialmente los grupos se conformaban para apoyar el desarrollo de proyectos establecidos en los grupos de investigación o en propuestas externas a la universidad provenientes de algunas empresas, docentes o personas interesadas en solucionar algún problema. Los estudiantes se conforman en grupos de 6 a 8 integrantes alrededor del proyecto seleccionado, reuniéndose los días lunes con los profesores y los miércoles en sesiones plenarias donde reciben charlas sobre temas de interés en tecnología, desarrollo de proyectos, innovación, entre otros. En promedio la asignatura ha tenido por semestre 350 estudiantes de ingenieríay 22 profesores que acompañan grupos de 14 a 20 estudiantes.

Evolución. Durante los dos últimos años la asignatura ha pasado por varios cambios: 1) Participa la

facultad de diseño industrial y la de medicina permitiendo mayor interdisciplinariedad en el desarrollo del proyecto. 2) Las ideas de proyecto son propuestas por los estudiantes en un 80% y un 20% provienen de empresas. 3) Se han incorporado otros programas de la universidad: Programa de Lectura y Escritura Académica LEA para apoyar las habilidades comunicativas; Programa de innovación UNINNOVA para fomentar la cultura innovadora; Programa de emprendimiento de base tecnológica de la facultad innovaTE para fomentar el espíritu emprendedor 4) Se ha realizado convenio con la Cámara de Comercio de Bogotá CCB para el fomento del desarrollo del emprendimiento y la creación de empresa. 5) Se han conformado redes de apoyo empresariales para el desarrollo de conferencias en temas de ingeniería, espíritu emprendedor y temas de tecnología. 6) Se ha consolidado un syllabus que determina cuatro fases de desarrollo basado en las buenas prácticas de proyectos del Project Management Institute PMI y el aprendizaje basado en proyectos ABP. 7) Se han desarrollado rúbricas para el proceso de evaluación que consideran el trabajo en equipo, las habilidades comunicativas escritas y orales y la formulación del proyecto 8) Se consideran modalidades de proyectos: emprendimiento, innovación, consultoría, investigación.

3.1 La experiencia en resumen.

Atendiendo los lineamientos dados en el syllabus, está conformada por cuatro fases:

3.1.1 Fase de ambientación. Duración dos semanas

Días lunes: Los estudiantes preparan una exposición sobre una idea de proyecto que proponen a sus compañeros para conformar los grupos de trabajo. Dentro de las áreas o temas para seleccionar el problema a seleccionar se encuentran: agroindustria, ingeniería y organizaciones, ambiental, energías, cultura y sociedad, salud y bienestar y salud. Durante la primera sesión se presentan alrededor de 280 ideas y se seleccionan 50 proyectos para el semestre.

Días miércoles. En sesiones presenciales se conforman los grupos de trabajo en donde deben estar tres ingenierías diferentes y un diseñador como mínimo, escogen además el profesor mentor que los guiará durante el semestre y reciben una charla sobre los objetivos y características generales de la asignatura.

3.1.2 Fase de inspiración. Duración cuatro semanas

Días lunes: mediante reuniones con los profesores mentores se propende por el conocimiento del equipo y sus cualidades, desde un comienzo desarrollan roles de trabajo que se rotan entre el equipo para fomentar el trabajo en equipo. Se incentiva el proceso creativo mediante el pensamiento divergente con herramientas basadas en design thinking, permitiendo con ello la profundización en la problemática consultando actores, expertos, estudios previos y el fundamento teórico de la problemática. Lo anterior encaminado a reconocer visiones interdisciplinarias fomentar el desarrollo de habilidades blandas como el trabajo en equipo, la comunicación y la negociación, así como la argumentación de la problemática basada en las visiones interdisciplinares.

Los días miércoles se ofrecen charlas que permiten la reflexión para abordar la problemática : ética en los proyectos, habilidades escritas (LEA), trabajo en equipo e innovación (UNINNOVA), tipos de proyectos (UNINOVA, CCB y emprendedores invitados).

3.1.3 Fase de formulación y desarrollo. Duración ocho semanas

Días lunes: el mentor guía el trabajo para fomentar y el pensamiento estratégico y táctico para permitir el desarrollo de la alternativa de solución del proyecto, se incorporan metodologías de la ingeniería al realizar los estudios que justifican el proyecto (estudio técnico, organizacional, legal, ambiental, riesgos y financiero), se construye el prototipo en los talleres de la universidad y el equipo presenta los resultados

de forma escrita mediante un informe.

Días miércoles: se presenta una triple oferta donde los estudiantes seleccionan a su gusto la charla que más les convenga para el desarrollo de su proyecto. Una oferta está a cargo de la CCB donde desarrolla talleres de emprendimiento, otra a cargo de UNINNOVA para el desarrollo de la cultura de innovación y una tercera a cargo del programa LEA para el desarrollo de las habilidades escritas. Luego de la triple oferta que dura tres semanas se hace una sesión general por parte de LEA con los resultados de la revisión de los trabajos escritos para preparar la entrega final. Durante las cuatro semanas siguientes se desarrolla el prototipo en los talleres de la universidad y los aliados CCB, UNINNOVA y LEA ofrecen espacios de consulta en sus áreas de experiencia.

3.1.4 Fase de presentación. Dos semanas

Días lunes: el profesor mentor evalúa los resultados finales evidenciado las habilidades orales y escritas en la presentación de resultados, seleccionan los mejores equipos para escoger los mejores proyectos del semestre, lo que permite desarrollar la capacidad de argumentar el proyecto y los resultados obtenidos.

Días miércoles. Se presentan los proyectos para evaluar el potencial de emprendimiento, permitiendo que estos continúen en la etapa de desarrollo del emprendimiento con la CCB que dura un año adicional. Se realiza la presentación final donde se entregan reconocimientos al espíritu emprendedor y a la innovación.

En cada una de las fases se realiza la evaluación respectiva mediante la aplicación de rúbricas que son conocidas por parte de los estudiantes desde el comienzo del semestre.

La comunicación entre los estudiantes, los docentes y el grupo de coordinación y el proceso de evaluación se realiza mediante la plataforma moodle, en donde semanalmente se publican noticias de interés y se proponen foros de discusión para los profesores mentores.

El grupo administrados está conformado por un coordinador general y uno auxiliar, un pedagogo que aporta en el desarrollo y mejora de las rúbricas, un ingeniero que apoya la plataforma moodle y tres monitores que apoyan la logística.

El grupo de los veinte profesores mentores se dividen en pequeños grupos que se reúnen de manera autónoma para reflexionar sobre la acción pedagógica, compartiendo experiencias y metodologías y aportando a enriquecer el syllabus la guía de trabajo y las rúbricas de evaluación.

4 Resultados

Se aplicó un cuestionario al final de la asignatura obteniendo 137 respuestas y los siguientes resultados:

En la etapa de preparación e inspiración se formularon preguntas para evaluar el aporte del profesor mentor obteniendo los siguientes resultados. (Cómo valora el aporte del profesor mentor en cuanto a…), con opciones de respuesta, bajo, medio, alto, muy alto. Los resultados obtenidos se muestran en la siguiente figura:

Metodología para abordar el problema	76,7%
Compromiso para atender solicitudes de estudiantes	84,1%
Aporte metodológico para desarrollar el proyecto	82,4%
Cumplimiento de horario los días lunes	94,8%
Cumplimiento de horario los días miércoles	84,8%
Evaluación con base en rúbricas	63%
Motivación para el trabajo	67,5%
Relacionar temas de charlas de miércoles con el desarrollo del proyecto	40,8%

Figura 4. Relación del aporte del profesor mentor en la etapa de preparación e inspiración.

Traduce lo anterior que para las opciones Alto y muy Alto el porcentaje positivo en cinco de los ocho aspectos evaluados es superior al 84%, destacando el cumplimiento del horario los días lunes y los aportes metodológicos para abordar el problema, desarrollar el proyecto y atender las solicitudes de los estudiantes. Sin embargo, encontramos situaciones de mejora en varios aspectos: en la evaluación con las rúbricas pues se encontró que algunos profesores no las utilizan, igualmente la desmotivación es un aspecto que se encontró en grupos de algunos docentes, sobre la falta de relacionar las charlas de los días miércoles con el proyecto la causa principal es la inasistencia por parte de algunos de los docentes en tales días.

Cabe señalar que por parte del coordinador de la materia, estos resultados fueron entregados a cada docente, buscando con ello generar mejora continua en el proceso pedagógico.

En relación con la triple oferta ofrecida por los aliados de TPI, los resultados a la pregunta cómo valora el aporte para el desarrollo de TPI de la charla (Bajo, medio, ni bajo ni alto, alto muy alto), las respuestas obtenidas son las siguientes:

TALLER CCB	NOTA
Entrénate para aprender	87,1%
Design Thinking	78,3%
Modelo de negocio	86,3%
Financiero y financiamiento	86,1%
Legal y trámites	89,7%

TALLER UNINNOVA	NOTA
TECNOLOGÍAS EXPONENCIALES	79,6%
DESIGN DE EXPERIENCIAS	92,3%
INNOVACIÓN SOCIAL	86,9%
USABILIDAD	93,5%
METODOLOGÍAS ÁGILES	88,0%
GRUPOS PITCH	88,7%

Figura 5. Valoración del desempeño de los aliados

Es decir la oferta relacionada con el desarrollo del espíritu emprendedor por parte de la CCB y la cultura de innovación de UNINNOVA tienen una percepción entre alta y muy alta superior al 80%, salvo las charlas de design thinking y tecnologías exponenciales.

Sobre el impacto de TPI

A la pregunta: Con relación al desarrollo de la asignatura TPI (se listan las cinco variables) con opciones: totalmente de acuerdo, de acuerdo, Ni de acuerdo no en desacuerdo, en desacuerdo, totalmente en desacuerdo. Los resultados obtenidos son los siguientes:

	Totalmente de acuerdo	De acuerdo	Ni de acuerdo Ni en desac	En desacuerdo	Totalmente en desacuerdo
Se promueve el trabajo interdisciplinar	24	38	21	11	6
Se promueve el trabajo en equipo	23	46	21	6	4
Se promueven habilidades comunicativas tanto orales como escritas	16	40	26	13	5
Desarrolla aptitudes como la innovación y el espíritu emprendedor	19	39	22	13	6
Aporta a mi desarrollo profesional	16	40	23	11	10

%

Figura 6. Respuestas con relación al desarrollo de la signatura.

Lo anterior muestra que el desarrollo de la materia promueve el trabajo interdisciplinar y el trabajo en equipo para un 62% y 69% (Totalmente de acuerdo y de acuerdo) y en un 59% para el desarrollo de aptitudes relacionadas con la innovación y emprendimiento y tan solo un 56% consideran aporte al desarrollo profesional.

Se resalta que de las cinco variables anteriores solo cerca del 20% como máximo, valoran que no hay impactos y otro tanto se encuentra en la línea neutra pues no están de acuerdo ni en desacuerdo. Indicando con ello una oportunidad de mejorar en estos aspectos mediante el trabajo coordinado.

Otra visión de los resultados obtenidos se consiguió al reunir las evaluaciones de las rúbricas realizadas a 30 proyectos, permitiendo obtener los resultados de las habilidades escritas, orales y el trabajo en equipo durante el desarrollo del semestre.

La rúbrica de evaluación del trabajo final nos permite apreciar los siguientes resultados:

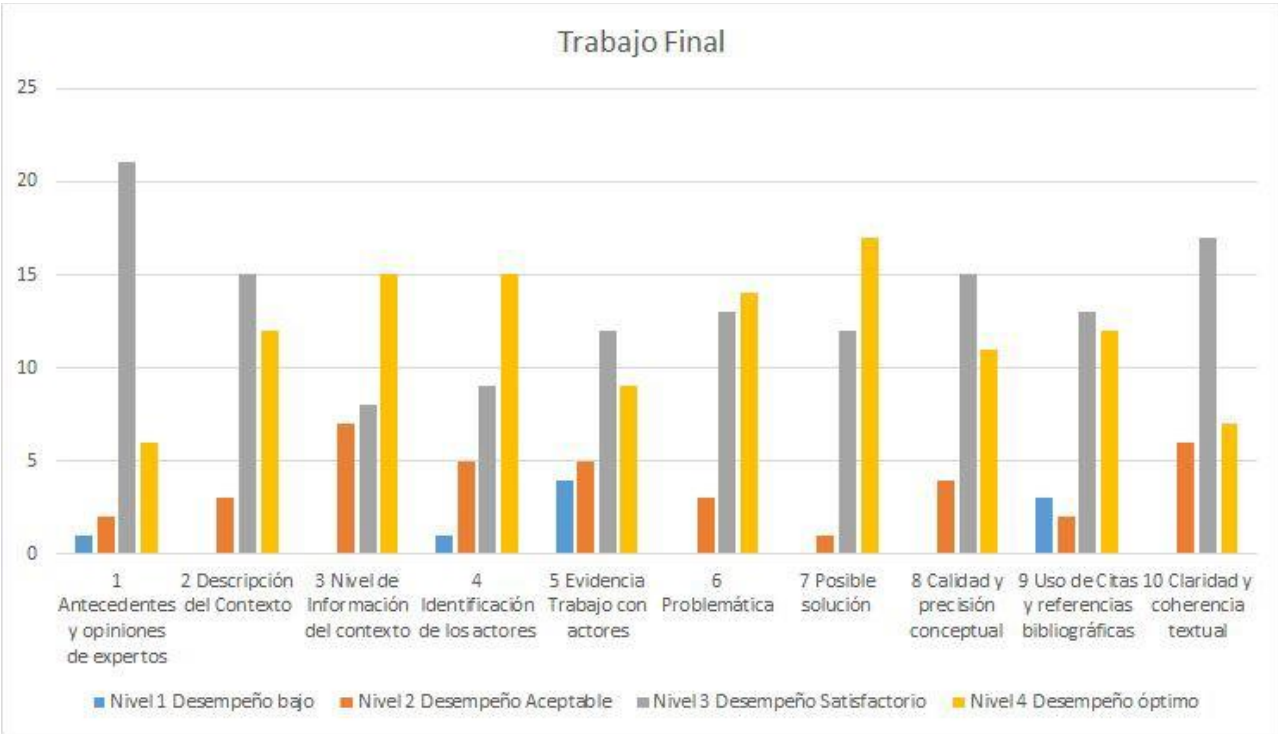

Figura 7. Resultados de la evaluación del trabajo final.

Puntúan con desempeño entre satisfactorio y óptimo con más del 90% cuatro de los diez (10) aspectos evaluados: el estudio de la problemática y la propuesta de la posible solución, la revisión de antecedentes y la descripción del contexto. Dos aspectos: el nivel de información del contexto y la evidencia de trabajo con los actores puntuaron entre el 70% y el 80% y los otro cuatro factores estuvieron entre el 80% y el 90%

En relación con las habilidades orales los resultados fueron superiores como lo muestra la gráfica siguiente:

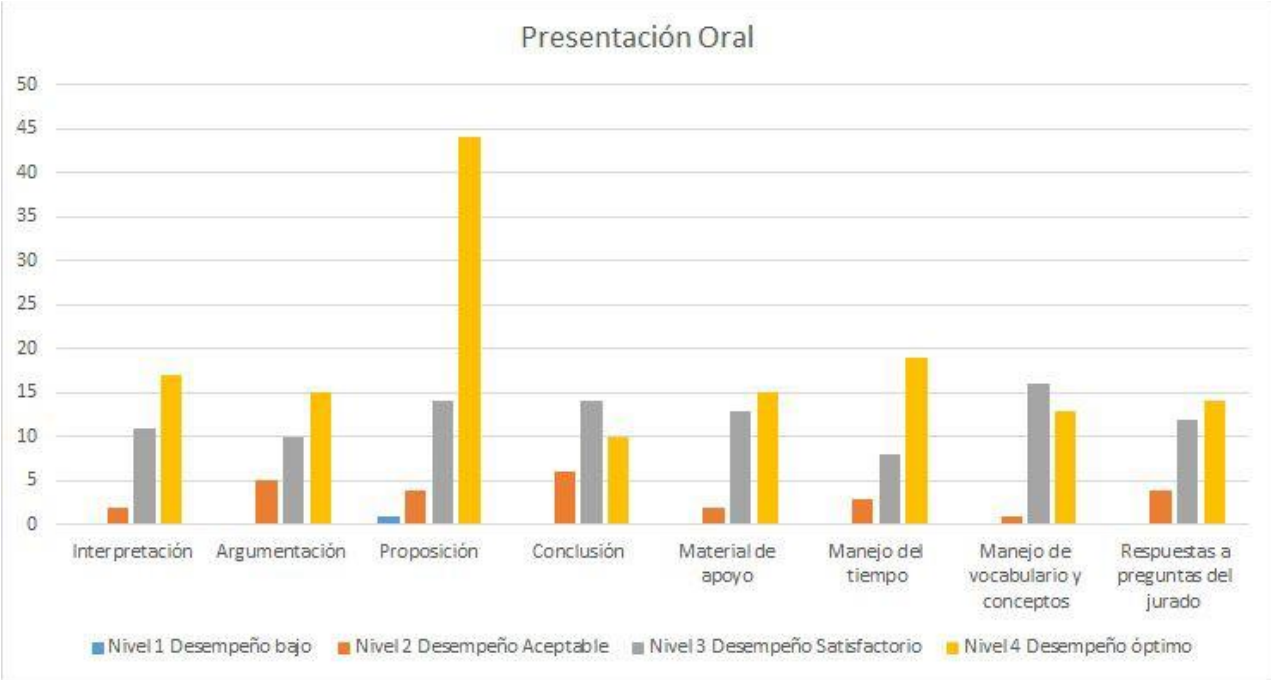

Figura 8. Resultados de la evaluación de las habilidades orales.

Puntúan entre el 90% y 100% con nivel de desempeño satisfactorio y óptimo los factores interpretación, proposición, material de apoyo, manejo del tiempo y manejo de vocabulario y conceptos. Los otros cinco factores puntuaron entre 80% y 90%.

En cuanto al trabajo en equipo, los resultados de la rúbrica realizada por heteroevaluación, los resultados obtenidos se muestran a continuación:

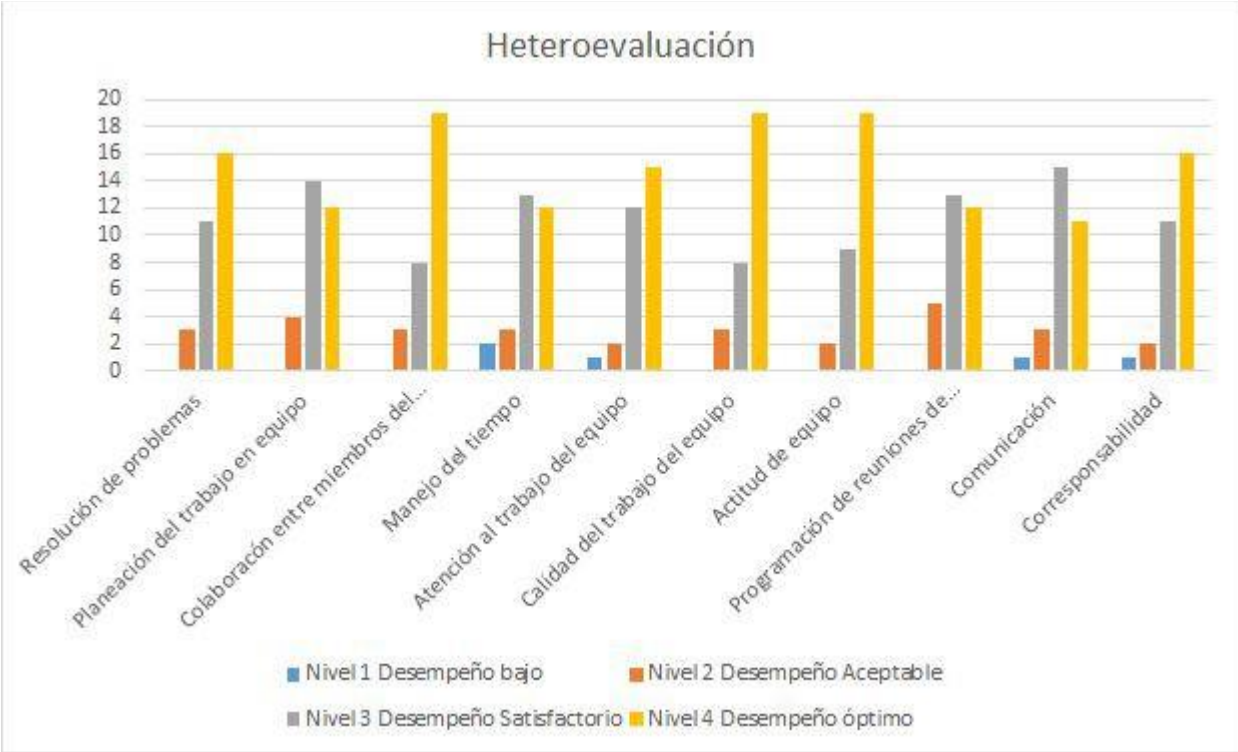

Figura 9. Resultados de la heteroevaluación relacionados con el trabajo en equipo.

Seis de los diez factores: resolución de problemas, colaboración entre miembros del equipo, atención al trabajo en equipo, calidad del trabajo en equipo y corresponsabilidad tuvieron resultan entre 90% y el 100% en niveles tres o cuatro. Los demás factores puntuaron entre 80% y 90% para los mismos niveles.

En cuanto al impacto en el desarrollo emprendedor, durante los dos últimos años se han obtenido cinco empresas que actualmente facturan y quince emprendimientos se encuentran recibiendo apoyo por parte de la Cámara de Comercio de Bogotá.

5 Conclusiones

La medición de los factores sobre el desarrollo de habilidades duras y blandas ha permitido un aprendizaje y mejora continua por parte de los docentes y grupo administrativo de TPI. Ha permitido la actualización del syllabus, la mejora de las rúbricas y de la guía de trabajo del docente y una reflexión permanente del acto pedagógico en pro de los objetivos.

La aplicación del PBL acarrea dificultades en un grupo tan grande, particularmente el manejo de una guía general de trabajo. los docentes muestran dificultades en el cambio de paradigma de ser los actores centrales a unos guías mentores para el desarrollo de las habilidades de los estudiantes.

La motivación de los actores externos para trabajar con una materia de características diferentes es muy alta, reconocen la importancia del trabajo interdiscipinar alrededor de los proyectos no solo para el desarrollo de las habilidades de los estudiantes sino para llevar el conocimimiento a aplicaciones concretas mediante soluciones en contextos reales.

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Bears in a Boat: A Problem-Based Enhanced-Language Learning Experience for Preservice Elementary Teacher Education

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Abstract

As a teachers college we resolved to prepare teachers to design and implement problem-based learning experiences in elementary grades. We also need to prepare our graduates to successfully work with students, who because of recently immigrated families, need more assistance with understanding and developing the language of instruction. In the US context, the language of instruction is English, and students developing this language—while simultaneously learning other content—are often referred to as English Language Learners (ELLs). We combine PBL and ELL methods into the Problem-Based Enhanced-Language Learning (PBELL) approach.

Bears in a Boat is a PBELL experience that helps learners develop an understanding of concepts related to floating and sinking. We have successfully taught this lesson with preservice elementary education students, second graders on the US-Mexico border, and in urban setting in Phoenix with a large population of third- grade ELLs. The science content outcomes are for students to be able to describe the difference between floating and sinking, to create a boat that can float, and to explain that the more weight in a boat the deeper it floats.

Embedded in the hands-on activity sequence are supports for learning including language enriching techniques such as realia manipulatives, sharing ideas, persuasion, sentence stems, and visuals. As a preservice teacher education experience, students have the opportunity to realize the potential of the approach for enhancing science engagement, content knowledge, academic language, problem-solving abilities, and social language. While the lesson uses English as the language of instruction, it could be a model for other world regions with learners who are working to develop mastery of the instructional language. The paper describes the PBELL approach and how the PBELL experience Bears in a Boat is conducted in a preservice elementary science methods class.

Keywords: science education, teacher education, elementary education, English Language Leaners, non- native language instruction

Type of contribution: best practice paper.

1 Introduction

Perhaps there are no better teaching moments than experiencing children, passionately talking and working together as they achieve important learning outcomes. Problem-based learning (PBL) can produce this environment. There is increased recognition of the importance of developing children's abilities to work together and solve problems. PBL leads with a problem for children to grapple with resulting in the development of inquiry skills, content knowledge, and problem-solving abilities. While these enhancements

are particularly important for English Language Learners (ELLs) (Wright 2015), all children benefit from greater opportunities to reflect and communicate as they develop abilities in and knowledge of science.

As a teachers college, we resolved to prepare teachers to design and implement problem-based learning experiences in elementary grades. We also need to prepare our graduates to successfully work with students, who because of recently immigrated families, need more assistance with understanding and developing the language of instruction. In the US context, the language of instruction is English, and students developing this language—while simultaneously learning other content—are often referred to as English Language Learners (ELLs). We combine PBL and ELL methods into the Problem-Based Enhanced-Language Learning (PBELL) approach. We are infusing the PBELL approach into our teacher education program (Figure 1). The science methods class contributes to the infusion by having the preservice teachers experience a PBELL lesson and later they design and implement a PBELL experience in their internship classrooms.

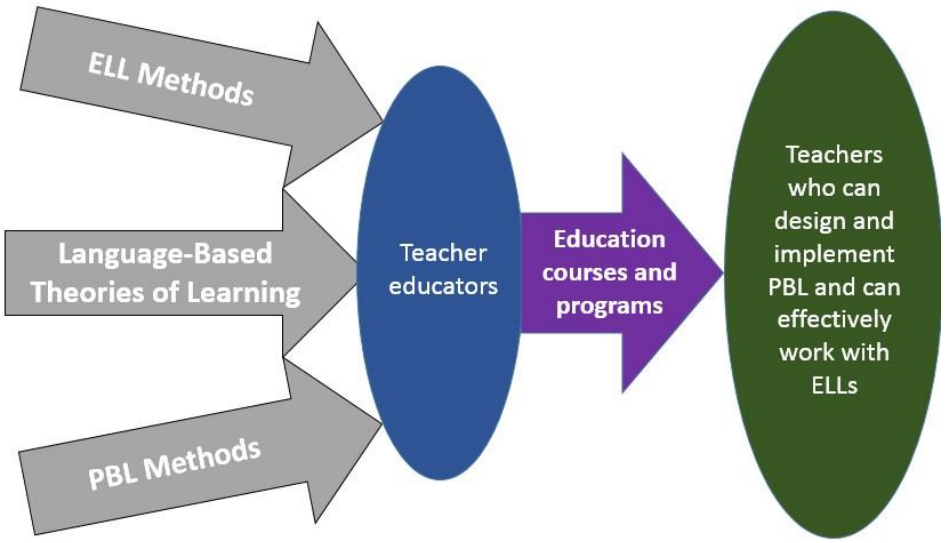

Figure 1. The framework for the PBELL project.

2 Problem-Based Enhanced Language Learning

PBL experiences infused with design elements to enhance language development can help all learners. PBL naturally presents opportunities for thinking, reading, writing, and discussing. By deepening these opportunities, PBL becomes an ally for the acquisition of content, the development of academic language, and enriching social language when working with language-minority learners. This approach can benefit all learners as they are both basic and needed skills. A recent study in elementary grades found the need for better oral and written language support in PBL (Nariman & Chrispeels, 2015).

We call our language-rich PBL approach Problem-Based Enhanced-Language Learning (PBELL). The paragraphs below are intended to be guides for the understanding, developing, and using PBELL. The framework for the approach are presented in Table 1.

Table 1. Components of Ideal PBELL Experiences

Component 1: Establish the problem
The problem is meaningful to students and related to a real-world experience. The problem is presented first, allows for a student centered experience, and guides the learning approach. The problem has multiple solutions.
Component 2: Solution Seeking
Lessons are structured to allow students to discuss, reject, modify, and propose potential solutions for a problem. Students gather knowledge to seek solutions through using manipulatives, experimenting, reading, writing, speaking and listening.
Component 3: Collaborative work
Students work collaboratively to grapple with and solve a problem. Students engage in reciprocal conversations and are encouraged to respond flexibly using multiple linguistic resources. Teachers use graphic, sensory, and interactive supports to enhance the experience (i.e. sentence stems, graphic organizers, purposeful pairing, etc.).
Component 4: Solution Sharing (definition of sharing-within groups in conversation applying academic language
Students share their solutions including: a description of the problem, methods they used and tested, and their evidence for why it's the best solution. Discipline specific language is explicitly taught and practiced (i.e. the language of argumentation in science). Solution sharing can happen periodically throughout the lesson and/or as a culminating activity.
Component 5: Evaluation
The experience has pre-identified content and language objectives and allows for multiple pre-planned assessment opportunities. Content knowledge is usually the highest priority, while students are also evaluated on selected factors such as their communication, collaboration, critical thinking, creativity, content learning, decision-making, inquiry skills, problem solving, reasoning, research skills, and teamwork. Additionally, students are evaluated on their language learning.

2.1 PBL in PBELL

There are several aspects of PBL that are fundamental to the PBELL approach. Learners grapple with an engaging, meaningful problem. The problem precedes instruction; learners work together and with materials to understand the problem and work toward a resolution. As such, student exploration occurs before explanation, which is consistent with learning cycles, such as those used in Science Curriculum Improvement Study (Atkins & Karplus, 1962) and the 5-E instructional model (Bybee, 2014). In the curriculum design, the focus is not merely on solving a problem but also developing mastery of academic standards and academic language. Embedded content supports maximize the learning potential of the experience.

2.2 ELL Methods in PBELL

PBELL seeks to amplify the natural role of language in learning. Content is made more comprehensible with planned activities for students to develop and practice academic language. Each experience has a content-language objective that addresses a specific language function—ways we use language for various formal and informal purposes. Language functions include argumentation, compare and contrast, and persuasion. For example, if we were focusing on the language function of compare and contrast in our lesson, we could use supports such as Venn Diagrams to visually represent similarities and differences. The most effective language function of PBELL are generalizable; once students learn the language of comparing and contrasting, for example, they can extend this concept to other topics and subjects.

The operational vocabulary of an experience refers to words that not all learners will know. It is important to pre-teach these words as needed. Conceptual vocabulary is developed during the experience and in the discussions after the experience. Language supports include sentence starters or stems as prompts to provide the initial direction to the writer. An important goal of PBELL is for language to become a vehicle instead of a barrier to leaning academic content.

3 Bears in a Boat as a Model PBELL Experience

Our team of science educators and ELL specialists developed the Bears on a Boat lesson to become a powerful PBELL experience. The evolution of the activity can be traced back to the classic clay boats activity of the Elementary Science Studies (1969), which evolved into foil boats (Science and Technology for Children, 1995), and was later, transposed by mathematics educators into Bears in a Boat (Rubillo, 2012). Our courses are for adult preservice teachers, however, we wanted to field test the experience in elementary classrooms with significant numbers of ELLs. Thus, we taught the PBELL lesson in a third grade classroom in a USA/Mexico border town in southwestern Arizona where the majority of the students are ELLs. Given the heavy emphasis on English language development for ELLs in a number of states including, Arizona, many of the students had limited exposure to science instruction and the classroom teacher agreed that this was a suitable lesson for her students (Jimenez-Silva, Gomez, & Cisneros, 2014). This paper describes the language-enriched Bears on a Boat problem-based learning experience for preservice elementary teachers.

4 Goals of the Experience

Although we are presenting this experience to preservice teachers, we model the experience. Thus, when we conduct this experience we make it very similar to how we would teach it to second or third graders with ELLs in the classroom. The learner outcomes for the lesson are show in figure 1. As learners develop the ideas of floating and sinking, as they observe that the more weight added to a boat the deeper if floats, they are developing intuitive understandings for later concepts of weight, mass, volume, density, relative density, buoyancy, and Archimedes Principle. The design, building, and testing of their boats also gives engineering experiences to be built upon. With a focus on supporting ELLs in the PBL experience, we also considered the language students would need to access the content and developed the following language function for the lesson: Students will explain the concepts of floating and sinking by using a word bank, small group discussions, sentence frames, a demonstration, and visuals.

LEARNER OUTCOMES

I can

- Describe the difference between floating and sinking
- Create a boat that can float
- Explain that the more weight in a boat the deeper it floats

Figure 2. Learner Outcomes for the experience.

5 Implementing the Experience

In the science methods class implementation, the preservice teachers are told they are second graders and within the class are ELLs. Before the lesson starts, the words bears, boats, and aluminum foil are reviewed with pictures of each. This models the practice of introducing operational vocabulary before the lesson begins to make sure learners have opportunities to fully engage. The learning model, however, is that most of the discussion happens after (rather than before) the experience. A short story creates the context for two bears that need to get across a lake by creating a foil boat.

Students are shown two small plastic counting bears and an 8 cm by 8 cm square of aluminum foil. They are asked to write the problem in their own words in their notebooks. Then they are asked to draw a possible design of the boat. The following sentence stem is provided: "I think my boat will sink/float because…" as a writing prompt. With a partner they compare diagrams and their statements, and then choose one boat to build. Each small group, composed of two dyads, was given a tub of water and two bears to test their boats' abilities to allow two bears to float. They test their boat in water with two bears, they then write their results with another sentence prompt: "I think my boat sank/floated because…". In the discussion, the words sink and float are reinforced. Whether with children or adults, about half of the boat trials sink. As students share their writings to the prompt a word wall is created to capture the emerging vocabulary.

A similar pattern occurs on day two of the PBELL experience but this time learners build a boat for eight bears with 10 cm by 10 cm foil. Again they worked in pairs, first drawing their boats, this time with prompts to draw it from above and from the side, and then writing why they thought their boat would float. They then discuss their designs and choose the best boat to build and test. Sometimes there are audible gasps when this eight-bear boat is introduced and in the most recent implementation, one student suggested that I am setting them up for failure. In reality, however, almost all of the boats float in this second round.

Again each small group had a tub of water with eight bears. As they test their boats, adding two bears at a time, they are asked to notice what happens as more and more bears are added. This important concept—adding more weight, causes the boat to float deeper into the water—is also reinforced with a demonstration. As learners progress through the PBL experience, they engage in discussions, make decisions, analyze results, and write. The experience promotes problem solving abilities, language acquisition, and deep-conceptual learning. Learners deepen their understanding of floating and sinking and begin to develop the concept that will later be important in understanding buoyancy, Archimedes' principle, and force diagrams: The more weight that is added to the boat, the deeper it floats. As

instructors, we had to modify our language for clarity. It felt natural to say that for a floating boat more weight caused it to sink deeper. This however seemed confusing as the boat is not sinking as we had discussed earlier—so we were intentional in using the term "floats deeper."

After students tested their boats, the final problem of the PBELL experience is revealed. Students have to predict which boat in their small group would hold the most bears. The nominated student's boat would be entered into a classroom competition, with one boat representing their group. The group only had eight bears to test their boats so they have to extrapolate beyond their observations to make their prediction. They then created a team name. The room became more energized as the competition began.

An NBA pregame situation was created with the room lights turned off, flashlights moving like spotlights, and the song Syrius (The Alan Parsons Project) playing. Students cheered as their team representative said their group name. Students were directed to add two bears at a time to their boats. Students had previously tested their boats with eight bears but in the competition, there was still excitement as each boat hit the eight bear mark. Then the suspense intensified as bears were added beyond the eight. One-by-one, boats sank under their load until one boat remained with students celebrating.

6 Processing the Experience

The experience was designed to have preservice teachers experience a science PBELL experience as learners—in this case as second grade children. After the experience, the students now returned to their preservice teacher selves. The following questions guided the class discussion: What was the role of PBL in the experience? How was the use of language encouraged? Why would the experience be appropriate for ELLs? What was the science content of the experience? After the discussion, it was explained that the preservice teachers would be developing and implementing their own PBELL experiences in their internship classrooms.

7 Conclusions

The increasing number of diverse language, ability, and culture learners in classrooms offers us the opportunity and presents the need to prepare teachers to design and implement PBL in K-8 classrooms. PBELL is an instructional model that combines PBL with ELL methods to enhance the use and development of language. Bears in a Boat is part of a broad changing of our teacher education program to infuse PBELL throughout. Aspects of this model may be considered for use in schools in worldwide contexts with recent language-minority immigrants.

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Student's perceptions towards a PBL-based strategy for the development of skills in the ninth grade within an educational institution of Cundinamarca

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Abstract

The project-based learning (PBL) is considered a teaching-learning methodology of inductive nature in which the students generate learning processes through the formulation and development of projects. Considering the elements of this methodology, a PBL-based didactic strategy was designed to foster the development of soft skills and language, science and mathematics competences in ninth grade students. The strategy includes phases of problem formulation, assessment of solution alternatives, design of the solution, development or implementation, and socialization. A set of activities and resources are proposed during these phases to foster basic and soft skills (self-regulation, creativity, teamwork and management).

The strengths and weaknesses related to the didactic strategy proposed were identified with a pilot implementation, which was developed during two months with ninth grade students of an educational institution of Cundinamarca (Colombia). The planning and execution of the strategy counted with the accompaniment of the pedagogical team that participated in the design of the didactic strategy.

After concluding the implementation of the strategy, certain questionnaires and focus groups were applied to students in order to know their perceptions towards the strategy developed. The instruments used inquired about aspects related to the suitability, affectivity and functionality of the strategy in terms of resources, learning methodology and management. According to the results, the students' perception towards the development of the strategy is positive in general, since they consider that it is a useful methodology to achieve learning goals. On the other hand, there is a less favorable perception towards the didactic resources that support the development of the strategy. This latter can be considered as an aspect to be evaluated in order to improve the proposed strategy.

Keywords: PBL, didactic strategy, high school education, students' perceptions, soft skills.

Type of contribution: best practice paper.

1 Introduction

Today's dynamics and requirements make us rethink education and find new ways to understand the learning process in order to teach civilians how to perform well in a globalized world, to use competences to deal with problems and propose creative solutions within their own context. To do so, it is important to have certain scenarios in schools, where the student could play an active role in the learning process and learn how to apply knowledge related to science, language and mathematics to solve problems. However, using the theoretical concepts provided by different disciplines is not enough to learn how to solve a

problem in a creative manner; the students must develop other skills like self-regulation, creativity, management and teamwork, also known as soft skills.

The methodologies and approaches that seek to transform the passive role of the student into an active role, focused on their own learning process, emerged with the rise of constructivism. Among these approaches, PBL emerged as a methodological proposal for the student to actively participate in knowledge-building, by engaging in a research dynamic within the framework of the development of a project that is based on their own interests and realities, which privileges teamwork, interdisciplinarity and skills development.

PBL is a far more demanding methodology than the traditional methodology, since it requires more time in the planning phase. However, it has more benefits: students incorporate learning more successfully and it stays longer, motivation towards learning gets improved, it allows to construct an interdisciplinary understanding of the subjects of study, and it takes place within scenarios in which the students not only learn contents, but also learn how to use them (Imaz, 2015). Despite the benefits of PBL, in the public educational institutions of Colombia the integration into the curriculum is uncommon, and in this respect, most of the studies refer to projects in specific areas where there is no evidence of integration between different disciplines.

Within the context of Colombian education, the factors that hinder the development of strategies with interdisciplinary projects include the lack of time for planning, the lack of spaces for interdisciplinary debates and the inherent difficulty in articulating contents from different subjects into the same project. These difficulties can be overcome if the teachers receive accompaniment during the design and development phases, or by providing them with the opportunity to implement structured interdisciplinary projects that can be adapted to the context, the student interests and the school reality.

Through the second proposal, the teachers would not need to invest time designing and planning the interdisciplinary project and could take advantage of the benefits of PBL with respect to the students learning. In this regard, a didactic strategy was designed with the purpose of strengthening the development of skills in science, language and mathematics – in articulation with soft skills – in ninth grade students. This strategy was implemented during an academic term in a rural school of Colombia. In order to know the perception of the students with respect to the strategy, a set of research instruments were applied during the implementation and the results are presented in this article.

The article is structured on four sections. The first one, literature review, frames the theoretical references with regard to Project Based Learning and soft skills; the second, methodology, describes the main characteristics of the didactic strategy, the population and the research instruments. The third section shows the results of the instruments, the main findings and the analysis of the students' perception with respect to the strategy. The last section presents the conclusions and some recommendations for further research.

2 Literature Review

2.1 Project based learning

Project Based Learning (PBL) is an inductive learning methodology, where students involve in different activities that lead them to build their own knowledge (Prince & Felder, 2006). Its main characteristic is that it endeavors to guide the students through a process of collaborative work that leads to achieving a common goal. This characteristic allows the student to assume a role within a working team, to contribute

with knowledge, skills and competencies in order to perform joint tasks that lead to the project success (Rodriguez, Vargas, & Luna, 2012). This element is very important, since it provides the student with spaces where they cannot only interact with concepts and knowledges, but also strengthen their skills.

PBL frames within the constructivist paradigm and is characterized by the active role of the student in their own learning, while the teacher plays a guiding role, creating and designing scenarios so that learning occurs. As a result, the teacher guides the student tasks, selects relevant information, encourages the student to use processes of metacognitive reflection to achieve learning, diagnoses problems, feeds back and evaluates the process (Rodriguez, Vargas, & Luna, 2012).

PBL focuses on developing an interdisciplinary project based on a guiding question. The project has to specify learning goals, activities, didactic resources, assessment processes, schedule and the integration of the project into the school context. During the development of the project, the students not only strengthen their skills in the knowledge areas involved, but also learn how to apply those knowledges and develop their problem-solving skills. Additionally, the project is the perfect scenario to develop soft skills, because during the execution the students learn teamwork-related skills, based on differences, and they become more creative and develop skills to plan and manage the activities (Imaz, 2015).

According to Imas (2015), PBL offers several benefits for the learning process: a better incorporation of learning and a greater persistence; better connection between previous knowledge and the knowledge acquired during the project; integration between different disciplines; and better grades in institutional or state exams in comparison to groups without any relation to PBL. Additionally, PBL is the perfect scenario for the student to apply their knowledge of different disciplines, in other words, is the perfect scenario for "know-how".

2.2 Students perceptions towards PBL

PBL was first used in the late twentieth century in the European and North American universities; therefore, it has a greater experience in universities than in middle and high school. It is in universities that most of the studies have been conducted with regard to the students' perception towards this methodology.

For example, in 2010 a study was conducted using a questionnaire in order to know the perception of the Food Engineering students of the Universidad Jorge Tadeo Lozano, with respect to the pedagogical strategy based on PBL "class project", used in several theoretical-practical classes. The results of the questionnaire show that the students consider the number of projects for each semester should be maximum 2, because a higher number would limit the time dedicated to the project and would discouraged them for not finding the solution to all the problems that may arise. When they were asked about the level of learning achieved after developing the project and applying the knowledge learned in class, most of the students considered they learned well and very well (Sandoval, Solano, & Luna, 2010).

In 2015, Imaz published the results of a study about PBL. It was implemented since 2010 in Sociology Education class, in the Faculty of Philosophy and Educational Sciences of the Universidad del País Vasco, with the purpose of knowing the relevance of the strategy and the students' perceptions. For the first purpose, the grades of the groups before 2010 – that did not used the PBL strategy – and the grades of the groups that participated in the strategy were compared. For the second purpose, a survey was applied to the students. The results show that the grades improved significantly when PBL integrated with the subject, and the students claim to have learned more rather than with other traditional methodologies, because they correlated better theory and practice. However, they considered there was too much work to be able to develop the project properly. Among the recommendations, it is advised to structure well the project

before working with freshmen students. Last semester or postgraduate students instead, determine the epistemological and methodological routes. On the other hand, a dense student population by course may implicate the difficulty in detecting individual contributions within group dynamics. For this reason, and in these particular scenarios, co-evaluation may be important. Finally, this study mentions that the main problems arise from the lack of experience of the students in teamwork (Imaz, 2015).

2.3 Soft skills

The concept *soft skills* refers to a set of skills related to personal and interpersonal attributes that are crucial for succeeding in life, especially in work environments (Stevenson & Starkweather, 2010; Robles, 2012). Recent studies demonstrated that this set of skills (also known as social-emotional or non-cognitive) have a direct influence on learning, personal development and social participation, becoming a determinant factor to achieve personal fulfillment (Heckman & Kautz, 2012; Gibb, 2014). Communication, resilience, creativity, self-regulation, teamwork and management are some examples of soft skills. The soft skills selected to develop the project are:

- Creativity: Even though there are many definitions for creativity, most definitions converge to define creativity as: "*the human capacity to produce new and valuable ideas; it is an ability held by all persons, that can be developed through training and can adopt, among other things, an artistic, literary or scientific form when it is implemented*" (Jimenez, Hernández, Rodríguez, & García, 2007, pág. 13). Creativity integrates different skills such as creative fluency, originality and flexibility. Creative fluency refers to the ability to generate a significant amount of ideas or alternatives in a specific time frame within a specific context; originality is the ability to provide fresh, different and unique ideas or that are separated from normality or conventionality; and finally, flexibility is the ability to respond to a changing situation or to use different action criteria (Jimenez, Hernández, Rodríguez, & García, 2007, pág. 12).
- Self-regulation: Self-regulation is defined as "*how a person exerts control over his or her own responses so as to pursue goals and live up to standards"* (Peterson & Seligman, 2004, pág. 500). Self-regulation exists, for example, in skills like motivation by achievement and perseverance. The first refers to the tendency to perform well in situations implying that the subject himself or third parties compete with a rule or standard of excellence, being evaluated in terms of success or failure (Lepper, Henderlong, & Iyengar, 2005); the second refers to the ability to respond to a situation in which the possibility of being rewarded is low or null, once a contingency relation has been previously acquired (Peterson & Seligman, 2004, pág. 232)
- Teamwork: The individuals perform a joint task through teamwork in order to achieve a common goal. To work as a team, it is necessary to develop skills such as: conflicts resolution, the ability to make agreements that improve the way a situation meets the expectations of different parties involved; positive influence, the ability to produce a desired positive effect in the behavior or thought of others; and effective participation or co-responsibility, the ability to assume and fulfill responsibilities, roles or tasks in a group situation (Stevenson & Starkweather, 2010).
- Management: The management skill refers to the ability held by the individuals to achieve goals or objectives through an organized and systematic process. This skill is made explicit when planning a sequence of actions or ideas that enable the achievement of the proposed goals; and when assessing and monitoring to evaluate the efficiency and effectiveness around a task before finishing (Peterson & Seligman, 2004).

3 Materials and methodology

3.1 Didactic strategy

The didactic strategy framed within the context of PBL, through the development of the project "Guardianes del agua", aimed at strengthening the skills associated to science, language and mathematics, in articulation with soft skills (creativity, self-regulation, conflicts resolution and management). The project, of an interdisciplinary nature, set the scene for the students to gain a deeper understanding of concepts related to biomarkers and environmental impact based on science; statistical analysis based on mathematics; and argumentative skills and texts production based on language.

The project was implemented for six weeks and it was structured on five phases: problem definition, assessment of possible solutions, design of the solution, development and implementation, and socialization. The guiding question was how can I contribute to water conservation in my community? In addition, the purpose was to design and implement a proposal for the water conservation in the community, developing activities related to science, language, mathematics and soft skills. Some co-teaching exercises were carried out during the development of the project, in which the teachers shared the responsibility for the group.

A set of resources were designed and developed to support the implementation of the strategy: handbooks for teachers and students; digital educational resources (DER) to strengthen scientific, linguistic and mathematical skills and soft skills; and a platform to manage the project, contents and resources related to each project phase. The platform was developed in an offline version to facilitate its use in case of restrictions in terms of Internet access.

3.2 Population

The didactic strategy was applied to the ninth grade students of Institución Educativa Departamental Bagazal, a rural school located in the municipality of Villeta in the state of Cundinamarca, Colombia. The group was formed by 27 students (18 girls and 9 boys) aged between 12 and 15 years. The areas of mathematics, science, language, technology and entrepreneurship participated during the implementation of the strategy.

3.3 Instruments

Two instruments were applied to identify the students' perceptions with regard to the strategy: a close-ended questions survey and a focus group.

The survey grouped 25 items that measured through a Likert scale the perceptions about the methodology, resources and learning goals proposed within the project. These categories were evaluated considering the suitability, affectivity and functionality. Suitability allows determining whether the strategy is useful for the context and for the institution requirements. Functionality allows identifying whether the performance of the strategy components match with the purpose for which they are intended. Finally, the affectivity reports the feelings and emotions triggered by the strategy. After analyzing the answers in the questionnaire, a focus group was held with six students to deepen the findings from the first instrument.

4 Results

4.1 Perception survey

To analyze the students' perceptions about the didactic strategy, the answers collected through the perception questionnaire were codified. Each level of the Likert scale was translated into a numerical scale ranging between 1 and 5, in which 1 means "strongly disagree" and 5 "strongly agree". In order to identify the general perceptions about the formulated items, a simple average was calculated for each item considering the answers codified in the numerical scale. The results are shown in the Table 1 below.

Table 1: Items average – perception survey.

Item	Average
I enjoy learning contents from the subjects involved through projects.	4.16
I think PBL is an appropriate methodology for the context and the educational institution requirements.	4.08
The student handbooks include the contents and activities required to perform the class.	4.12
It is important to develop skills related to self-regulation, teamwork, management and creativity through the project.	4.21
I like the resources from "Contenidos para aprender" and the ones related to soft skills.	4.08
The spaces for autonomous work (individual), collaborative work (with other classmates) and tutoring (with teacher) allow me to participate actively in the project development.	4.12
The proposed platform adapts to the characteristics of the educational institution and to my learning requirements within the framework of the project development.	4.16
I think now I am more aware of my learning process.	4.32
The participation of different teachers motivates to develop the project.	4.40
The platform facilitates the development of activities related to the project (visualizing handbooks and resources; interactive activities; evaluations).	3.88
The spaces for autonomous work (individual), collaborative work (with other classmates) and tutoring (with teacher) are in accordance with the project and class requirements.	3.88
PBL allows us to develop skills in mathematics, language and science.	4.28
I like that the strategy involves activities that allow me to reflect on "why" and "for what" learning.	4.12
The project allows me to develop skills related to self-regulation, teamwork, management and creativity.	4.42
I enjoy using the student handbook during class.	4.36
I consider that what I have learned through the project is in accordance with the topics from the subjects involved (language, science, mathematics, etc.).	4.20
The resources from "Contenidos para aprender" and the ones related to soft skills are in accordance with my learning requirements within the framework of the project proposed.	4.17
I like the PBL methodology for classes.	4.12
It is important to involve different areas or subjects during the project development.	4.04
The resources from "Contenidos para aprender" and the ones related to soft	3.88

skills are working well and they have no failures.	
I feel comfortable performing activities of autonomous work (individual), collaborative work (with other classmates) and tutoring (with teacher) during the project development.	4.08
I enjoy using the platform to develop activities related to the project.	3.83
The student handbooks are appropriate for the project proposed.	4.21
The learning goals proposed for the areas involved (mathematics, science, language, etc.) can be achieved by developing the project.	4.32
I am thrilled to develop skills related to self-regulation, teamwork, management and creativity through the project.	4.08

According to the answers, developing the interdisciplinary project enabled the students to develop soft skills (average 4.42) and achieve the learning goals in mathematics, language and science (average 4.32). PBL enabled them to strengthen skills in the areas involved (average 4.28), they liked the methodology in class (average 4.04), they considered it appropriate for the context and their requirements (average 4.08), and they enjoyed learning mathematics, science and language through this methodology (average 4.16).

The students perceived co-teaching exercises and interdisciplinarity positively, as can be observed in the following items: "The participation of different teachers motivates to develop the project" had an average of 4.40 and they thought it was important to involve other areas or subjects during the project development (average 4.04). Additionally, the students reported that the proposed strategy favored metacognition, since the item "*I think now I am more aware of my learning process*" had a score of 4.32; and the item "*I like that the strategy involves activities that allow me to reflect on 'why' and 'for what' learning*" had a score of 4.12 in average.

With regard to soft skills, the students considered it was important to perform activities related to self-regulation, teamwork, management and creativity through the project (average 4.21), and they were motivated to develop those skills through the strategy proposed (average 4.08).

The didactic resources used during the strategy development were well-evaluated in terms of suitability and affectivity, but not in functionality. The students recognized they enjoyed working with the handbooks in class (average 4.36), they also liked DERs, and considered them as elements that facilitated their learning process (average 4.08); although the perception towards functionality was not that positive (average 3.88). Regarding the platform, its usage was restricted because of some failures in the intranet capacity of the institution. This factor could have influence on the low positive perception towards the platform functionality, which presented an average score of 3.83., and the item related to the perception of the platform as a tool that facilitated performing the activities related to the project (visualizing handbooks and resources; interactive activities; evaluations) had an average of 3.88.

Another item with a low score (compared to the others items evaluated on the survey) refers to the suitability of autonomous work (individual), collaborative work (with other classmates) and tutoring (with teacher) during the project execution, which had a score of 3.88. This low score may be the result of the conflicts that arose while working in teams, because the students had to work with people they have never worked with.

After considering the results of each item, the percentage of positive perceptions about the defined dimensions (suitability, affectivity and functionality) can be analyzed for each category (methodology, resources and learning goals). This percentage was calculated as the proportion of positive perceptions

(items scored between 4 and 5) towards the items that belong to each category. The results are shown in the Table 2 below.

Table 2: Percentage of positive perceptions according to the categories proposed

Factor	Percentage of positive perception
Methodology – Suitability	72%
Methodology - Affectivity	84%
Methodology – Functionality	84%
Resources – Suitability	72%
Resources – Affectivity	76%
Resources – Functionality	64%
Learning Goals – Suitability	72%
Learning Goals – Affectivity	84%
Learning Goals – Functionality	84%

These results suggest that the students had a general positive perception in relation to suitability, functionality and predilection for the methodology, the resources and learning goals. However, only 64% of the surveyed had a positive perception with regard to the resources functionality, which is the lowest value within all the percentages. As mentioned above, this perception could be influenced by the failures in the intranet network. Likewise, the scores related to the suitability of the methodology, the learning goals and resources have a lower percentage of positive perception in comparison to other categories. In contrast to these results, 84% of participants considered they liked the methodology and it functioned properly. Similarly, they consider the strategy allowed them to reach the learning goals proposed, which is evidenced in the percentage of positive perceptions towards functionality and affectivity within the learning goals category.

4.2 Focus group of students

In order to deepen the results obtained in the survey about perception, a focus group with students was conducted at the end of the implementation of the strategy. This focus group inquired about the strengths and weaknesses of the strategy with respect to three categories pre-defined in the questionnaire: methodology, resources and learning goals.

In relation to the methodology, the students emphasized that working as a team while developing the project was a positive factor, although they did not have the opportunity to choose their group. On the other hand, the students also identified flaws associated to team working, for example, not everyone worked in the same way during the activities. Additionally, they remarked that it was difficult to set a meeting to plan or perform the tasks related to the project, because not everyone lived in the same area. Hence, the students suggest they would like to choose their colleagues the next time the strategy is implemented.

The students also reported that the strategy constituted a scenario for changing the routine. They consider that the working methodology was innovative in comparison to the way they were learning, since they never worked based on projects. They also highlighted the interest generated about this new methodology

due to the articulation of different classes around the same topic. The following comment from a student provides evidence of this insight:

> *"Well, the five classes, the five subject we were working on… we started working on the water project, so each class had its own collaborative… point of view towards the same topic; let's say that mathematics was useful to make calculations... [Umm] technology to advertise the campaigns... [Umm] biology to test the samples and other stuff."* Perception of a ninth grade student.

As regards the didactic resources used in the strategy, the students emphasized that they enabled a faster learning and a better understanding of topics through the contents that involved fun animated characters and explanatory situations that matched their reality. The following comment from a student provides evidence of some of these elements:

> *"It was fun, I mean, at the beginning I thought it was very fun and you could learn easier watching the characters, and then I focused more on the explanations and I understood better… [Ok]... and then you had to read, I mean… the text appeared and they read it, but I think reading is boring, it is better to listen… [Ok]."* Perception of a ninth grade student.

Despite the positive perception towards the methodology and resources evidenced on the focus group (particularly in relation to the affectivity dimension), regarding the functionality of the platform, the students mentioned that it was impossible to perform the activities individually, so they had to work always using the DERs in group.

In general, the students were pleased with the project and the PBL methodology, but they also emphasized on the lack of time to perform all the activities proposed. Upon enquiry about their willingness to conduct another project, they did not propose anything other than "Guardianes del Agua" and they would like to continue working around the same topic. The only new idea provided by the students was related to the scope of the project. They considered that the campaign has to impact beyond the educational institution, thereby having a greater participation from the community and analyzing the problems of different water resources in the municipality.

5 Discussion and conclusions

According to the results of the focus group and the survey applicated to identify the students' perceptions towards the didactic strategy proposed, *affectivity* –a factor related to the feelings and emotions triggered by the strategy-, was the dimension with the highest percentage of positive perception in the three categories proposed for the questionnaire: methodology, resources and learning goals. This was confirmed during the focus groups, when the students said they were motivated by the idea of working in projects that take them out of the routine, and they considered it as an aspect that favors their learning process. In this sense, as Blumenfeld, and others (1991) described, Project-Based Learning methodology increases motivation when specific problems are addressed in a contextualized way within the student reality; and improves satisfaction with learning, as claimed by Rodriguez, Vargas, & Luna (2012).

Another advantage of PBL is that the students play an active role in their own learning and it can create spaces for metacognitive reflection (Rodriguez, Vargas, & Luna, 2012). According to these considerations, the questionnaire results and the discussion within the focus group allow to affirm that the students

involved in the strategy implementation played an active role, even though they did not participate in the project formulation; they were aware of their own learning process, and they also found, by their own, the answers to "why" and "for what" learning.

The students' perceptions were positive too with respect to the interdisciplinary work. Throughout the project, the students understood the interdependencies, convergences and complexities between mathematics, science and language, so they understood the interdisciplinarity of the subject of study and acknowledged the contribution made by different areas to knowledge-building.

Furthermore, the students considered that working in groups brought benefits to the achievement of goals and it provided them with multiple interpersonal skills, such as learning how to work with people with whom they did not have affective relationships or a friendship, and in this same situation, learning how to solve conflicts. Developing the project allowed them to strengthen soft skills through action, and the didactic resources designed served their purpose. According to Heckman & Kautz (2012), this is how the development of soft skills becomes a determinant factor in personal development and participation in social groups.

Although it is necessary to improve the functionality of the didactic resources and the time management for the activities, the students' perception towards the strategy was positive in general. The methodology proposed was appropriate for the education community and it was innovative because it suggested a new way to learn. Even though the project was not the students' idea (in fact, the didactic strategy was designed by an interdisciplinary group of the Universidad Nacional), the students assumed an active role in their learning process through the didactic strategy. The project also encouraged metacognitive reflection, increased motivation to learn and allowed to pursue the objectives proposed for science, language and mathematics in articulation with soft skills.

In addition to the resources functionality as an aspect that needs improvement, the pilot test provided valuable information for the research group with respect to the development and implementation of the didactic strategy, transcending secondary education. First, the experience allowed evidencing the importance of providing the teachers with an accompaniment in the design and planning of PBL-based strategies, in particular when the teachers are not familiar with those kinds of methodologies. Second, it is important to design a holistic evaluative strategy that enable the evaluation from different dimensions (hetero-evaluation, self-evaluation and co-evaluation) and that count with all the processes and interactions that arise during the implementation of the PBL methodology. Finally, it is important to take into account the time agreed for the development of the activities of the project, so this variable will not become a stress factor affecting the students or teachers. It is worth noting that, in relation to this variable, the strategy has to be designed allowing sufficient time for each phase and activity of the project. In this sense, the results will be achieved within the proposed timeline and the students will be motivated to put into practice their knowledge by solving problems.

In order to face the new challenges of current education, it is important for the educational institutions to offer spaces of teacher education and reflection on new educational methodologies. Consequently, the teachers will be encourage to integrate strategies like PBL in their classrooms, so the students will play a more active role in their own learning process and use theoretical knowledge to solve problems within their context.

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Learning perception of engineering students derived from a PBL implementation in an undergraduate manufacturing processes course

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Abstract

This work reports on mechanical and mechatronics engineering students' learning perception derived from an ongoing PBL (project-based learning) implementation in an undergraduate engineering manufacturing processes course at Universidad Nacional de Colombia. The considered PBL approach is expected to contribute bridging the gap between academy and industry and is aimed students to attain a strong background and skills in materials science, design engineering, scientific communication and project management. Along the six semesters in which the PBL approach program has been implemented, 40 projects have been developed with an average of five students per project, allowing 210 participating students. Case study and survey research were designed and conducted as a part of the research methodology to evaluate the learners' perception of the implemented PBL approach. Deming´s PDCA cycle (Plan, Do, Check and Act) was also considered in this work to facilitate the management of the processes, improving the quality and effectiveness regarding product lifecycle management (PLM) of the manufacturing processes projects developed. According to the assessment of students´ perception, this initial PBL experience has shown to have a marked positive learning effect promoting the development of professional skills, demanding, in contrast, important time-consuming requirements to achieve the expected learning outcomes.

Keywords: Project-based learning, Manufacturing processes, Learning perception, PDCA cycle.

Type of contribution: best practice paper.

1 Introduction

Important efforts around the world involving key participants have been made expecting to bridge the gap between academy and industry in aspects of manufacturing and production, looking for a strengthening of higher education institutional capacity for professional education and the application of development and implementation strategies within the enterprises (Ashton et al, 2017). At the same time, to achieve other associated aspects of sustainability and competitiveness, contemporary manufacturing industry must be transformed permanently (Jovane, Westkämper and Williams, 2009). It is also subject to a dynamics requiring high levels of flexibility and an adequate capacity to interpret what is happening in its environment, as well as the ability to plan and carry out different manufacturing strategies (De Treville, Bendahan and Vanderhaeghe, 2007). To reach these objectives, the new knowledge acquired in research and development at all levels must be appropriated, including innovations in manufacturing engineering education (Rolstadås and Moseng, 2002).

On the last aspect, project-based learning (PBL) is a learning methodology used in many engineering learning contexts. From the second semester of 2016 In the Engineering School at Universidad Nacional de Colombia, a group of several engineering teachers has started a formal education (Master in PBL, Aalborg University) on the topic. This learning approach has begun to have positive effects in the training of engineering students within the Department of Mechanical and Mechatronics Engineering, some of which are reported in this work. From a conceptual point of view, the main characteristics of PBL are (Prince and Felder, 2006):

- Mainly major projects provide context for learning.
- The end product of a project-based assignment is typically a formal written and/or oral report.
- Probably increases motivation.
- Project-based learning is similar to problem-based learning in several respects, but a project typically has a broader scope and may encompass several problems.
- In project-based learning, the end product is the central focus of the assignment.
- The emphasis in project-based learning is on applying or integrating knowledge while that in problem-based learning is on acquiring it.
- Project-based learning is well suited to the capstone design course in engineering and to laboratory courses that are more than collections of cookbook experiments.

The Manufacturing Processes I course thought at the Mechanical and Mechatronics Engineering Department, Universidad Nacional de Colombia, Bogotá, is a theoretical-practical subject with 6 hours per week of class-laboratory and 9 hours of independent work per week. This course is intended for students in the sixth semester of mechanical and mechatronics engineering programmes. Students are usually 19-22 years-old and this is a core subject within the syllabus. The learning outcomes are focused on developing the skills needed to improve productivity, reduce costs, and ensure products and services that fulfill the engineering requirements in a manufacturing context. The specific content is about the related volumetric fabrication processes of metallic, ceramics and composite materials used in high-value sectors such as the automotive, aerospace, civil building, chemistry and petrochemistry (Universidad Nacional de Colombia, 2013a).

As mentioned earlier, nowadays the Engineering School wants to strengthen pedagogical innovation using the PBL (project-based learning) approach which has been implemented as one of the many others strategies supported by the University. One of these strategies was the research initiation program in engineering for undergraduate students (here RIPEUS), that was launched to promote research skills in the undergraduate students through their participation in disciplinary projects (Universidad Nacional de Colombia, 2013b). This program has provided the grant to support the projects carried out in the course as part of the ongoing PBL implementation. The grant program is national in the sense that it covers all the campuses of the University in Colombia and requires all applicants to adhere to the eligibility requirements and application guidelines according to the National Research Directorate of the University (Dirección Nacional de Investigaciones - Universidad Nacional de Colombia, 2015).

In this work, the PDCA (Plan, Do, Check and Act) cycle of Deming (Venkatraman, 2007, Rodrigues and dos Santos, 2016) was applied as a framework to facilitate the management of processes within the PBL approach. More specifically, the Deming´s PDCA cycle framework was applied in the undergraduate course to the development of quality systems supporting continuous improvement and effectiveness regarding product lifecycle management (PLM). The implementation of new learning strategies supported by the

projects developed in the course of manufacturing processes seeks to satisfy the need to promote professional engineer skills to perform in various fields of knowledge, without leaving aside the necessary interpersonal relationships. The designed projects are assessed in a constant way each semester to adapt them looking for the achievement of the learning outcomes intended for the course.

This work reports in the learning perception of engineering students derived from the PBL implementation in the undergraduate course mentioned before. The research question was stated as follows: from the students' perspective, in what extent the application of a project-based learning approach in a manufacturing processes course contributes to bridging the gap on professional skills?

As a part of the research methodology to evaluate the learners' perception of the implemented PBL approach, case study and survey research were designed and applied. The methodology, research strategies, results, discussion and conclusions of this work are presented in the next sections.

2 PBL context

The adopted PBL approach supported by the research initiation program in engineering (RIPEUS) for the manufacturing processes projects is intended for students to gain a strong background in engineering sciences, design engineering, scientific communication and project management. Along the six semesters in which the PBL approach program has been implemented, 40 projects have been developed with an average of five students per project, allowing until now 210 participating students in total. Three aspects of the methodology are reported: the design and implementation stages of the PBL approach, implementation, and the consideration of research strategies as methods of research in engineering education.

2.1. Design stage

The ongoing PBL implementation for the different course projects has been designed following the four stages described below:

(1) Projects definition: the projects are based on real-world materials processing problems, including learning outcomes, and exemplarity of the project, as a principle of selecting relevant specific learning outcomes and content / scientific knowledge (Barge, 2010). In this stage, the working groups are defined, and the roles of the teacher, the instructors or coach who provide expert guidance, and the student teams are clarified and established.

(2) Project schedule and working: The work on the project development is performed depending on the manufacturing process that each project team has chosen; for example related to the casting process, solidification phenomenon in alloys, heat treatments, 3D printing, powder metallurgy, and sintering process, among others. Design and simulation process are supported by PLM (product lifecycle management) methodology and engineering software tools available at the University.

(3) Peer and self-learning: the student teams work together on designing the project using collaborative internet resources like Google Drive, Gantter, and Google Calendar. At this point, each team plans and executes the project in an open environment in which both professor and tutors could review and comment permanently facilitating the learning process. Each team defines the required tasks according to the project outcomes, including state-of-the-art research to obtain technical standard methods. Additionally, meetings are planned with the tutor where ideas (i.e., applying brainstorming techniques) about the achievement of project goals are shared.

(4) Assessment and self-assessment: the evaluation of the student's achievement is performed through the course, including a presentation for the public and the University academic community.

2.2 Implementation stage

This stage is based on the design one, according to the following aspects:

(1) Projects definition and (2) Working on the project schedule:

Each project was composed of teamwork of five third-year mechanical and mechatronics engineering students, and there are eight projects per semester, which means that each tutor has four projects during the semester. Students start working on their projects in the second week of class. Two tutors are assigned to each project, who are involved in overseeing the scientific-technical support for the project. The projects begin with a meeting which takes place outside of the class schedule, in which the methodology is explained. The work teams are introduced with these two tutors who will be with them during the development of their projects. Before this meeting, all groups should brainstorm how to go about making the materials proposed in the projects, and with this information professor(s) can evaluate the proposals and decide the protocol to follow. Each team is assigned a workspace within the faculty as well as a space in the laboratory for the development of the project throughout the semester.

(3) Peer and self-learning: Each team also receives a work directory on google drive, which must include all the project information and advancement. The project plan is defined and controlled with a Gantt diagram that each group develops at the beginning of the project. With this, students are encouraged to organize among themselves, define responsibilities, manage their time, set their deadlines and define the order in which activities must be carried out to complete the production of the materials.

(4) Assessment and self-assessment: A project supervision meeting is planned with the work team each month, to see the progress and difficulties they may have in the development of the project. In this meeting, they must also discuss the final presentation of the project, which consists of a public exposition within the Engineering School, where each group must present a poster and a video lasting 5 minutes in which they explain the development of their project. The final evaluation is both group and individual. The group evaluation consists of the presentation, which is an oral examination including the presentation of the poster and the video and answers to questions posed by the tutors and the project supervisor.

The individual evaluation is performed by a self-reflective assessment report that the students must hand in two sides of paper at the end of the project, which covers the knowledge they have acquired as the course has developed. The assessment report is aligned with the following aspects: The individual contribution within the group, What was learned from each activity developed, What could be improved, Achievements obtained by individuals, Consulted literature, and Individual conclusions.

3 Research strategies

Malmi et al (2012) and De Graff (2016) reported some methods of research strategies applied in engineering education. In this work, it is included some found keys that are used in the outline of European taxonomy for engineering education research, and especially in the field of research strategies. Specifically, survey research is used as a method in the case study that was designed and conducted as a part of the research methodology to evaluate the learners' perception of the implemented PBL approach.

Research Study Cases: To accomplish the functionality of the proposed methodology in the design and implementation stage, in this work a case study is considered as an example of a typical project developed within one semester,

Survey research: To know how satisfied the students are with regard to the methodology of the manufacturing processes subject, the impact that the development of the PBL methodology has had upon students, and students' perception at the end of the project were investigated with a survey (interview - focus group) to evaluate the functionality of these PBL strategies implemented in the manufacturing processes course. This survey is focused on determining the participants' perception of the effect of the PBL methodology on some of their professional skills by a qualitative method when the students answer open-ended questions, and we use an observational protocol for recording the answers by making handwritten notes. After this, the answers were grouped in the principal ideas and plotted in percentage using qualitative analysis integrating a mixed method. This survey is focused on determining the participants' perception of the effect of the PBL methodology on some of their professional skills. The survey includes the following four questions:

(A) Do you have previous experience in project-based learning? The grouped answers were yes or not

(B) What impact has project-based learning had on your professional education? The grouped answers were: strengthening of knowledge, use of analysis capacity, better comprehension of theoretical phenomena.

(C) What did you find most difficult during the development of the project? The grouped answers were: teamwork, managing interpersonal skills, time management.

(D) What research strengths have you acquired through the development of the project? The grouped answers were: Information analysis, collaborative learning, industrial approach.

4 Results and discussion

In this work, Deming´s PDCA cycle (Plan, Do, Check and Act) was also considered to improve the quality and effectiveness of product lifecycle management (PLM) of the manufacturing processes projects developed. In particular, the PDCA cycle was used as a framework to link the design and the implementation stages considered for the intended PBL approach. The correspondence of each part is as follows: Plan: Project definition, Do: Working on the project schedule, Check: Peer and self-learning, and Act: Assessment and peer assessment. Figure 1 shows the "Deming´s PDCA cycle" related to the proposed methodology.

To illustrate the proposed approach, an example of one of the developed projects along one academic semester using the adopted PBL methodology is described below, as a case of study.

Project: *Compaction pressure effects on physical and mechanical properties of a hard metal manufactured by Powder Metallurgy*.

The first stage **"Project definition"** could be compared with the "P" part of PDCA (plan), in this stage, it is established the project goals to develop during the academic semester, and also students define the following learning objectives:

- To recognize the compaction stage relevance for the powder metallurgical manufacturing process.
- To determine the optimal compaction pressure to obtain a hard metal that meets the demanded quality requirements.

- To identify and recognize the hard metal microstructure and aspect as a function of the compaction parameters.

Working on the Project Schedule is associated with the "DO" part in the Deming´s Cycle. Students create their Gantt diagram based on their time availability. They establish how they will develop the multiple tasks using for that the technical information specifications, and managing the information to make it easy to access, so avoiding multiple report versions at the deadline.

Figure 1: Deming´s PDCA cycle applied in the project-based learning methodology

Check in Deming´s cycle is one of the most important stages because of its relation to the "Peer and Self-learning." The application of the peer learning strategy has demonstrated the acceptation by the students because their traditional learning model has been based on an individual type of learning. Additionally, the development of the projects has proven to stimulate the team work where students can coordinate all the learning process to accomplish the proposed goals in the manufacturing processes I course.

The last stage in the cycle Deming is the **Act** that is associated with the **Assessment and self-assessment**. In this stage, students show the developed skills along the process in areas such as communication and relationships, and knowledge application, among others. On the other hand, it is evaluated the support given by the facilitators along the learning process. Finally, the projects are evaluated by team presentations and individual questions throughout the poster presentation. In the end, the group presents a video in which they show the most relevant developed aspects, and that video cannot last more than 5 minutes.

The functionality of the learning process proposed in this work is given through the continuous improvement. Such functionality is focused on the learning goals fulfillment for the manufacturing process I course. For this reason, and because projects are constantly modified according to the results obtained semester by semester, the learning process proposed as evaluation method is integrated to the **survey research** process in parallel to the **ACT** part of the PDCA cycle**.** That fact shows why those process should be circulars instead of linear because those process must adapt to the different types of the population taking into account the experience gained over the last three years in the course.

Figure 2 shows photographs of the public presentations at the last semester of the PBL-based course. In this presentation, the students explained their corresponding poster to the public and the tutors and

supervisor of the project, and also they exhibited a video showing the most relevant aspects of their experimental work. In the last six semesters, 40 projects have been developed with an average of five students per project, giving 210 participants.

Figure 2: Poster session of the final project of the manufacturing processes course - student peer assessment activity

A specific students' perception survey was developed and conducted in mid-October 2016 where 23 participants took part as a part of the research methodology to evaluate the learners' perception of the implemented PBL approach. Some of the more relevant results are depicted graphically in Figure 3. It can be observed that one of the greatest difficulties is their ability to work as a team, followed by managing the necessary time required to complete the project.

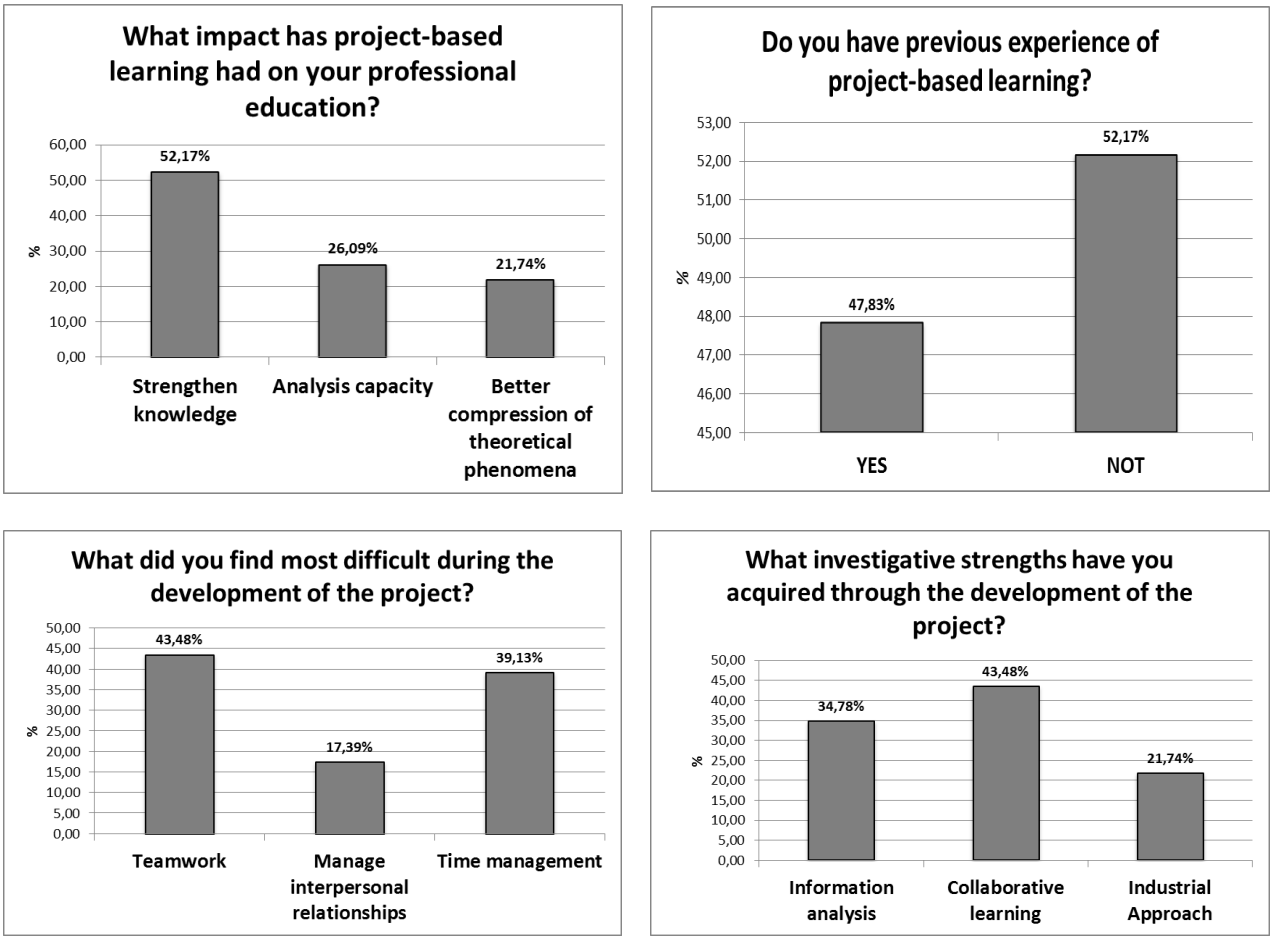

Figure 3. Results of the survey with open-ended questions showing main grouped answers.

The results also make evident that collaborative learning skills were strengthened. Despite the fact that more than half of the participants did not have prior experience in project development as a learning path, the responses indicate that the majority of participants perceive that the methodology contributes to strengthening their knowledge in manufacturing processes. The results demonstrate that personal relationships play an important role when developing a project given that it is a collaborative task. Moreover, the students have acquired strengths and skills in research, which can be applied to future work both inside and outside the university. The developed projects have facilitated collaborative learning because of the diverse people who participate in the group work, despite the fact that many claimed to have had difficulties with team work. Although the percentage of students who have developed projects is just 47.83% and those who do not make up 52.17%, it is recognised through their results that the PBL approach strengthens the diverse areas of knowledge; to know, to know how to, and to know how to be. The students emphasize that this methodology improves their analytical capacity, as well as their understanding of physical phenomena. The project work seems to strengthen and reinforce their subject knowledge, and they are aware of the impact it has on their professional training.

5 Conclusions

In the last three years, the projects developed during each semester in the Manufacturing Processes I course, are designed in such a way that they are aligned with the syllabus and the learning objectives of the class. The objective of the application of this methodology based on the learning through the projects is to generate a continuous improvement in the teaching and learning process. This is why it has been very important to apply the PDCA (Plan, Do, Check and Act) of Deming cycle, to continuously evaluate the processes in all the fundamental nodes covering the planning, execution and controlled verification, for each semester, to improve the teaching and learning practices, methods and strategies.

According to the assessment of engineering students´ perception, the PBL implementation on the course Manufacturing Processes I at Universidad Nacional de Colombia has shown to have a noticeable positive learning effect promoting the development of desirable professional skills, like strengthen the knowledge, collaborative learning, information analysis and approximation to a real-world industrial project. In contrast, the development of the project by the student teams and the facilitation task of tutors and supervisor (preparation) demanded important, time-consuming requirements to achieve the expected learning outcomes. The initiative of the PBL implementation has been supported by the Engineering School and is considered a work in progress due to the possibility of continuous improvement and the methodology adopted, covering Project definition, Scheduling and working on the project, Peer and self-learning, and Assessment and self-assessment.

From the students' point of view, the specific designed and conducted survey has revealed, as the main difficulty, their poor ability to work as a team. The other major issue is about managing the necessary time required to complete the project. The opinions of participants also make evident that their collaborative learning skills were strengthened. Despite the fact that more than half of the participants did not have prior experience in project development as a learning path, the responses indicate that the majority of participants perceive that the methodology contributes to strengthening their knowledge significantly in manufacturing processes.

The presented student´s learning perception and applied methodology derived from the positive PBL implementation in the Manufacturing Processes I course regarding the enhancement of professional skills would encourage the investigation of further aspects to deploy a full PBL approach in the course, promoting both engineering and education improvement initiatives looking for bridge the gap between academy and industry.

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Addressing the Barriers to the Implementation of Grand Challenges Through Problem Based Learning

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Abstract

This paper results from a feasibility study into the introduction of 'Grand Challenges' into the curriculum at the author's university. Grand Challenges are opportunities for students to work collaboratively, potentially across disciplines, on real-world problems. From the early stages of the study it became very clear that problem based learning would have an important role to play in such an endeavour.

Through meeting with academic staff across the university, a series of barriers to the implementation of project and problem based learning were identified. This paper reflects on those barriers in relationship to published scholarly literature in an attempt to understand how such barriers may be surmounted. The paper identifies barriers categorised into the broad categories of staff culture and student perceptions. It highlights the need for a culture change to move from faculty seeing their role as providing content that students 'need to know' to that of a facilitator of learning The paper uses Barnett and Coate's (2005) conceptualisation of the curriculum as comprising Knowing, Acting and Being as a means to encourage faculty to review their curriculum objectives to provide space for fuller student engagement in the curriculum.

Furthermore, it was identified that many students start university having undertaken secondary education programmes that provided low levels of autonomy and need support to become independent, self-directed learners There was a perceived need for students to be guided in developing a greater tolerance to working with uncertainty and disjunction. The paper concludes that in order for this to happen, students need to have the necessary space and support to manage disjunction, and provision needs to be given to enable students to make mistakes and 'fail' without jeopardising their overall degree.

Keywords: Grand Challenges, Problem Based Learning, Student Engagement, Conceptions of Knowledge, Curriculum Design.

Type of contribution: Review Paper

1 Introduction

This paper results from a feasibility study conducted in the authors' institution looking into the introduction of project-based *Grand Challenges* into the curriculum and goes on to address how some of the identified barriers might be surmounted. Grand Challenges are opportunities for students to work collaboratively on real-world problems and in doing so develop and apply their individual subject knowledge. This had been a common approach in the university's School of Architecture but this study was looking into the broader potential for other schools to learn from their experience, opening up opportunities for interdisciplinary projects run across schools.

The feasibility study aimed to identify a series of actions that the university and its constituent schools might need to take in order for Grand Challenges to become part of the student experience. It aimed to identify

- The potential benefits to the university and student experience of the introduction of cross-school project based grand challenges.
- The form that such challenges might take
- How challenges might operate
- The nature of possible challenges and how the problems students address might be established
- The opportunities that already exist within the university
- The barriers that might prevent the implementation of grand challenges how these might be surmounted
- Training & Staff-development needs

The study consisted to two main components. The first was desk research looking examples of Grand Challenges and how they are being implemented in other universities. The desk research also attempted to pedagogically ground the idea of Grand Challenges, particularly focussing on literature on curriculum design, including problem based learning. Through doing this it would be possible to identify benefits and good practice in implementing Grand Challenges. The second part was through a series of meetings and workshops with colleagues in schools across the university. Staff given a contextual introduction to Grand Challenges and were shown examples from other institutions. They were also shown a short video clip about problem based learning at Maastricht University as this summarised an approach to teaching that might be adopted as part of a Grand Challenge exercise (Maastricht 2015). Following the introduction staff were asked to highlight what (if any) current practice was being undertaken in this area, what opportunities might exist and what barriers might need to be surmounted.

2 Grand Challenges

Grand Challenges aim to develop students by asking them to engage in projects which address some of societies difficult, often intangible problems for which there are often no established answers. For example, in the UK, Exeter University holds a grand challenge week, once a year, where students from across many subject areas work collaboratively to address one of a number of key issues selected by faculty (Exeter 2017). In the US, Olin College of Engineering has been established to revolutionise how engineering is taught through asking students to engage in Grand Challenges (Olin 2015).

Grand Challenges require students to draw on knowledge from many disciplines. Often, they will work in teams; and collaborate with organisations outside higher education. In doing so, students become better prepared for meeting the needs of the world. Students focus on developing questions as much as answers, which encourages a deep approach to learning, encourages critical thinking and greater levels of self-organisation. Such Challenges helps to foster a greater interaction between theory and practice. Students develop a research-focussed approach to their learning, they learn to question and evaluate evidence. They learn to collaborate and deal with conflicting views and feedback. Furthermore, the project-based nature

of such challenges provide an important motivational aspect of students learning (Mulgan and Townsley 2016).

Mulgan and Townsley (2016) argue that whilst global higher education is rapidly growing, it has changed little since the second world war. Lecture-based learning remains a key part of the educational programme for many students. This comes more than 40 years after Donald Bligh (Bligh 1998) first published his seminal book *Whats The use of Lectures*, arguing that this was not necessarily the best way to deliver a programme and that alternatives should be sought. Recent innovations in MOOCS, lecture recording etc… continue to promote a transmission model of higher education, where the all-knowing lecturer, passes knowledge onto students. It often ignores any consideration of what students do in order to develop their individual understanding of the world (Biggs and Tang 2007). Teaching methods that place the student at the centre of their own learning provides greater opportunities for full development of that knowledge (Barnett and Coate 2005).

From the early stages of the study it became very clear that Grand Challenges were often structured in a very similar way to certain forms of problem Based Learning. For instance Maastricht's 7-jump process enables students to explain underlying mechanisms, processes or principles of phenomena described in a problem (Schmidt 1983). This is a key requirement for a Grand Challenges project where, under the guidance of the tutor students address complex problems from everyday practice. As with Grand Challenges, problem based learning has the potential to prepare students for future learning because it is based on what Dolmans et al. (2005) describe as four modern insights into learning: constructive, self-directed, collaborative and contextual.

This paper specifically addresses the barriers that were identified during the conversations with faculty using published scholarly literature in an attempt to understand how such barriers may be surmounted. The identified barriers were clustered into two key areas: staff culture and student perceptions, although practical issues such as physical space and timetabling were also identified.

3 Barriers related to Staff Culture

It was noted from the conversations with staff, particularly in professional disciplines with external accreditation, that staff felt that there was limited potential to introduce Grand Challenges, because of insufficient time to teach aspects of the programme that students 'need to know about'. There is however little in the way of evidence that states that a body of knowledge that has to be delivered is so large, that it becomes difficult teach in any other way than the traditional lecture. Indeed professional and accrediting bodies strive to provide education providers with flexibility to develop a curriculum as they see best; for instance JBM in UK Engineering (JBM 2009). More likely, is that this view arises from an established view of learning and teaching held by both academics, and the discipline communities within which they sit. This view might include the belief that lectures are the most effective way of getting information across (even if they are less successful at promoting changes in attitude, or behavioural skills) (Bligh 1998, pp. 6-9). Margetson (1991) argues that this attitude is resultant of an assumption that knowledge is something that is established to be certain, which is used to justify didactic teaching. Cowan and Bowe (2004) argue that the prevalent view that students require a sound body of knowledge and skills before they can engage with problems results from a misunderstanding of the difference between problem-based learning and problem-solving.

Biggs and Tang (2007, pp. 16-22) argue that faculty can adopt three hierarchical conceptions of teaching, with Level 1 seeing teaching as the delivery of information to a passive student, Level 2 is similar to level 1, although it focusses rather more on developing concepts and understandings through good teaching techniques. The final Level 3 focusses on the learning that actually happens within the student, questioning the nature of understanding and the ways in which students are (and are not) developing their understanding. Similarly Prosser and Trigwell (1999) related different conceptions of teaching to conceptions of learning and approaches to teaching. They contrast an 'incomplete' conception of teaching, where the lecturer's awareness is limited to what he/she is doing to a 'complete' conception where the lecturer will also consider the content and the students' understanding of the content. Those with an 'incomplete' conception, will typically see learning as about the accumulation of information, whereas those with a 'complete' conception will see learning as about developing a personal meaning in students. The former are likely to adopt a transmission approach to teaching, whilst the latter are more likely to adopt a student-focussed strategy to help students to reconstruct their understanding. It is this latter approach that is adopted in problem-based learning, and as such the challenge is to encourage staff to adopt such a stance.

Margetson (1997) argues that there is a difference in how expertise is conceived between problem and subject based learning. In traditional 'Subject Based Learning' the definition of expertise, relates to knowledge of content, either as propositional (knowing what) or procedural (knowing how). He argues that problem-based learning with its focus on making sound judgement, will require access to a combination of propositional and procedural knowledge, but that individually they are not the principal outcome of the learning.

> *"It does not therefore deny the importance of 'content' – but it does deny that content is best acquired in the abstract, in vast quantities, and memorised in a purely propositional form, to be brought out an 'applied' (much) later to problems" (Margetson 1997, p. 38)*

The arguments thus far have focussed on the conceptions of teaching and learning held by individuals. Nevertheless, such potential barriers to the introduction of the type of problem or challenge-based learning may have their root in the disciplines themselves. Savin-Baden (2000) argues that attitudes that lead to the assumptions about the need to deliver a body of knowledge, are a consequence of the need to define professional boundaries. Becher and Trowler (2001) argue that disciplines define themselves in response to the interdependent cognitive and social dimensions of their knowledge base and practices. They distinguish between disciplines that adopt hard and soft fields of knowledge and those that produce either pure and applied knowledge. From a social perspective, Becher and Trowler distinguish between those disciplines that are convergent, with a high degree of homogeneity, as opposed to those who offer a more divergent set of cultures with a broader range of approaches to their discipline. Dahlgren and Dahlgren (2002) argue that given every discipline has its own frames of understanding and traditions with regards to the construction of arguments and the development of reasoning, it is reasonable to expect that differences in academic cultures will influence how (and presumably whether) problem-based learning is adopted. Disciplines that are defined by fields of pure, hard (incontestable) and narrowly defined knowledge may be less inclined to adopt a student-focussed approach to learning. Savin-Baden (2000) argues that courses where trans-disciplinary dialogue can take place tend not to happen where lecturers focus on discipline-based knowledge and critical thinking skills. This requires a focus on negotiable frameworks, and knowledge boundaries (p109). Professional conflicts in transcending disciplinary boundaries means that encouraging critique is not always seen as desirable. She argues that given that problem-based learning can be trans-disciplinary and that disciplinary boundaries are becoming

increasingly blurred and continually shifting (p116) and that there is a need for an alternative model of higher education stripped from disciplinary boundaries. Whether problem-based learning can be the means by which discipline boundaries can be broken down is questionable. The challenge of breaking down such boundaries, and pre-conceptions is considerable, particularly as Barnett and Coate (2005, p. 30) argue, an unquestioned consequence of the outcomes approach of contemporary higher education is that boundaries are further reinforced.

In order to break-down many of the pre-conceptions of teaching and learning which can act as a barrier towards the implementation of Grand Challenges higher education institutions need to think strategically about how they frame their teaching activities. This requires consideration in two principal dimensions, the first being with regards to the curriculum, primarily in terms of what it is trying to achieve (Barnett and Coate 2005) and the second being with regards to the expectations of faculty, and how they might be supported to operate in ways that can enable them to develop a more complete conception of teaching (Prosser and Trigwell 1999).

One of the challenges faced by staff developing Grand Challenge based learning within an outcomes-Based system of higher education, is definition of those outcomes themselves. Quality assurance systems require the lecturer to define in advance of any teaching, the likely outcomes. Furthermore, a proliferation of small study modules atomises the curriculum, placing less emphasis on the interconnections between areas of knowledge. At the lowest level this is often framed in terms of content that might be 'demonstrated'. This suggests an often 'incomplete' conception of teaching based on the accumulation of propositional and procedural knowledge. Biggs and Tang (2007) amongst others have suggested frameworks that can go beyond, that allows consideration in terms of how students understand knowledge and the levels of that understanding. They suggest casting learning outcomes in terms of active verbs, which each hint at a specific cognitive level (such as Evaluate, Analyse, Explain, Describe). These provide evidence that a student has met the required level of understanding, even if they do not measure the understanding itself. Whilst systems such as this can lead to a more 'complete' level of teaching as high-level verbs highlight what the student does, over what the teacher does, such outcomes are still often very difficult to predict when planning a curriculum based around a real-world situation. Barnett and Coate (2005) argue that such tightly focussed learning outcomes, often seem unduly mechanistic, and can in themselves lead to mechanistic outcomes from a student perspective.

In order to reach a 'complete' approach to teaching, where students are able to construct their own knowledge from across a range of areas there is a need to reconsider the whole basis of curriculum design. Barnett and Coate (2005) argue that curriculum (as opposed to a syllabus of content) is rarely discussed in higher-education circles. They argue for a framework where consideration is given to how both students and staff actively *engage* with the curriculum. They argue that for a curriculum to be successful then it should be focussed on three key domains: Knowing, Acting and Being. These are distinguished from the more traditional areas of Knowledge and Skills that are often used to frame the curriculum in that they better respond to the needs of a changing world inside and outside of academia. *Knowing* suggests a move away from there being a prescribed body of knowledge that needs to be known to *how* students know something and places an emphasis on individual discovery. This accords with what Gibbons et al. (1994) might describe as Mode 2 knowledge and includes their ability to locate knowledge, question its validity and develop personal meaning. *Acting* suggests something more than a capability, or set of skills that need to be developed in independence of other aspects of the curriculum. It suggests that students are actively engaging with their knowing whilst undertaking relevant tasks. *Being* refers to how the curriculum might develop students themselves as individuals. It might include them developing as learners, but also as

potential world citizens. It might include aspects such as curiosity, energy, enthusiasm and openness to learning. Most of these latter aspects are rarely found in formally documented learning outcomes, but are often desired by both academia and society.

With respect to these three domains, Barnett and Coate (2005) argue in any curriculum, the three domains need to be present and there should be some overlap between the three domains – so that (for instance) Knowing is developed through the process of Acting, whilst Being might develop through development of knowing. In order for this to happen they advocate that space and time must be provided within the curriculum for students to engage with the curriculum, pedagogy is placed into these spaces to enable students to provide appropriate scaffolding. They argue that curriculum design should be seen as

> *"the imaginative design of spaces as such, spaces that are likely to generate new energies among students and inspire them, and so prompt their triple engagement—in knowing, acting and being." (Barnett and Coate 2005, p. 3)*

Grand Challenge type projects have the potential to provide the time and space for students to engage in this way through discovery, debate and interaction. Where students are engaging in the curriculum, it might be difficult to define a fixed set of learning outcomes, as part of the process of engagement may lead to discovery in areas that were not previously anticipated. Should unintended learning outcomes not be rewarded, as a result of a need to confirm to a quality assurance process? Barnett and Coate (2005) address this issue by making a distinction between *Curriculum as Designed* and *Curriculum in Action,* suggesting a need to recognise that whilst the Curriculum as Designed may represent no more than the scaffolding, the curriculum in action is likely to be a much broader, or messy set of outcomes that take place around, but attached to that scaffolding. We need to review how teaching is documented to enable this distinction between Curriculum in Action and Curriculum as Designed to be made clear and to ensure that the Curriculum as Designed contains that space for creative engagement by students. A focus on the development of the three domains of Knowing, Acting and Being may be the starting point with learning outcomes highlighting discovery, engagement, developing judgements and collaboration with peers (Boud and Molloy 2013).

Whilst traditional lectures would still have a place within this new understanding of the curriculum, Barnett and Coate argue that these should be as a means to inspire students and provide them with the energies required for further engagements. As with all problem-based learning, there is a necessity for faculty to take on a new role as facilitators of the learning experience, engaging in the learning alongside the students. Brew (2012) takes this further by calling for a reconceptualization of the relationship between student and teacher to form academic communities of practice, working together around research problems. Nevertheless, Wilkie (2004) argues that unless there is a change in the underpinning attitudes and beliefs of faculty then such changes will not occur, particularly where those beliefs are teacher-centric. Those with a teacher-centric view were inclined to intervene in the students thinking and ask directive questions, rather than giving the students space to explore the ideas themselves. She highlights the importance of developing a dialogue between teacher and students which she saw as leading to the realisation amongst faculty that a student-centric approach was appropriate.

Providing the space in the curriculum to enable student engagement might be perceived resource hungry. For instance if there is a necessity to meet students in small groups, rather than in a large lecture theatre then demands on staff time and physical resources will be higher. Nevertheless, scrutiny of workload models suggest that a move towards staff acting in a facilitator mode, may require a reduction in time required for preparation (see for instance Mennin and Martinezburrola 1986; Donner and Bickley 1990).

Others might argue that moving to problem-based learning would also have implications on the student workload, and this may cause difficulties, particularly when there are conflicting demands on students' time (Moust et al. 2005). A reconsideration of a curriculum as providing space for engagement, rather than one that is totally fixated on delivering a fixed knowledge base, may provide the opportunity for aspects of both staff and student workload to be re-appropriated imaginatively (Barnett and Coate 2005)(Dolmans et al. 2005).

4 Barriers related to student perceptions:

The conversations with staff identified a concern that many students started university having undertaken secondary education programmes that provided low levels of autonomy and need support to become independent, self-directed learners. This concurs with commonly held views in published literature (for example: Thomas et al. 2015). Grand Challenges are likely to be ill-defined and structured, perhaps even wicked problems, with no clear correct answer. As has previously discussed, problem-based learning rejects the idea that there is a fixed body of knowledge that has to be delivered to the student and students have to see knowledge as a fuzzy, indefinite, and constantly changing state of affairs. There is a need to change their perception of learning from what Margetson (1998) in terms of *Convenient Peg* on which to hold knowledge to a *Growing Web* which recognises the interconnectivity of aspects of knowledge.

Where this has not been a feature of earlier education this is likely to lead to feelings of uncertainty (Dahlgren and Dahlgren 2002). Savin-Baden (2000, pp. 101-110) talks about problem-based learning providing a transition towards greater complexity skills and also engaging and looking beyond the discipline. Barnett (1997) recognises the importance of students developing critical thinking skills which he classifies as Critical action, Critical reflection and Critical Reasoning. Developing such skills may be challenging and a change in approach to learning could lead to a sense of disjunction, particularly when students are subjected to a transition in perspective. Mezirow (1985) suggests that perspective transformation may also be an "epochal [and] painful". Perry (1997) argues that students may experience a sense of loss as a result of a change of perspective from one which they have previously followed. This suggests that there is a need for students to be guided in developing a greater tolerance to working with uncertainty and to develop a courage of their own convictions. Given that these transitions can be painful there is a clear need to work with students to set expectations and manage the disjunction. He argues that there is a process of 'allowing for grief' in learning. Savin-Baden (2000) argues that these transitions are educative in themselves (hence we can't avoid the grief – but we need to support students). She argues that students need to engage with legitimated experience, authentic dialog and identity rebuilding. She cites Jarvis (2011), who claims that teachers create a sense of disjunction through their questioning. She argues that staff have to validate students experiences of disjunction and facilitate transitional experiences

Thomas et al. (2015) citing Soilemetzidis et al. (2014) suggest that students often arrive in higher education situations with a conception that educational quality can be measured in terms of contact hours. They argue that there is a need to help students to reconceptualise perception of quality to recognise learning gain (Gibbs 2010) rather than mere contact hours. It may be necessary to guide students (and their parents) in this prior to arriving at university. Once studying they need faculty to provide the scaffolding necessary to provide reassurance as they transition to independent learners. This requires formal and informal opportunities for students to check that they are on the right track, embedded into their learning.

Such reassurance may also help students to learn from mistakes and even failure. Students worry about failure, assuming that they will be penalised for coming up with a wrong answer, even if there is no correct

answer. Making mistakes can provide a valuable learning experience, although often higher education quality systems act against this.

Sitkin (1992) argues that failure is necessary in any organisation, but that this has to be managed. He uses the term "Intelligent failure" to describe this. The scale of failure is important, regular monitoring over with small steps any of which might fail are key. This leads to dynamic assessment in a similar way to Schon's reflection in action (Jones and Thomas 2015). Harriss (2015) argues that it is important to enable students to take risks, and in order to achieve this failure must be facilitated. McGonigal (2005) suggests that students should be set up for failure in order to gain the disorientating dilemma that Mezirow (1991) suggests is necessary to achieve transformative learning. Tawfik and Jonassen (2013) suggest that it is important that students have an understanding as to what might 'successful failure' might look like. They found that students subjected to case-based examples of success and failure scored more highly in terms of developing counter-arguments. They argue that it may be that failed examples enable greater recall of personal prior experience,

Whilst the April 2011, *Harvard Business Review* dedicated a whole issue to learning from failure, much of the literature on learning from failure focusses around how this might happen within organisations, rather than as part of a dedicated learning situation. There is little on how one might prepare students to tolerate failure. One possibility might be to consider basing formal assessment around a student's reflection on the task being undertaken, rather than on the success of the task itself. This may help students to identify the 'learning gain' Savin-Baden (2000) suggests that reflection following a transition in perspective can also help students to not revert back to their previous way of thinking

5 Conclusions

Much writing on problem based learning addresses definitions, methods of implementation, and outlines the impacts of such teaching. There is less written about how institutions might enable the cultural change in attitudes towards teaching and learning, which is necessary to provide the foundations on which further developments in problem based Learning can be made. It is clear from the literature that in order to introduce Grand Challenges as a key pedagogic vehicle, such cultural changes are required to reflect an understanding of the curriculum that focusses on student engagement, rather than knowledge transfer. This cultural change needs to consider both staff perceptions teaching, and student perceptions of learning. From a faculty perspective, it is necessary to rethink the underpinning curriculum objectives to consider a broader range of outcomes than might be defined when considering the knowledge and skills required to complete a module. Barnett and Coate's framing of the curriculum in terms of Knowing, Acting and Being, is particularly helpful here, in that it not only recognises the dynamic nature of knowledge, but it also encourages consideration of how that knowing is put into use and its impact on the student as a developing person. Rethinking the curriculum in this way requires space to be provided in the curriculum for student engagement and Problem Based Learning, potentially implemented through running of Grand Challenges would seem like a logical opportunity to achieve this. From a student perspective, the complexity of working with real-word challenges means that disjunction becomes an inevitability and whilst learning through Grand Challenges often lead to high levels of motivation, space and support needs to be provided in order for students to come to terms with that disjunction. As part of this process, students will make mistakes, and will learn from those mistakes. For Grand Challenges to be implemented, curricula need to ensure that there are opportunities where students can be allowed to 'fail' without jeopardising their overall degree.

This paper focusses primarily on the social and cultural barriers to introducing 'Grand Challenges' into the curriculum. There are other substantial barriers not covered in this paper including timetabling constraints preventing cross-disciplinary working. Furthermore, a move towards problem based learning requires potential changes to the physical teaching environment to enable a greater focus on small group, rather than large lecture teaching. These barriers need practical consideration at institutional level, although a critical consideration of the curriculum may free up time to make these issues less problematic. One further challenge not covered in this paper, for which further investigation is required is how we might assess student learning conducted during Grand Challenge projects. Traditional methods such as exams, privilege quantity of knowledge acquired are no longer appropriate and alternatives, that can measure 'learning gain' (Gibbs 2010) need to be considered including consideration of reflective logs and journals.

As an afterword, during one of the workshops, a sceptical member of staff asked what happens to the role of the expert if the focus of education moves away from that of knowledge transfer towards student engagement. Why should students opt to go to a research-intensive university as opposed to a teaching institution? The model proposed does not preclude the need for expertise, indeed it sees the expert as someone who can guide the students in the right direction and engage with them in a dialogue as part of a learning community. Grand Challenges provide such opportunities for the development of such a learning community, but require the lecturer to think more broadly about how they define the curriculum that students engage with.

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PBL and Engineering Curriculum Change in Latin America: 10 examples and the lessons learned

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Abstract

In the spring of 2016, the Aalborg Centre for PBL in Engineering Science and Sustainability, under the auspices of UNESCO at Aalborg University (Denmark), took the initiative to collect and compile examples of PBL cases implemented in engineering education in Latin America. To fulfil this purpose, the Aalborg UNESCO Centre joined forces with three universities from Colombia: Universidad Nacional de Colombia, Universidad de Los Andes, and Universidad del Valle. The aim is to: i) compile and describe PBL models implemented in engineering education in Latin America, ii) summarise underlying learning principles, and iii) reflect upon challenges and drivers of the curriculum change towards PBL. The project also provides examples and inspiration for the engineering education community who envision changing their curriculum and implementing more student-centred learning approaches in engineering programs. The procedure for collecting the PBL cases follows five steps: i) create guidelines for case descriptions and selection; ii) call for abstracts; iii) select abstracts based on pre-defined criteria in the guidelines; iv) submit full chapters for peer review; and v) compile and publish them in book format. The book compiles 10 cases of PBL in engineering education from Brazil, Colombia, Puerto Rico, Chile, Peru and Costa Rica. In this paper, we summarise the main lessons drawn from the PBL cases and their implementation in Latin America, anticipating the content of the book.

Keywords: Problem-Based Learning, Project-Based Learning, Latin-America engineering education

Type of contribution: Best practice paper

1 Introduction

In recent decades, engineering education institutions have been putting considerable effort into revising their curricula. One of the purposes is to develop the skills required by the profession to perform in global contexts and meet market, customer and social demands (National Academy of Engineering, 2004; UNESCO, 2010). As an example, the accreditation boards refer to critical thinking, communication, problem-solving and teamwork as part of their criteria for quality assurance of engineering programmes (ABET, 2015; Gnaur, Svidt and Thygesen, 2015).

Similarly to other parts of the world (De Graaff and Kolmos, 2007; Du, De Graaff and Kolmos, 2009), Latin American countries have been changing their curricula by implementing active, student-centred learning approaches, such as problem-based, project-organized learning (PBL) (e.g. PAEE, 2017). PBL is an innovative learning methodology in which a team of students learn by solving real problems. By doing so, students select, learn and apply new knowledge, and develop collaborative, communication and self-directed learning skills.

PBL can be defined in terms of three dimensions which encompass its core principles: i) the learning dimension, ii) the content dimension, and iii) the social dimension. The learning dimension involves organising the process around real problems carried out in projects, which contextualises students' learning. On the content dimension, learning is interdisciplinary (i.e. traditional subject boundaries are expanded, and students integrate knowledge from different disciplinary fields), is exemplary (i.e. activities performed are examples of the curriculum's overall objectives), and it emphasise the relationship between theory and practice (i.e., students apply theoretical knowledge and research methodologies in real contexts and practice). On the last, the social dimension, PBL is teamwork-focused and collaborative, and students collectively decide what activities to carry out (Kolmos, Graaff and Du, 2009).

The literature shows many examples of PBL implementation sharing these fundamental learning principles. Nevertheless, each PBL model is unique because it is designed and implemented in, and for, specific contexts (e.g. institutions, groups of students and educators, and programmes). It takes into consideration the discipline, institutional and country cultures, resources, learning objectives, facilities, academic staff and assessment. It is necessary to revise the curriculum to implement PBL, and it is important to have the knowledge, resources and inspiration to start and carry out these processes. Perhaps inspiration is the main purpose for gathering PBL cases and compiling them into a book, which illustrates how some institutions design and implement PBL. The book will be published in July of 2017 as part of the 6th International Research Symposium on PBL (IRSPBL2017) activities.

This paper anticipates the book's formal presentation and provides a sneak peek at PBL models implemented in Latin America and the lessons learned. We start by providing the context and initial process to gather the cases (section 2), followed by the learned lessons (section 3). We finish the paper by making final recommendations.

2 Setting the stage: From vision to case examples collection

The vision for compiling and publishing PBL cases in Latin America emerges from the need to provide engineering educators with examples of curriculum change and innovation. The overall aim of curriculum change and PBL implementation is to develop engineering education and qualify future engineers for the work force by helping them develop skills needed for professional practice. Finding Latin American authors who have been implementing PBL in engineering education was the point of departure to identify PBL models. To do so, we started by doing a search of publications on related themes, resulting in a list of 60 references and, consequently, authors, who also took a scholarly approach to curriculum change. In this section, we describe the process where we define criteria and guidelines based on vision and goals (subsection 2.1), and identify and gather the PBL case examples (subsection 2.2).

2.1 Organisation and guidelines

We start by defining criteria and guidelines to identify and describe PBL cases. In a two page document, we stated: i) the overall goal of the book, ii) its organisation and guidelines, iii) its format, iv) criteria for submissions and the review process, v) deadlines, and vi) target audience. This document not only provides a share understating of how the process has been carried out but also what content the cases should cover. Consequently, this document was used as a guideline and sent in the call for extended abstracts.

The guidelines started by being inspired by the PBL curriculum elements in Kolmos *et al.* (2009) (see Figure 1). All these elements are elementary in a curriculum and must be aligned. They also provide a holistic understanding of the curriculum, and if one element changes, it will affect all the others.

Figure 1: PBL alignment of elements in the curriculum (adapted from Kolmos *et al.*, 2009, p. 15)

Furthermore, the contributions should not only give a description of the PBL model and its elements but also a story of how the change process has been triggered, the type of challenges faced, and how they were managed. Therefore, we add drivers for change, implementation process and challenges, future perspectives and visions to the guidelines. In sum, the guidelines for authors are as follows:

- Drivers for change
- PBL model and elements of curriculum
- Implementation process and challenges
- Future perspectives and visions

We also encouraged authors to use their experiences, bring testimonies of people involved in the process of change, and refer to previous work.

By using these guidelines, we identify and gather examples that tell the story of the change process and its contextual, complex and dynamic nature. The guidelines also make the process of selection and review more transparent. In the following, we describe the process of gathering the PBL case examples.

2.2 Collecting PBL cases from Latin America

Once the guidelines document was prepared, we proceeded to the identification and collection of PBL cases. The process includes the following steps: i) identification of PBL cases in the literature (approximately 60 potential cases gathered through literature search), ii) call for contributions as extended abstracts, iii) review of abstracts (where primary criteria for selection was PBL and engineering education), iv) call for full chapters of the selected abstracts, v) review of full chapters (where primary criteria are the points given in the

guidelines) involving experts in PBL, and vi) compilation of selected chapters for the book's publication. Figure 2 shows the process from identification, selection and gathering of PBL cases.

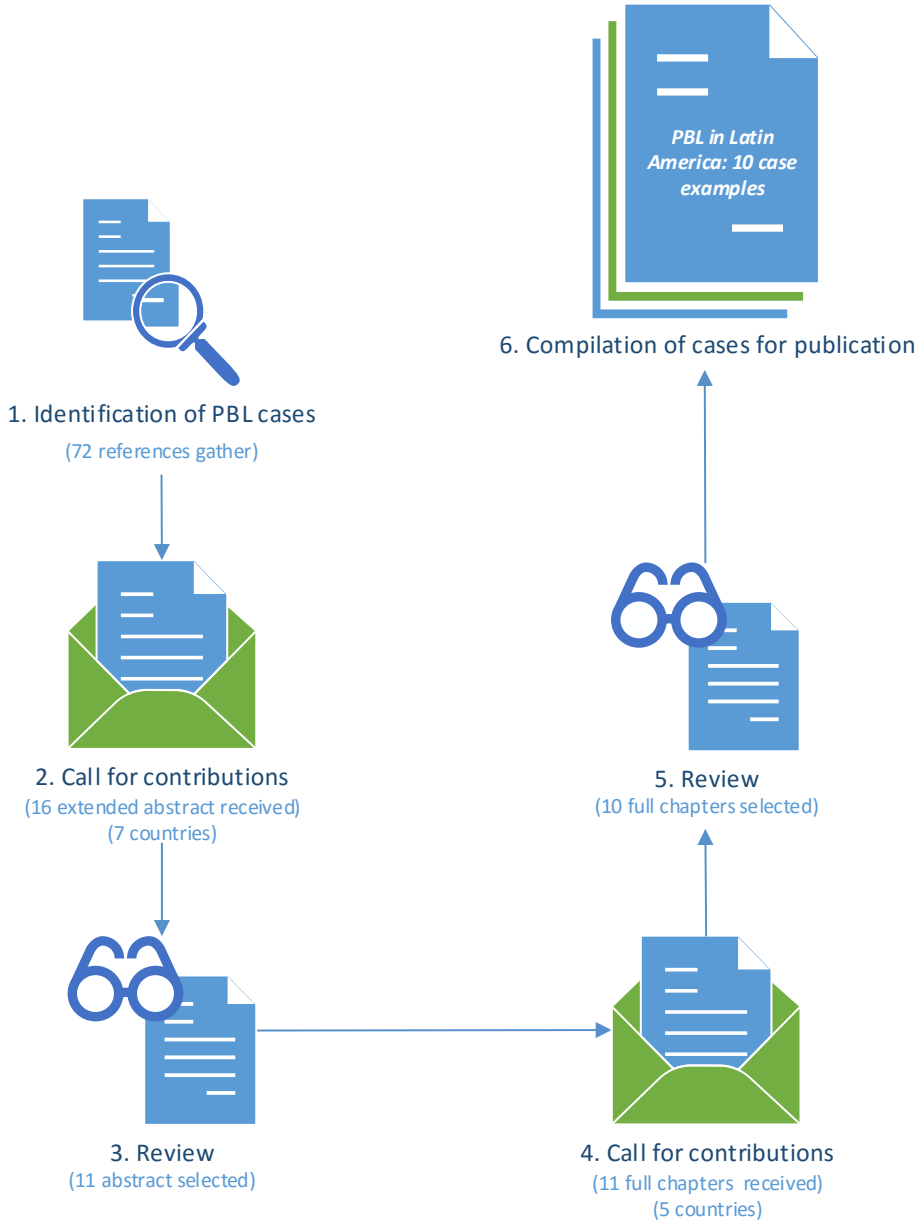

Figure 2: Scheme of process of Latin America PBL cases identification and gathering

This process resulted in ten PBL cases from Latin America, namely from Brazil, Chile, Colombia, Peru and Costa Rica.

3 Lessons drawn

This section summarises the selected PBL cases in Latin America, referring to aspects such as drivers and strategies to change, a variation of PBL models and the challenges reported during the implementation process. As stated above, ten cases of PBL implementation in engineering education from five countries among Latin America were collected: four from Brazil, one from Chile, three from Colombia, one from Costa

Rica and one from Peru. All cases present different approaches to PBL and describe students' learning through curriculum and learning activities in engineering undergraduate programmes. Table 1 summarises the selected cases of PBL in five Latin American countries.

Table 1: Summary of PBL cases

COUNTRY*	INSTITUTION	PBL IMPLEMENTATION	CODE NAME
Brazil	Universidade Virtual do Estado de São Paulo - Universidade de São Paulo	Institution Level	UNIVESP-USP
	Universidade de Brasília	Course Level	UNB-1
		Course Level	UNB-2
	Universidade de São Paulo	Program Level	USP
Chile	Universidad de Los Andes	Course Level	Uniandes
Colombia	Pontificia Universidad Javeriana	Program Level	PUJ
	Universidad de los Andes	Course Level	UNIANDES
	Universidad Pedagógica y Tecnológica de Colombia - Universidad del Valle	Course Level	UPTC-UV
Costa Rica	Universidad Nacional	Program Level	UNA
Peru	Universidad de Piura	Program Level	UDEP

*By alphabetic order

3.1 Main drivers and strategies to change

The major issue taken up in this subsection is to show the common drivers for ten PBL cases and to provide an understanding of all different elements that motivated change, type of implementation and which existing educational model (PBL or not) served as the basis for the curriculum change. At first glance, the curriculum change is observed from many different angles because various institutions use PBL principles with different purposes and approaches. The process of change from a traditional curriculum into a student-centred curriculum is a demanding task. Also, it is a comprehensive process aiming to address social demands and enhance knowledge, lifelong learning skills and competencies. Regardless of the process, each subject (i.e. institution, program or course) utilising PBL principles has its history to tell.

Brazil in recent years has invested in computer resources and computers for teaching. Also, the investment in innovation and research has been growing from 2001 and with impacts on education (Calmanovici, 2011; OECD, 2015). The new resources in the classroom promote alternative ways of pursuing educational goals and enhance collaborative learning (Abreu *et al.*, 2011; Araújo *et al.*, 2015). There is also a concern to strengthen professional skills (Roberto and Ribeiro, 2008; Siqueira-Batista and Siqueira-Batista, 2009).

In the Brazilian context, the UNIVESP-USP and UNB universities have experience in working with different active learning strategies. The UNIVESP-USP is a public higher education institution (the first Brazilian university that is exclusively virtual) based on a didactic-pedagogical model focused on active learning and problem-solving approaches. The UNB, the Federal University of Brasilia, is built with the promise of reinventing higher education in Brazil and presents two particular cases: The first is the undergraduate Production Engineering program, which implemented a PBL model with solutions through projects. The

second is an undergraduate Mechanical Engineering course called "Integrating Projects" with an emphasis on interdisciplinary projects. Finally, the undergraduate Civil Engineering program at the USP adopted PBL combined with the use of distance-learning platforms as a pedagogical strategy. All of these universities agree that the PBL model is an educational approach that allows developing a set of skills and competencies through the educational process.

Two national programs have had an impact on educational change in Chile. In 1998 a program to improve the quality and equality of education in Chile, MECESUP, was conceived. With this program, many universities could get funds for academic innovation. The Clover Engineering 2030 program is a joint project of the *Pontificia Universidad Católica de Chile* and the *Universidad Técnica Federico Santa María*. The Chilean universities began the initiatives in 2014 (see for example, Graham, 2016; INGENIERIA 2030, 2017).

Since 2012, the Faculty of Engineering and Applied Sciences of UANDES in Chile has been developing a systematic change in teaching-learning methodologies for engineering education. The combination of PBL and JITT (i.e. Just-in- Time Teaching) in two courses (e.g. programming and databases) has proved to be an excellent way to improve course's grades, increase student's motivation and participation, and support students' independent work outside the classroom. It is important to highlight the reduction in using the institutions' main resources (e.g. infrastructure and teachers' time) due to the participation of institutional authorities in the methodological intervention process.

In Colombia during the first decade of the 2000s, there were problems with the training of engineers related to educational level, high repetition rates in basic science courses, dropout and a low number of new students because of the low level of secondary school graduates. There were also a small number of Ph.D. graduates. Only in 2008, 3.7% had a PhD degree, so not very much research could be expected (Peña-Reyes, 2011). In this decade there were governmental and private initiatives to evaluate the competencies of graduates who have motivated academic innovation (Rodríguez, Peña and Peña-Reyes, 2015). In 2006, the Visión 2032 was created in order to improve the competitiveness and development of the country with participation of government, companies and industrial sectors including guilds and workers (Consejo Privado de Competitividad, 2007). In addition, since 2006, high school students in the PISA international have been showing a deficiency in critical thinking and competencies in solving real problems. Therefore, combined efforts to improve secondary and tertiary education were created. The ministry created committees, and with the spirit of being the most educated in Latin America in 2025 at all levels. I also raised funds to improve the quality of education, accreditation, and participation in the industry (Ministerio de Educación Nacional, 2013, 2015, 2016). Although they have been approached with different initiatives, the educational problems of the decade of 2000-2009 persist, and it is necessary to deepen in the actions that must be followed (CPC, 2014).

In Colombia, the Universidad Pedagógica y Tecnológica and the Universidad del Valle (UPTC-UV universities) have been working together with the objective to implement a PBL model as an "add-on" strategy in a traditional curriculum. It is exemplified with courses in Automatic Control Systems in both universities. At the Pontificia Universidad Javeriana (PUJ) there was a curricular reform to foster skills and competencies in undergraduate students. PBL is implemented in the course of digital systems in Electronic Engineering, where students solve problems through product development cycle. The UNIANDES presents a particular case of PBL implementation in a graduate program (i.e. Master of Education) focused on the integration of Science, Technology, Engineering and Mathematics (known as STEM).

In Costa Rica, the initiatives to improve education seek to provide graduates with competencies relevant to the industrial reality of the national context (Rivera, Chotto and Salazar, 2014). Cases such as the pedagogical

model of the *Universidad Nacional de Costa Rica* have opened up, and encouraged academic innovation. Its model was born in 2004 and is based on the results of the UNESCO World Conference in 1998 on education (Contreras *et al.*, 2013). The pedagogical model included aspects such as the need for training in skills and sustainability. In 1998, there were also initiatives to incorporate information technologies into the *Tecnológico de Costa Rica* **(**TEC). However, in 2007, those initiatives were reformulated with the purpose of incorporating changes in educational policies and expanding the academic offerings, in order to improve process competencies, relationships between teachers and students and administrative processes (Garita and Chacon-Rivas, 2012).

Since 2006, the Universidad Nacional de Costa Rica (UNA) has been developing a bottom-up strategy to implement a PBL model in Systems Engineering courses. At UNA, the aims are closing the gap between industry and academy, promoting more practical classes, and development of transversal and technical skills. This example highlights the importance of involving the faculty in the processes of change to encourage more inclusive and participatory work.

The *Consejo Nacional de Educación* in Perú proposed the *Proyecto Educativo Nacional* (PEN, or National Education Project) for education with the aim of meeting the demands of society, development of the country and the inhabitants. It was approved in 2007 and focuses on access, equal opportunities and quality (Consejo Nacional de Educación, 2005, 2007). In 2008 the Ministry introduced the program "Un laptop per niño" (One laptop per child) for students and teachers in primary and rural schools. These programs have not been effective in meeting the PEN goals (Ames 2016). Its subsequent efforts have focused on rural access to education. The low student performance on international tests in the area of science and the lack of computer skills have motivated different teachers to pursue academic innovation (e.g. Cueto et. al (2016). Therefore, from the *Ministerio de Educación* (Ministry of Education) of Peru, emergent initiatives such the program "*Enseña Perú*" with the participation of several universities and the program Construyendo Escuelas Exitosas have been implemented (Castro-Carlín and Lavado-Padilla, 2016; Enseña Perú, 2017).

The *Universidad de Piura* (UDEP), in Peru, has been using a PBL model for nine years in the chemistry courses, which have been assessed by students and professors. The results show increased motivation and student involvement that arguably is attributable to students taking responsibility for their learning. The teachers' participation and training are decisive factors for achieving a sustainable PBL model.

In sum, the above-mentioned examples and the main drivers to change are inserted in a wider context and reflect efforts and initiatives to potentiate the countries' human capital by implementing new educational approaches, tools and development of skills. Furthermore, the examples also present different responses to curriculum change.

Kolmos *et al.* (Kolmos, Hadgraft and Holgaard, 2016) refer to three curriculum change responses and strategies. They are: (i) add-on strategy characterised by course level changes, (ii) integration strategy characterised, mainly, at the program level, and (iii) re-building strategy characterised as systemic change at the institutional level. Frequently, course level changes are initiated by academic staff while changes at the programme and institutional level have their point of the department on middle and top management. The add-on strategy is a component strategy that adds or modifies elements without disturbing the existing structure. The integration strategy goes one-step further by mapping and coordinating various courses and integrating different aspects in the curriculum structure of the entire academic program. The re-building strategy corresponds to a new kind of emerging university with strong institutional support. Based on the above, there are cases representing all levels of change, where PBL implementation at the course and programme levels are the dominate ones. That indicates the existent of highly motivated academic staff in

improving their teaching practices, who also take a scholarship approach to curriculum reform by evaluating the outcomes and impacts of change implemented.

3.2 Variation of PBL models and practices

Like any other learning environment, PBL is a complex and dynamic one with actors (e.g. academic staff, students), structures (e.g. curriculum, facilities) and frameworks (e.g. content and assessment). PBL practices and models exist in different areas of education, contexts, countries and cultures (De Graaff and Kolmos, 2007). Even though the cases used the same guidelines and overall structure (see section 2.1), there is a variety of PBL models developed and practised. This variation results from the interplay of the different elements of the curriculum such as the type of problems, resources and time allocated, role of teacher, learning spaces, and institutional/ country culture. For example, the UDEP case presents an active hybrid approach, where PBL is combined with pre-designed learning activities to replace lectures. The USP case implements PBL along with distance-learning platforms as a pedagogical strategy. The PUJ case uses role-play as an activity within the PBL approach. The Uniandes case combined the Just-in-Time Teaching (JiTT) methodology with PBL, and finally, the cases from UNIVEST, UPTC-UV, UNIANDES, UNB and UNA describe the use of the Project-Oriented Problem-Based Learning as an “add-on” strategy in a traditional curriculum. Also, in most Latin American cases the contributors emphasise project organisation of PBL and not so much in the problem orientation. However, this is closely related to disciplinary and professional traditions of the engineering and architecture practices.

In this way, each one of these PBL cases is unique even though in earlier stages inspiration and knowledge are gathered from established models such as the ones from McMaster University, Maastricht University, University of Minho and Aalborg University.

3.3 Challenges to overcome

The process of change usually involves different strategies and levels at the institution and it is not absent of challenges. The cases have mentioned the following as the most common challenges when implementing PBL:

- Developing learning activities with PBL principles implies a new curricular conception, and changing the paradigm of the traditional educational model is sometimes a challenge. If the curriculum is part of a rigid system, then trying to make a change in the curriculum structure of an academic program is a difficult task to achieve.
- Motivating change of pedagogical activities in professors is a challenge that all universities must overcome. No matter the type of educational approach, the professor must be continually improving their teaching skills.
- The process of change must include students; otherwise, there is a risk of failure in teaching-learning activities. The student is the main actor in the PBL model.

Institutional support is important for any process of change and a key element for a successful implementation of the PBL. Also, it is up to the institution to nurture and support these pioneering changes to achieve educational innovation.

4 Final remarks

In the above, we briefly present and summarise ten cases of curriculum change and PBL implementation in Latin America. The overall aim is to implement a student-centred curriculum and active learning activities capable of fostering the skills needed for professional practice, increasing students' motivation and lowering dropout rates. The cases presented use mainly problem oriented, project-organized learning strategies implemented at course, programme and institutional levels. They provide examples of add-on, integrated and re-building strategies.

The cases were described regarding drivers for change, PBL model (e.g. learning objectives, assessment, teacher & student roles, facilities and progression) and learning process, challenges and future perspectives. Moreover, even though a common frame is used, the cases show a variety of PBL models emerging from different drivers, available resources, contexts and countries. Each model is uniquely linked by a common vision of what education should be (e.g. student centred) and to what end (e.g. to prepare students for professional practice as best as possible). In this sense, designing and implementing PBL does not take a "copy paste" approach, but rather a social construction approach where a knowledge of PBL theory, context culture, structures, resources and actors involved are needed, and the existent models are used as examples to collect knowledge and inspiration for change. The change process also requires time and is not absent of challenges. In this sense, knowledge sharing and multinational collaborations, institutional and governmental support, staff training and evidence-based evaluations are important factors to overcome the challenges countered.

Unfortunately, we could not elaborate more on what each specific case presents; however, these will be fully compiled and published along with the 6th International Research Symposium on PBL, in Bogotá (Colombia). Moreover, we hope that these examples inspire the wider engineering educators and teachers' community to develop engineering education and educate the next generation of engineers for Latin America and contribute to countries' development and growth.

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Seminario de Proyectos de Ingeniería: Un cambio en la forma de enseñanza de ingeniería en la Facultad de Minas

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Resumen

Desde 2009, la Facultad de Minas de la Universidad Nacional de Colombia adoptó la metodología de enseñanza basada en proyectos y problemas como una estrategia de enseñanza y aprendizaje para sus doce programas de ingeniería. Estas asignaturas buscan que los estudiantes entren en contacto con problemas reales, asociados a empresas o industria por medio de equipos de trabajo interdisciplinarios. Con Aprendizaje Basado en Problemas y Proyectos (APBs), un proyecto se configura a partir de un problema complejo, basado en situaciones del mundo real y despliega estrategias de aprendizaje en las cuales el estudiante identifica, encuentra y utiliza los recursos apropiados. El objetivo de tener los cursos bajo esta forma de educación en ingeniería es capacitar a los estudiantes para que puedan: Identificar, proponer y desarrollar proyectos en el campo de la ingeniería, trabajar en entornos de colaboración e interdisciplinarios, argumentar escritos, gráficos y conceptos oralmente y definir y estructurar la evaluación de un proyecto en cada uno de sus componentes: financiero, técnico, económico, social y ambiental.

Por medio de los resultados, provenientes de encuestas realizadas a los estudiantes por medios electrónicos al final de los periodos académicos, del análisis de diferentes referentes internacionales y de las experiencias de docentes, personal administrativo, monitores y estudiantes, se propone una nueva metodología de enseñanza de ingeniería en la Facultad de Minas que será implementada desde el segundo periodo de 2017.

Palabras claves: Aprendizaje Basado en Problemas, Aprendizaje Basado en Proyectos, Enseñanza, Proyectos en Ingeniería, Metodología.

Type of contribution: best practice paper.

1 Introducción

El escenario para la práctica de la ingeniería ha cambiado de forma rápida e irreversible en las últimas décadas. La relevancia de la tecnología y la innovación en el crecimiento económico en los últimos tiempos ha promovido la utilización de los términos "*sociedad del conocimiento*" y "*economía de la innovación*" para describir la dinámica socioeconómica actual, sustentada en la acelerada producción de conocimiento, la expansión intangible en el plano macroeconómico, la innovación convertida en actividad económica dominante y la revolución de los instrumentos del saber (David & Foray, 2002).

Desde la Facultad de Minas se ha abordado, como estrategia de adaptación a los cambios en los requerimientos en el perfil de los ingenieros, la implementación de la agrupación de asignaturas Seminario de Proyectos en Ingeniería, la cual busca desarrollar en el estudiante la capacidad de aplicar los conocimientos adquiridos en el área de formación, enlazados a los demás programas ofertados por la Facultad; lo que a su vez, permite el desarrollo de competencias transversales inherentes al trabajo interdisciplinario, como lo son: el trabajo en equipo, el aprendizaje autónomo, el desarrollo de capacidades

de pensamiento sistémico, razonamiento y creatividad, la comunicación y el aprendizaje para la vida; en donde aplique las habilidades desarrolladas en el marco del aprendizaje basado en problemas y proyectos.

2 El ingeniero del futuro

Las grandes transformaciones tecnológicas y los acelerados cambios políticos, económicos y culturales, experimentados por la sociedad en el último medio siglo, son los generadores de los nuevos escenarios del ejercicio de la ingeniería. Como resultado de esos procesos socio-técnicos, los campos de acción para el ejercicio de la ingeniería se han ampliado.

El ingeniero del futuro debe ser capaz de actuar como gestor de la innovación y emprendedor, con capacidad para dirigir una empresa, elaborar planes de negocio, desarrollar estrategias de marketing y generar crecimiento económico. Para lograr este perfil profesional es necesario desarrollar nuevos conocimientos y habilidades en los ingenieros; esto demanda cambios importantes en los programas de estudio de todo el mundo, que deberán centrarse cada vez más en el desarrollo sostenible, la internacionalidad y los enfoques interdisciplinarios. (Fuchs, 2012)

3 El contexto del ingeniero colombiano

Desde hace varias décadas en Colombia se debate sobre estrategias económicas y sociales, que le permitan salir del escenario caracterizado por la dependencia tecnológica, la venta de materias primas sin valor agregado, el empleo mal remunerado o informal y los altos índices de pobreza e inequidad (CEPAL-SEGIB 2010).

Es así que la ingeniería colombiana tiene la gran responsabilidad de liderar los procesos de cambio tecnológico necesarios para el desarrollo en el contexto presente del país, pues es considerada el puente entre la ciencia y la tecnología, y entre la tecnología y la innovación (Malpas, 2000). Sin embargo, la importancia de la ingeniería no corresponde solo a sus capacidades de investigación y transferencia de conocimiento. La formación de recurso humano es una categoría del desarrollo en la que la ingeniería tiene un papel fundamental. Estos elementos, por lo tanto, generan retos para la compleja estructura curricular, cultural y organizacional de la educación en ingeniería.

En este terreno se requieren cambios importantes: nuevas métodos de enseñanza y aprendizaje, currículos más flexibles y atrayentes para la juventud, mayor conexión entre los sistemas educativo y productivo, entre otros. Es necesario promover el reconocimiento de la educación en ingeniería como área estratégica dentro de las facultades de ingeniería, más allá de la perspectiva de actividad marginal de algunos docentes y especialistas. Estos elementos son vitales para la formación de líderes, maestros, y egresados que actúen como agentes promotores de la innovación en su espacio laboral y en su convivencia ciudadana, en lugar de ingenieros manipuladores de información.

4 La innovación en la enseñanza de la ingeniería

Durante los últimos cincuenta años se han producido un considerable número de diagnósticos, estudios y prospectivas sobre la educación en ingeniería a cargo de paneles de expertos utilizando diferentes metodologías (Bourne, 1995) (Institution of Engineers & Wragge, 1987) (Phase, 2005) (Pister 1995) (Walker, 1968). Algunas conclusiones identificadas en esos estudios son:

- La necesidad de hacer una reingeniería de los procesos de enseñanza y aprendizaje utilizados en la educación en ingeniería.
- Reconocer la práctica de la ingeniería y la investigación en ingeniería como campos de acción igualmente importantes para el profesional.
- Superar la visión reducida que identifica la ingeniería con una disciplina o una ocupación.

Sin embargo, a pesar de la consciencia de requerir un nuevo norte para la educación en ingeniería, evidenciada en las recomendaciones, propuestas y advertencias contenidas en esos estudios, la estructura de la formación en ingeniería ha permanecido inalterada en el último siglo (White 1940). El profesional egresado, tiene un perfil tradicional, diseñado para desarrollar tareas "técnicas" asociadas a un campo disciplinar específico, o a una ocupación.

La formación profesional basada en las ciencias de la ingeniería y en los cursos propios de una especialidad es un modelo limitado para la formación del ingeniero del siglo XXI; no confiere al egresado las actitudes y habilidades que el actual escenario mundial exige en la práctica de la ingeniería. El profesional se enfrenta a un contexto laboral caracterizado por la alta competitividad y regido por la innovación, en un planeta con un crecimiento exponencial de la población y con gran fragilidad ambiental.

Como lo advierte la UNESCO, uno de los problemas y desafíos internos más serios que enfrentan las universidades e instituciones de educación es la disminución del interés de los jóvenes en la ingeniería como una opción profesional, en la mayoría de los países del mundo. Esto tendrá un grave impacto en las capacidades nacionales en ingeniería, necesarias para enfrentar los retos de reducción de la pobreza, desarrollo sostenible y los demás objetivos de desarrollo del milenio (ODM) en los países en desarrollo (BOKOVA, 2010). Es imperativo hacer transformaciones que garanticen la innovación permanente en el sistema de educación en ingeniería.

Las metodologías de Aprendizaje Basado en Problemas (ABP) y Aprendizaje Basado en Proyectos (ABPy), pretenden organizar los procesos de aprendizaje de una forma que involucre activamente a los estudiantes para encontrar respuestas por sí mismos.

El concepto que identifica estas metodologías tiene referencias en la filosofía Clásica y China. Sócrates cuestionaba a sus aprendices para activar lo que él llamaba conocimiento latente; Confucio, por su parte, expresó la importancia del aprendizaje activo en las siguientes líneas: "*Dime y lo olvidaré; mostrarme y me acordaré; involucrarme y lo entenderé*". Expresiones más recientes de estas estrategias se encuentran en conceptos como '*Learning by Doing', 'Experimental Learning', y 'Student-centred-learning',* que muestran la búsqueda constante de estrategias de aprendizaje efectivas (Savin-Baden 2007).

La estrategia ABP tienen su origen en la Universidad de McMaster's en Canadá. Las prácticas realizadas durante la residencia en la Escuela de Medicina generaban gran entusiasmo en los estudiantes, en comparación con la actitud que se tenía en las clases teóricas (Barret 2005, Kolmos, Kuru, et al. 2007). El aprendizaje fue sacado del aula de clase y movido a un escenario de la vida real (Gavin 2011)

El uso de ABP se extendió rápidamente en la educación médica y en otras disciplinas como el derecho y la ingeniería. El problema que el estudiante desea resolver, es el motor del ABP y el punto de partida del proceso de aprendizaje; permite desarrollar capacidad de trabajo en equipo, habilidades de resolución de problemas y liderazgo dentro de un marco, en el que el estudiante tiene el control de lo que necesita y debería aprender (De Graaff and Ravesteijn. 2001).

Por su parte, el ABPy surge en Dinamarca en los años 70, resultado sinérgico de la creación de nuevas universidades, movimientos estudiantiles y demandas de la industria sobre el perfil del egresado. En la estrategia ABPy se identificaron seis principios fundamentales del aprendizaje: orientación por problemas, organización por proyectos, integración de teoría y práctica, trabajo en equipo, interdisciplinaridad y autocontrol de la participación (Barge 2010)

El ABPy refleja, en general, el modo de acción propio del ejercicio profesional de la ingeniería, es decir frente a un problema complejo o una oportunidad, se responde con una estrategia de proyecto, basado en situaciones del mundo real; y se propician experiencias de aprendizaje en las que el estudiante identifica, encuentra y usa los recursos apropiados. El trabajo se realiza en equipo, preferiblemente interdisciplinario; el aprendizaje es activo, integrado, acumulativo y conectado con el mundo real; se desarrollan habilidades de comunicación, dentro y fuera del equipo de trabajo.

El ABPy se asume como un proceso de enseñanza aprendizaje centrado en el estudiante, donde aplica conocimientos básicos, profesionales y transversales para gestionar la solución de problemas reales. Lo anterior brinda a los alumnos la oportunidad de presentar sus propias soluciones en proyectos de ingeniería y les permite tener confianza en la propuesta y realización de proyectos de trabajo dentro de la disciplina ingenieril escogida por ellos (Chandrasekaran, et al. 2012).

4.1 Antecedentes internacionales en Universidades

El modelo de aprendizaje basado en problemas y proyectos que se ha implementado en los cursos de Seminario de Proyectos en Ingeniería I, II y III de la Facultad de Minas de la Universidad Nacional de Colombia, y que se pretende potenciar con el presente proyecto tiene diversos referentes y antecedentes internacionales, cuyos principios se describen en la Figura 1.

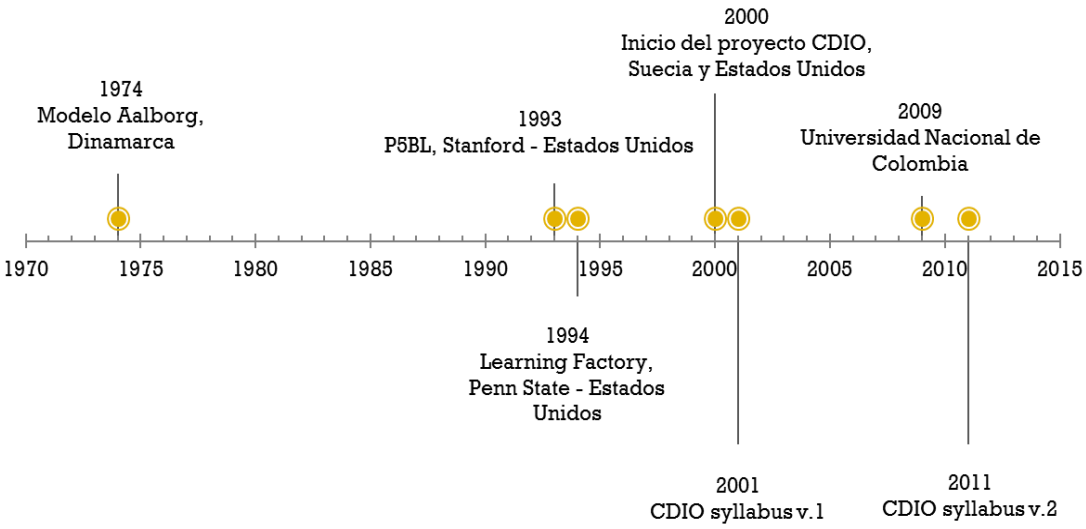

Figura 1. Modelos pedagógicos de referencia. Elaboración propia

A continuación se presenta una breve descripción de los antecedentes mencionados en la Figura 1.

- **Modelo pedagógico de la Universidad de Aalborg: aprendizaje basado en problemas y proyectos.** Desde su fundación en el año 1974, la Universidad de Aalborg tuvo un gran interés por dar a los estudiantes un rol activo en su proceso de adquisición y creación de conocimiento, y por redefinir el

rol del docente en el proceso de aprendizaje; en razón de esto, planteó un modelo pedagógico de aprendizaje basado en problemas y proyectos, conocido como el Modelo Aalborg (Barge 2010).

- **P5BL – Universidad de Stanford.** El Laboratorio de P5BL (Problema, Proyecto, Producto, Proceso y Personas) inició en 1993 en el Departamento de Ingeniería Civil y Ambiental de la Universidad de Stanford (Fruchter and Lewis. 2003). P5Bl es una metodología de enseñanza y aprendizaje que se enfoca en actividades basadas en problemas y proyectos que generan un producto para un cliente.

- **Fábrica del Aprendizaje – "Learning Factory".** La Fábrica del Aprendizaje tuvo sus inicios en 1994 en Estados Unidos, con la participación de la Universidad de Pennsylvania, la Universidad de Puerto Rico-Mayagüez, la Universidad de Washington, el Laboratorio Nacional Sandia y 24 socios corporativos más. La Fábrica del Aprendizaje se fundamenta en el aprendizaje activo, colaborativo y basado en problemas, sus iniciadores se plantearon la misión de "*integrar el diseño, la manufactura y las realidades de los negocios en el currículo de ingeniería*" a través de (Lamancusa, et al. 2008): instalaciones para el aprendizaje activo, un currículo basado en la práctica y asociaciones con la industria.

- **CDIO (***Concebir – Diseñar – Implementar – Operar***) – Estrategia Global:** El desarrollo y la implementación del enfoque CDIO inició con tres universidades suecas y una estadounidense: Chalmers University of Technology (Chalmers) en Göteborg, the Royal Institute of Technology (KTH) en Stockholm, Linköping University (LiU) en Linköping — y Massachusetts Institute of Technology (MIT) en Cambridge, Massachusetts, Estados Unidos; y se ha expandido a más de 100 universidades alrededor del mundo (E. F. Crawley, et al. 2014). En 1997 empezó la labor de planear la estrategia e identificar habilidades que eran deseables en los ingenieros; en el 2001 "nació" la primera versión de la iniciativa CDIO syllabus, v. 1.0 (E. Crawley 2001); en el año 2011 se propuso la segunda versión CDIO syllabus v. 2.0 (E. F. Crawley, et al. 2011).

5 Estrategia de enseñanza de la ingeniería en la Facultad de Minas

En respuesta a los requerimientos de articulación de la formación del nuevo ingeniero con la realidad actual, la Facultad de Minas de la Universidad Nacional de Colombia ha adoptado desde el año 2009 la metodología de enseñanza basada en proyectos y problemas como estrategia de enseñanza y aprendizaje.

5.1 Antecedentes y Estructura Actual

El objetivo general de los cursos basados en Proyectos de Ingeniería es cubrir los campos de formación relacionados con liderazgo, comunicación efectiva, gestión de proyectos, trabajo en equipo, formación de líderes y maestros; en lugar de ingenieros manipuladores de información. Una formación con esta visión debe mejorar el perfil del egresado y, con certeza, aumenta la motivación para ingresar a programas de ingeniería (Kolmos, Du, et al. 2008).

La manera de implementar la metodología de trabajo por proyectos dentro de los programas de ingeniería, ha tenido variantes en función de los contextos culturales y organizacionales. Esta metodología puede ser aplicada a un curso o a una parte específica del mismo, a un área o componente del currículo o, a un programa curricular (Kolmos, Holgaard and Dahl 2013, Harmer 2014, Gerhart and Fletcher. 2011).

La inclusión de este componente curricular en los planes de estudio de pregrado de la Facultad de Minas, tuvo como objetivo general inculcar valores personales (éticos, sociales y ambientales) y desarrollar

competencias profesionales, transversales y esenciales, en la formación del ingeniero del siglo XXI y posteriores. La estrategia para lograr ese objetivo fue implementar un espacio académico donde el estudiante debe enfrentar los retos reconocidos en el ejercicio de la profesión de ingeniería, entre los que se destacan:

- Identificar y plantear problemas, necesidades y oportunidades (PNO)
- Formular proyectos en el campo de la ingeniería y plantear la factibilidad técnico-económica.
- Desarrollar un ejercicio de puesta en marcha de un proyecto, que incluya los componentes: gestión, financiero, económico, social, ambiental, normativo y legal.
- Trabajar en ambientes colaborativos e interdisciplinarios
- Expresar sus argumentos y conceptos, de manera aclara por medios orales, escritos, gráficos;
- Identificar y medir los impactos ambientales, sociales y políticos derivados de los proyectos de ingenierías.

Para la estructuración del grupo de asignaturas en la Facultad, se tuvo en cuenta el Acuerdo 033 de 2007 del Consejo Superior Universitario, el cual establece que el programa curricular de ingeniería lo conforman tres grandes componentes identificados como fundamentación, formación disciplinar o profesional y libre elección. Bajo el concepto de que la capacitación en Proyectos de Ingeniería es parte esencial del componente disciplinar (profesional), se creó la agrupación de Seminario de Proyectos en Ingeniería que ofrece tres cursos distribuidos en las diferentes etapas de la formación del ingeniero, para los doce programas de pregrado de la Facultad de Minas. Algunos elementos importantes que sustentan esta estructura son:

- La búsqueda de soluciones a problemas originados en la industria y en las comunidades (o la identificación de necesidades y oportunidades), a través de la formulación de proyectos lleva al estudiante, y al profesor, al terreno de las preguntas no estructuradas, abiertas, complejas y con múltiples soluciones.
- El desarrollo de competencias transversales requiere periodos prolongados en la vida académica.
- Es deseable que el estudiante tenga una aproximación a la solución de problemas reales desde los inicios de su programa curricular.
- La capacidad de trabajo en equipo y la interdisciplinaridad fueron considerados como un sello del egresado.

La agrupación actual comprende tres cursos obligatorios, con los objetivos que se indican en la Tabla 1.

Tabla 1. Objetivos de los cursos actuales de Seminario de Proyectos en Ingeniería - SPI

Asignatura y créditos	Objetivos
SPI 1 (3)	1. Identificar y plantear problemáticas, problemas, necesidades u oportunidades (PNO) con base en el análisis de las necesidades de desarrollo de una comunidad. 2. Utilizar información y conceptos elaborados autónomamente en la solución de problemas. 3. Generar capacidades de trabajo en ambientes colaborativos e interdisciplinarios 4. Mejorar la capacidad de argumentación oral y escrita
SPI 2 (3)	1. Conocer los métodos de Formulación de proyectos en el campo de la Ingeniería teniendo en cuenta los elementos propios de la metodología de proyectos 2. Desarrollar capacidades para la evaluación de proyectos en los tópicos financiero, económico y de mercado, ambiental y político. 3. Generar capacidades de trabajo en ambientes colaborativos e interdisciplinarios
SPI 3 (4)	1. Desarrollar capacidades gerenciales y de diseño de plantas industriales. 2. Realizar evaluaciones financieras y de riesgos de proyectos enfocados en la fabricación de productos de consumo masivo y productos tecnológicos. 3. Generar capacidades de trabajo en ambientes colaborativos e interdisciplinarios

5.2 Nueva estructura de los Cursos de Proyectos en Ingeniería

A partir del estudio de la literatura sobre la estrategia de Aprendizaje Basado en Problemas y Proyectos en los programas de formación en ingeniería, a nivel internacional, y del análisis de los resultados de los cursos de Seminario de Proyectos en Ingeniería presentes en la malla curricular de los doce programas de pregrado que ofrece la Facultad de Minas desde enero de 2009, cuando se implementó el Acuerdo 033 de 2007. Se propuso hacer una reingeniería de la agrupación de enseñanza de proyectos en sus diferentes dimensiones: nombres, objetivos, contenidos y metodologías utilizadas, estrategia de operación y evaluación de resultados, la cual se presenta a continuación.

Se espera que en esta nueva etapa, que comienza a partir del segundo semestre de 2017, se consolide el uso de las metodologías activas en los procesos enseñanza/aprendizaje y se generen beneficios para la Institución, adicional a las competencias transversales en la formación de los ingenieros, como:

- La disminución de la deserción en los inicios del programa, atribuida por algunos autores al distanciamiento entre teoría y práctica en la estructura curricular de ingeniería y a la falta de conexión entre los contenidos de los cursos básicos y los problemas reales que enfrenta la práctica de la ingeniería (Froyd & Ohland, 2005).
- La vinculación del estudiante de pregrado a los proyectos de investigación y extensión.
- La identificación de temas trabajo dirigido de grado.
- Facilitar el acceso a los programas de posgrado.
- Abrir las puertas al emprendimiento desde el pregrado y acercar al futuro egresado a la realidad de la vida laboral.

Se propone que la estrategia de los cursos de Proyectos en Ingeniería de la Facultad de Minas de la Universidad Nacional tenga dos objetivos, el desarrollo de habilidades en la gestión de proyectos y la formación en diseño en ingeniería. El primer propósito busca consolidar la formación en gestión de proyectos, en cada una de las fases del ciclo de vida del proyecto: Identificación, Formulación, Presupuesto, Implementación, Evaluación y Cierre (informe). Por otro lado, el segundo propósito hace referencia al reconocimiento del diseño como una componente sustancial de la ingeniería; se hace énfasis en el diseño conceptual, la toma de decisiones, los criterios de sostenibilidad y el uso de herramientas avanzadas en el proceso de diseño.

Para la modificación a los planes académicos en los que se fundamentan los cursos, se parte de las experiencias reportadas por docentes, monitores, estudiantes, egresados, directivos de la Facultad y colaboradores externos, durante los siete años de existencia de la agrupación SPI. Además, se tienen en cuenta las encuestas realizadas a los estudiantes al final de los periodos académicos a partir del 2015, en las que se obtuvieron los siguientes resultados.

- En promedio, el 84% de los estudiantes considera que es adecuado el trabajo en la asignatura bajo la metodología de ABPs.
- En promedio, el 91% de los estudiantes considera que han mejorado las competencias transversales a través de los cursos.
- En promedio, para el 87% de los estudiantes, la asignatura ha permitido tener una experiencia referente al desempeño profesional de la ingeniería igual o mayor que otras asignaturas.

Los conocimientos básicos y la capacidad de razonamiento, considerado como primer nivel, son respaldados por el conjunto de asignaturas de los componentes de fundamentación y de formación disciplinar o profesional que los estudiantes de cada uno de los programas curriculares asisten, como Cálculo, Estadística, Física, entre otras.

En la Tabla 2 se presentan los nombres propuestos para los tres cursos obligatorios de Proyectos en Ingeniería con sus restricciones curriculares, que son modificaciones a la estructura actual, ya que al momento no existen prerrequisitos para las asignaturas.

Tabla 2. Cursos de Proyectos de Ingeniería (PI)

Nombre actual	Nombre propuesto	NC	Prerrequisitos	Obligatoriedad
Seminario de Proyectos en Ingeniería I	Fundamentos de Proyectos de Ingeniería - PIF	3	Introducción a la Ingeniería + 40 % Fundamentación	Sí
Seminario de Proyectos en Ingeniería II	Estructuración y evaluación de proyectos 3 - PIEE		PIF + 20% Disciplinar	Sí
Seminario de Proyectos en Ingeniería III	Proyecto Integrado en Ingeniería - PII	4	PIEE + 100% Fundamentación + 70% disciplinar	Sí

Nota: NC=número de créditos

5.3 Plan de temas y Contenido detallado de los cursos

Los tres cursos de Proyectos en Ingeniería pretenden dar una formación progresiva respecto a la formulación y evaluación de proyectos y el diseño en ingeniería, como se presenta en la Figura 2 y son descritos a continuación.

El curso de ***Fundamentos de Proyectos en Ingeniería*** está enfocado en desarrollar capacidades de análisis de problemas u oportunidades y en generar los conocimientos necesarios para resolverlo; se centra en introducir al estudiante en las metodologías de identificación y formulación de proyectos en ingeniería, partiendo del análisis del problema y oportunidad, la identificación de soluciones de tipo ingenieril y el análisis para la escogencia de la más viable. Se pretende desarrollar en el estudiante habilidades para el trabajo en equipo, la búsqueda y el análisis de información de calidad y la toma de decisiones. Conocimientos básicos y aplicación de la herramienta Marco lógico

El curso de ***Estructuración y Evaluación de Proyectos en Ingeniería*** desarrolla conocimientos avanzados sobre formulación, evaluación y gestión de proyectos, con un mayor énfasis en herramientas de evaluación financiera, económica y ambiental. Este curso se centra en introducir al estudiante en el uso de criterios y herramientas básicas para la estructuración y evaluación de proyectos, que los apoye en la toma de decisiones sobre la factibilidad y viabilidad de los mismos.

El curso de ***Proyecto Integrado en Ingeniería*** por su parte, pretende poner en práctica conceptos sobre formulación, gestión y evaluación de proyectos adquiridos en los cursos previos, y desarrollar habilidades de análisis, diseño e implementación de sistemas de ingeniería en problemas reales. Se desarrolla a modo de Proyecto Integrador, incorporando los elementos de ingeniería de proyecto, diseño, modelizado y simulación a los de formulación y gestión, de forma tal que el diseño técnico y el análisis de factibilidad tengan aplicabilidad y aprendizaje práctico.

Los tres cursos cumplen con objetivos comunes o transversales, de formación personal, inter-personal y profesional, que se dirigen a cinco grupos de competencias, siendo estos:

- Trabajo en Equipo: Desarrollar capacidades de trabajo y gestión de equipos interdisciplinarios.
- Aprendizaje Autónomo: Desarrollar capacidades para el aprendizaje autónomo, la adquisición de nuevos conocimientos y la investigación.
- Pensamiento/Creatividad: Desarrollar capacidades de pensamiento sistémico, razonamiento y creatividad.
- Comunicación: Mejorar las competencias en comunicación oral, escrita y gráfica.
- Aprendizaje para la vida: Acercar al estudiante a la realidad de su futura vida profesional, en donde aplique las habilidades desarrolladas.

Figura 2. Descripción general de los cursos de Proyectos en Ingeniería

Asimismo, en la Tabla 3 se presentan los objetivos específicos para cada uno de los tres cursos, cada uno de los cuales apunta al desarrollo de competencias de complejidad creciente en la medida que se avanza hacia los cursos superiores.

Tabla 3. Objetivos de los cursos de Proyectos en Ingeniería

Curso	Objetivos específicos.
Fundamentos de Proyectos de Ingeniería PIF	1. Conocer y aplicar técnicas de identificación, caracterización y análisis de problemáticas, problemas, necesidades u oportunidades (PNO) en ingeniería. 2. Desarrollar habilidades de búsqueda y análisis de alternativas de solución en ingeniería. 3. Plantear soluciones en ingeniería adaptadas a PNO reales y/o locales. 4. Adquirir conocimientos sobre fundamentos de gestión y planeación de proyectos en ingeniería. 5. Identificar costos mínimos de la puesta en marcha de la alternativa propuesta.
Estructuración y Evaluación de Proyectos -PIEE	1. Identificar, caracterizar y analizar PNO de acuerdo a una situación real. 2. Adquirir conocimientos en el uso de herramientas para la gestión y planeación de proyectos de ingeniería. 3. Introducir al estudiante en el diseño y la evaluación de proyectos de ingeniería a nivel técnico, financiero, económico y ambiental. 4. Evaluar la viabilidad técnica, financiera, económica y ambiental de proyectos productivos.

Proyecto Integrado en Ingeniería - PII	1. Formular un proyecto de ingeniería dirigido a la solución de un problema real o al aprovechamiento de una oportunidad 2. Adquirir habilidades de gestión y planeación de proyectos de ingeniería 3. Adquirir conocimientos sobre métodos, estrategias y técnicas para el diseño en ingeniería 4. Proponer y desarrollar una solución real aplicando conceptos de diseño en ingeniería a nivel técnico, ambiental y financiero. 5. Evaluar la viabilidad técnica, financiera, económica y ambiental mediante técnicas de análisis, modelos y prototipos de funcionamiento

Con la implementación de la nueva estructura presentada basada en enfoques más específicos para los cursos y en el uso de herramientas y adquisición de conocimientos enfocados a la gestión y planeación de proyectos; comienza un ciclo para la enseñanza en la ingeniería de la Facultad de Minas a partir del segundo periodo académico de 2017, para el cual se deben tener en cuenta los impactos que se tienen en los estudiantes, referentes a las competencias, conocimientos y herramientas con las que se presentan a la vida profesional. Para poder cuantificar los cambios, es necesario continuar con el proceso de evaluación representado por evaluación de los estudiantes al final del periodo académico, y además, se buscan nuevas estrategias para la medición de la efectividad de la metodología, lo cual se encuentra en construcción a la fecha.

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Incluyendo los proyectos integradores en las guías de aprendizaje: proceso de análisis, control y gestión de guías

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Abstract

Con el Espacio Europeo de Educación Superior (EEES), se buscan unos principios de convergencia en las titulaciones surgiendo las "guías de aprendizaje". Éstas recogen los contenidos de cada asignatura, su estructura, criterios de evaluación, las competencias propias del título y el trabajo a desarrollar por los estudiantes, garantizando que la materia cumple con la función asignada dentro del plan de estudios. Su elaboración supone un ejercicio de planificación, reflexión y coordinación pues ha de relacionar los resultados de aprendizaje de la asignatura con las competencias a desarrollar, a través de actividades formativas y de evaluación. Para los estudiantes es un documento de referencia que les permitirá obtener el máximo aprovechamiento del proceso de enseñanza-aprendizaje.

La integración del Aprendizaje Basado en Proyectos en nuestros grados implica, para estas guías, que han de servir además como un instrumento de coordinación de los proyectos en las asignaturas. Así, este documento ha de incluir una descripción detallada del proyecto y su planificación para integrarlo con el resto de metodologías y de asignaturas.

Se presenta una experiencia de creación de una guía de aprendizaje nacida de la colaboración de los profesores a través de una comunidad de prácticas. La guía es una herramienta de coordinación entre los estudiantes, el profesorado, el departamento y el centro que, como instrumento de transparencia, comprensible y comparable, sirve para mejorar y aprender. Gracias a esta comunidad se detectaron carencias en las guías de aprendizaje anteriores, se incluyeron los proyectos integradores y se generó un formato único. Se propuso el uso de herramientas informáticas para facilitar a los profesores el completarla y compartirla entre los distintos agentes, así como la búsqueda, procesado y análisis de la misma al filtrar por campos.

Keywords: Guía docente, estandarización de procesos docentes, colaboración entre profesores, comunidad de prácticas, PBL

Type of contribution: Best practice paper.

1 Introducción

El Espacio Europeo de Educación Superior, EEES (Ministerio de Educación, Cultura y Deporte 2003; Bergen 2005), da lugar a grandes transformaciones fruto de la necesidad de homogeneizar los títulos universitarios en Europa. El EEES requiere que los estudiantes se coloquen en el centro del proceso de enseñanza-aprendizaje (Velasco Quintana et al. 2012) lo que implica que ha de haber una mayor coordinación del profesorado. Surgen así las "guías de aprendizaje o de asignatura" en sustitución de los programas de

asignatura con sólo su contenido. Las Guías de Aprendizaje recogen, además de los contenidos de cada asignatura, su estructura, sus criterios de evaluación, las competencias propias del título y el trabajo a desarrollar por los estudiantes. El fin de las guías es garantizar que la materia cumple con la función asignada dentro del plan de estudios, facilitando la movilidad de estudiantes entre universidades y la coordinación del profesorado en una titulación (Ramos Maestre 2010).

Elaborar esta Guía supone para el profesorado un auténtico ejercicio de planificación, reflexión y coordinación ya que ha de relacionar los objetivos de aprendizaje de la asignatura con las competencias a desarrollar, planteando las actividades formativas que se realizarán y como se evaluarán. Para los estudiantes, por su parte, la Guía de Aprendizaje es un documento de referencia que les permitirá obtener el máximo aprovechamiento del proceso de enseñanza-aprendizaje (Zabalza Beraza and Zabalza Cerdeiriña 2012).

2 Contextualización

En este contexto del EEES, se han producido una serie de cambios en el paradigma de la educación superior. Con el fin de hacer que el estudiantes sea el responsable de su aprendizaje se han integrado metodologías activas de enseñanza-aprendizaje como son, por ejemplo, el aprendizaje cooperativo, el aprendizaje basado en problemas o el aprendizaje basado en proyectos (Benito, Bonsón, and Icarán 2005; Terrón López, Velasco Quintana, and García García 2012). Estos cambios metodológicos, que inicialmente fueron pequeñas experiencias aisladas en asignaturas o materias, dieron lugar a que, en el curso 2012-2013, y después de una revisión general de la situación se decidiera integrar el Aprendizaje Basado en Proyectos en todas las titulaciones de Ingeniería de la Universidad Europea de Madrid como metodología general y coordinada.

Nace así el proyecto “Project Based School” (PBS) cuyo fin es crear una Escuela de Arquitectura, Ingeniería y Diseño que incluya el Aprendizaje Basado en Proyectos (en adelante PBL, por sus siglas en inglés) en el modelo académico de todas las titulaciones que la componen (Terrón-López et al. 2016). Así en nuestra Escuela, los estudiantes aprenden a través de la realización de al menos un proyecto cada curso.

Consideramos dos niveles de implantación:

- proyectos fuera del currículo, que son los proyectos que se desarrollan dentro de clubes de estudiantes, que son de gran importancia para el desarrollo integral del estudiante pero que quedan fuera del objeto de este artículo.
- proyectos curriculares, que se traducen en la realización de dos tipos de proyectos: los proyectos de asignatura y los proyectos integradores.

Los proyectos de asignatura se enmarcan en una única asignatura. Son proyectos más pequeños o sencillos que consiguen que el alumno se familiarice con esta forma de trabajar. Por otro lado, denominamos proyectos integradores a aquellos proyectos de más envergadura que abarcan entre dos y cuatro asignaturas. Es en estos casos en los que, al tener que relacionar varias materias, el alumno debe aplicar lo aprendido en todas ellas para encontrar la solución a su proyecto. Estos proyectos trascienden a cada asignatura para promover un aprendizaje traslacional y tiene siempre apariencia de proyecto real. De hecho, se intenta que en la medida de lo posible participe un agente externo a la universidad en su diseño, desarrollo y evaluación posterior.

Todos los proyectos curriculares comienzan del mismo modo. El profesor (o profesores, si se trata de un proyecto integrador) plantea un reto que los alumnos deben alcanzar trabajando en grupo, permitiéndoles más o menos grados de libertad en función de la problemática descrita, el curso académico en el que se encuentren, de la titulación y del tiempo del que se disponga dentro de la asignatura.

Durante el periodo de trabajo, los profesores van haciendo seguimiento de los avances de los grupos y orientando a los estudiantes en caso de ser necesario y al final del trimestre los estudiantes entregan su proyecto y lo exponen en público. La nota final obtenida repercute en todas las asignaturas vinculadas al proyecto.

Puesto que la PBS tiene ente sus objetivos acercar el "mundo real" a los estudiantes, se solicita la colaboración a agentes externos (empresas, instituciones u ONGs). La implicación de estos colaboradores varía en función de cada proyecto yendo desde el planteamiento del desafío, al seguimiento del mismo o a la evaluación del proyecto.

Al finalizar cada curso académico se celebra la "Jornada de premios a los mejores Proyectos Integradores" cuya finalidad es motivar a los estudiantes, premiar su buen trabajo y reforzar el vínculo entre el alumno y el sector empresarial donde se premian los mejores proyectos del curso. Para ello los profesores proponen los proyectos integradores merecedores de premio y una comisión formada por personal interno selecciona a los finalistas. El día de la celebración del premio se invitan a empresas, fundaciones y ONGs (hayan participado o no como colaboradores en la elaboración de los proyectos integradores) como miembros del jurado.

La coordinación entre los docentes participantes así como el soporte institucional, es imprescindible para poder realizar todos estos proyectos de forma eficiente y efectiva. El profesorado, en sus reuniones para plantear los proyectos integradores, busca la forma de coordinar el contenido de los mismos e integrarlos en la "Guía Docente". Surge así la necesidad de una ficha de proyecto que recoja todos los datos relevantes (Terrón-López et al. 2016).

Institucionalmente, viendo la envergadura que tomaba la metodología PBL en la Escuela, se ha creado la "Oficina de Proyectos Integradores" para fomentar que la filosofía del Aprendizaje Basado en Proyectos siga formando parte del ADN de la Escuela.

3 Motivación

Aunque según el informe de la UNESCO (2010) una de las metodologías activas más efectivas para la educación en ingeniería es el Aprendizaje Basado en Proyectos, se detecta la necesidad de una herramienta que permita su planificación y seguimiento en el aula, y que ayude en la gestión y homogeneización de las asignaturas de una misma titulación (Terrón-López et al. 2016; Kolmos, Hadgraft, and Holgaard 2016). Se decide apostar por la Guía Docente como elemento clave en la organización, planificación y desarrollo de los Proyectos (integradores o no) de las distintas titulaciones.

El Espacio Europeo de Educación Superior y la definición de los nuevos Grados Universitarios hacen que el eje de los programas ya no esté situado únicamente en torno al contenido de la asignatura (selección de contenidos, su estructura y distribución en el programa, criterios para su evaluación, etc.). A partir de este momento, el eje de los programas añade las competencias propias del título y el trabajo que el estudiante ha de realizar para desarrollar esas competencias. Surgen así las guías de aprendizaje o guías de asignatura como una herramienta que permite garantizar que la materia cumple con la función que se le asigna en el

plan de estudios, suponiendo una serie de ventajas tanto para el profesorado como para los estudiantes. Según García Aretio (2014) las guías de aprendizaje son el "elemento motivador que despierta en los estudiantes el interés por la asignatura".

Para el profesorado, la elaboración de la Guía Docente supone un auténtico ejercicio de planificación y reflexión pues ha de relacionar los objetivos de aprendizaje de la asignatura con las competencias a desarrollar, a través de las actividades formativas y de la evaluación como elemento de seguimiento y control del aprendizaje (Zabalza 2009). Además ha de ocuparse de aspectos como la adecuada distribución de la carga de trabajo del estudiante, la organización temporal de las actividades formativas y los procedimientos e instrumentos de evaluación. Para los estudiantes, por su parte, es un documento de referencia que les permite obtener el máximo aprovechamiento del proceso de enseñanza-aprendizaje. Tal y como señala García Areitio (2014) debe ser el "instrumento idóneo para guiar y facilitar el aprendizaje, ayudar a comprender y, en su caso, aplicar los diferentes conocimientos, así como para integrar todos los medios y recursos que se presentan al estudiante como apoyos para su aprendizaje".

Las guías son, por tanto, el instrumento de transparencia, comprensible y comparable entre las diferentes universidades, y que además podrá servir para mejorar y aprender (Sánchez-Báscones, Ruiz-Esteban, and Pascual-Gómez 2011).

Por tanto, el nuevo modelo de la Guía de cada asignatura debe aportar todos los datos necesarios para los estudiantes, el profesorado, el departamento y el centro, sirviendo como herramienta de coordinación entre todas las partes implicadas (Learreta Ramos 2006; Velasco Quintana et al. 2012).

En el año 2015, empiezan los procesos de re-acreditación de las titulaciones (ANECA 2014) por parte de los Organismos de gobierno encargados de dicha acreditación (Fundación Madrid+d en el caso de Madrid, España). En dichos procesos se analizan, no sólo los programas (contenidos) de las asignaturas y materias, sino también sus guías de aprendizaje. En este análisis se detectaron algunas carencias y limitaciones y se sacan algunas conclusiones sobre las actuales guías de aprendizaje utilizadas en nuestras titulaciones:

- No existe un formato único lo que provoca que haya mucha disparidad en contenidos y en calidad de las guías de aprendizaje.
- Es casi imposible gestionar las guías en conjunto porque el sistema de creación es personal (cada profesor hace la suya) y, el de difusión, es a través del campus virtual de cada asignatura. Esto hace que cada estudiante tenga su guía, pero que el responsable de la calidad del título no pueda comprobar fácilmente si están publicadas todas las guías o si, por el contrario, faltan algunas.
- En nuestro caso, los programas (PR) son públicos (visibles en la web de la universidad), únicos y no se actualizan porque en ellos figuran datos del título aprobado en el plan de estudios, sin embargo las guías están en el campus virtual de la asignatura y se actualizan cada año.
- El problema derivado de tener dos documentos distintos es la falta de coherencia entre ambos, lo que en ocasiones provoca confusión. Sucede que hay profesores que rellenan uno y creen tener ya los dos; hay asignaturas donde el PR tiene una información distinta e incompatible con la que hay en la guía, debido por ejemplo a que se hayan rellenado en años distintos (la guía se actualiza y el PR no); o se cumplimentan por profesores distintos y poco coordinados; etc.
- El proceso no maneja bien la rotación docente (profesores entrantes o profesores que cambian de asignatura).
- Muchos campos y su posible contenido no son bien entendidos por algunos profesores, o bien, existen diversas interpretaciones sobre lo que debe contener, lo que hace difícil comparar las guías

de aprendizaje. Un estudiante puede tener guías de aprendizaje con el mismo formato y con contenidos distintos en muchos epígrafes.

- Algunos intentos previos para homogeneizar contenidos y formatos han tenido impactos desiguales en los departamentos y titulaciones. Como consecuencia:
    - Existen varios formatos "parecidos, pero no iguales" de la Guía docente.
    - Confusión provocada por la diversidad de versiones.
- En las guías no estaba recogida la información sobre los proyectos integradores, ni de asignatura.

A partir de estas limitaciones, un grupo de profesores decidió crear una comunidad de prácticas cuyo objetivo fue dar respuesta a estas necesidades y realizar una mejora profunda. Se usó como instrumento de comunicación el campus virtual de la universidad con el fin de lograr una mayor participación de todos los profesores del claustro, ya que ésta permite una cooperación asíncrona. La participación en la comunidad fue voluntaria.

4 Desarrollo de la experiencia

Se estableció un proceso para mejorar la elaboración de las guías que facilite la coordinación del profesorado en la implantación de la metodología PBL en sus asignaturas. Para ello se establecieron las fases que se explican a continuación.

4.1 Fase 1: Creación de una comunidad de prácticas

Con el fin de mejorar el proceso, se crea un foro de discusión para que los profesores opinen y consensuen un formato de guía común, con directivas sobre los contenidos y donde se establezcan los campos comunes a los programas de asignatura existentes. Este nuevo formato debe reflejar el desarrollo de los proyectos, su evaluación, el cronograma, etc.

En Febrero de 2016, 40 profesores de la Escuela formaron una Comunidad de Prácticas. Todos ellos eran profesores que estaban interesados en formar parte de un proceso que hasta ahora les había venido, en muchos casos, impuesto. Partiendo de un formato de guía inicial, basado en la versión generada de Guías de aprendizaje para el último proceso de acreditación, se abrió un espacio de debate en el que cada profesor tuvo la oportunidad de hacer sus aportaciones. Dichas aportaciones fueron, desde la dificultad de rellenar algunos campos, a temas de formato, posibles ayudas, definición más clara de conceptos o la incorporación de los nuevos elementos derivados del aprendizaje basado en proyectos.

Los campos que contenía hasta ese momento la guía de aprendizaje eran: Datos descriptivos; Contextualización de los contenidos de la asignatura; Resultados del aprendizaje de la asignatura; Competencias; Temario; Actividades formativas; Metodologías docentes; Evaluación; Materiales y otras consideraciones; Código Ético y Normativa específica.

Algunas aportaciones iniciales sugirieron añadir nuevos apartados como una parte de procedimientos de evaluación que completara el anterior; un apartado específico que describirá el proyecto vinculado a la asignatura; o un apartado con el cronograma detallado de impartición y de integración del proyecto en la asignatura.

El apartado del proyecto vinculado a la asignatura tiene como fin incorporar la ficha de proyecto generada en nuestra PBS (Terrón-López et al. 2016) dentro de la guía de forma que tanto profesores como estudiantes sientan el aprendizaje basado en proyectos como una parte esencial de la asignatura. En ella el

profesor detalla algunos aspectos relacionados con el proyecto como qué otras asignaturas están implicadas en la realización del proyecto, en qué consiste el proyecto, de qué forma se va a llevar a cabo y cómo se va a evaluar.

12. Proyecto
(proyecto integrador o de la asignatura si procede) • Título del Proyecto: • Empresa vinculada (si la hubiera): • ASIGNATURAS ASOCIADAS AL PROYECTO
▯ Coordinador (si hay más de una asignatura): ▯ RESUMEN: ▯ Objetivos: -del proyecto: - del proyecto en esta asignatura: ▯ Evaluación: ▯ Plan de Trabajo: ▯ Otros (anexos como rúbricas, guión del trabajo, etc.)

Figura 1: Apartado del Proyecto integrador dentro de la "Guía de aprendizaje"

Finalmente, basándose en las todas las recomendaciones y propuestas de los profesores se consensuó un modelo de guía general que fue aprobado posteriormente por la Junta de Escuela. La Guía de aprendizaje establecida sirve como herramienta principal para la gestión de bien los Proyectos Integradores, bien los proyectos de Asignatura. Esta guía de aprendizaje incluye un espacio específico para la información relativa a estos proyectos.

Este modelo de guía se desarrolló en los idiomas inglés y español para su utilización en todas las asignaturas.

4.2 Fase 2: Prueba piloto

En la segunda fase se estableció un mecanismo que permitiera distribuir dicho formato entre todo el claustro y que facilitara su cumplimentación. Uno de los objetivos fue, además, definir un proceso que ayudara a los responsables de los Grados en la puesta en marcha de planes de mejora de las titulaciones. Este proceso debía permitir conocer en todo momento las guías de aprendizaje y su contenido.

Una vez generado el documento general de Guía de aprendizaje se eligió una pequeña muestra de profesores compuesta por docentes de la comunidad de prácticas y otros que no lo fueron, para realizar testar el modelo. A este pequeño grupo se le solicitó que rellenara las guías de aprendizaje generadas y tras incorporar sus opiniones y sugerencias, se consideró el proceso cerrado y se generaron las plantillas finales.

Se discutió bastante acerca del formato en el que se debían elaborar las plantillas tipo, decidiéndose finalmente un formulario pdf por presentar las siguientes ventajas:

1. No permite modificar el formato, con lo que se garantiza homogeneidad en la configuración de las guías.
2. Permite insertar comentarios con aclaraciones que ayudan a los profesores a rellenar los campos, evitando así, tener un mismo epígrafe con contenidos diferentes.
3. Son fácilmente convertibles en formato pdf para facilitársela a los alumnos.
4. Una vez cumplimentada por el claustro, permite volcar de forma automática la información de todas las guías en un archivo Excel ordenada por campos.

Los directores de departamento, actuando en este caso como responsables de calidad de las titulaciones, disponían ahora de dos archivos, un formulario "pdf" y otro documento exportable a EXCEL. El primero fue el que enviaron a los profesores que impartían clase en las distintas asignaturas de la titulación y una vez rellenado por el profesor y devuelto al director, éste tuvo, por un lado la Guía de aprendizaje en formato "pdf" y por otro, una fila del EXCEL completada de forma automática con todos los datos divididos en campos incluyendo los códigos de asignaturas como base de datos.

4.3 Fase 3: Generación de Guías y recogida sistemática de información

El sistema, en su tercera etapa, permitió la realización de iteraciones en las que se solicitó a los profesores que no habían enviado la guía que la rellenasen, detectando si había problemas como por ejemplo: casos de profesores recién incorporados que no conocen la guía, asignaturas incluidas de forma incorrecta en el sistema, etc. El registro en un formato EXCEL permitió el filtrado por campos de manera sencilla y de esta forma, tanto los coordinadores de materia como los directores de departamento, podían encontrar incoherencias, o buenas prácticas extrapolables a otras guías.

Durante el presente curso académico, y en lo que a seguimiento se refiere, el proceso de solicitud de guías se repetirá en tres ocasiones marcadas por el primer, segundo y tercer trimestre. En ellas, se espera depurar el proceso para conseguir simplificarlo y contar con un repositorio general de consulta que permita que el curso 17/18 suponga únicamente una actualización. Esta base de datos facilitará la compartición de dichos contenidos con sistemas informáticos actuales o futuros y con otros organismos que lo demanden, internos (calidad, junta de escuela, etc.) o externos (paneles de acreditación, certificaciones nacionales o internacionales).

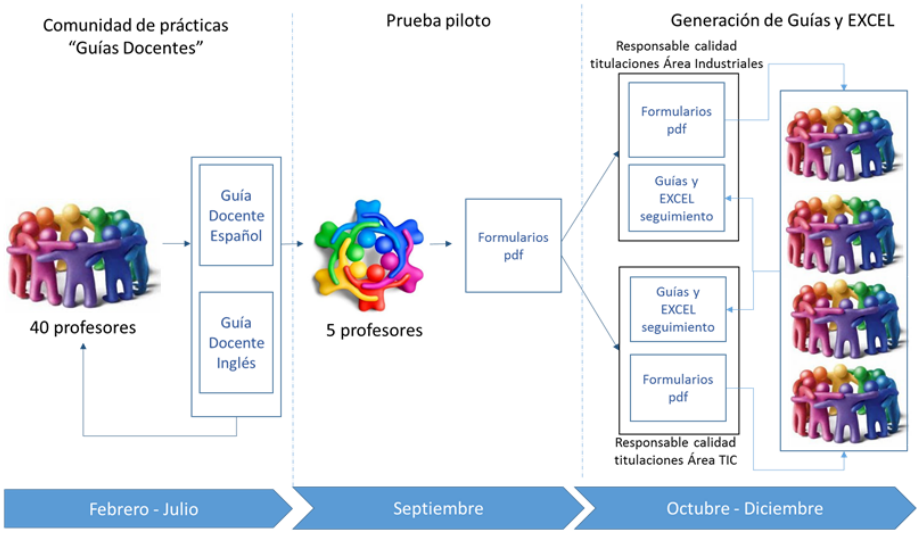

Figura 2: Diagrama del proceso seguido para consensuar la "Guías de aprendizaje"

5 Resultados

En primer lugar, se puede considerar la propia comunidad de prácticas como un resultado ya que han sido los propios profesores los que han actuado como motor de generación de las nuevas guías de aprendizaje.

Fruto de esta cooperación, se han obtenido dos plantillas de "Guías de aprendizaje", una en inglés y otra en español, con la que todo el profesorado participante se siente cómodo, ya que emergió de las sugerencias y comentarios realizados en la comunidad de prácticas en un proceso cíclico hasta llegar a la versión definitiva. El hecho de haber participado en su mejora ha generado una gran satisfacción en el claustro.

Las numerosas aportaciones recogidas en los foros de dicha comunidad de prácticas se pueden agrupar en las siguientes:

- Se ha creado y estandarizado un espacio específico con información acerca de los proyectos realizados en las asignaturas, donde todos los profesores deben detallar en qué consisten los proyectos que están realizando y con qué profundidad implementan la metodología PBL. Gracias a esta información es posible una mayor coordinación entre los profesores participantes en un mismo proyecto integrador que permita alinear objetivos y estrategias.

- Se ha puesto de manifiesto la necesidad de una redacción de la guía de aprendizaje en idioma Inglés, con el mismo formato estandarizado y vocabulario común para aquellos alumnos de habla no española.

- Se ha detectado la necesidad de tener un mapa de secuencias (pre-requisitos) de otras asignaturas de la titulación conectadas incluido en la propia guía.

A partir de las plantillas de guías propuestas por la comunidad de prácticas, se generó un formulario pdf que facilita el proceso de cumplimentación de la guía así como su estandarización. En este formulario existen campos fijos en los que el profesor debe ir introduciendo la información relativa a su asignatura, evitando la diversidad que teníamos hasta ahora en las guías y programas y generando un mismo formato para todos.

Es posible un rápido procesamiento de la información recogida en las guías a partir de la hoja de cálculo generada de forma automática.

6 Aprendizajes de la comunidad

Para lograr un desarrollo exitoso del aprendizaje basado en proyectos es necesaria la coordinación del profesorado (Kolmos 2010). Esto implica la realización de algunas tareas adicionales por parte del docente como son, por ejemplo, una rigurosa planificación del proyecto y su proceso. La guía de aprendizaje surgida de la comunidad de prácticas ha servido de ayuda al profesorado en esta planificación. Además, facilita la coordinación de proyectos integradores (que involucran a varias asignaturas) y permite diseñar proyectos más ambiciosos y con un grado de integración de competencias de diversas áreas de conocimiento que lo hacen más desafiante y más parecido a los proyectos reales. La necesidad de una mayor coordinación entre los docentes participantes para asegurar la convergencia de los esfuerzos de cada uno en el mismo proyecto y con los mismos objetivos. La guía facilita a los docentes compartir resultados de aprendizaje y balancear los tiempos de dedicación de los estudiantes a las distintas asignaturas, dentro y fuera del proyecto. Asimismo sirve para comunicar a los estudiantes los objetivos concretos del proyecto dentro de sus asignaturas.

Esperamos que la reflexión del el profesorado y las posteriores modificaciones propuestas en las guías de aprendizaje de sus asignaturas realizadas mediante la comunidad de prácticas permitirá esta coordinación entre docentes y mejorará la comunicación con los estudiantes.

La inclusión del proyecto, como apartado especial dentro de la guía de aprendizaje permite que el estudiante conozca desde el primer día de clase el objetivo final.

El uso de una comunidad de prácticas para llegar a la versión definitiva de guía de aprendizaje incluyendo proyectos integradores ha logrado simplificarla y homogeneizarla, lo que hace más sencillo al docente su cumplimentación. Esto es especialmente importante cuando éste debe desarrollar varias guías de aprendizaje de materias similares, pero no iguales.

El mecanismo elegido para llevar a cabo la revisión de las guías de aprendizaje y la inclusión de información sobre los proyectos, con la participación de los docentes en su rediseño, ha recibido una gran acogida entre el claustro. Participar en el desarrollo del nuevo formato ha hecho que los docentes la sientan más suya, más útil y cercana a lo que se necesita en el aula.

Por último, la guía resultante, facilitará la preparación de los sucesivos procesos de acreditación y auditoría programados en el futuro inmediato, gracias a un mejor acceso a la información recogida.

Lo aprendido durante todo el proceso de elaboración del nuevo formato de guías de aprendizaje con información de los proyectos desarrollados en cada asignatura, ha permitido mejorar procesos de forma colaborativa. Este método de trabajo, en el que se involucra a un gran número de docentes y se trabaja de forma colaborativa, será utilizado para la mejora de otros procesos relacionados con la docencia y la gestión académica, como puede ser la gestión de los clubs de estudiantes o la realización de un calendario de actividades universitarias fuera de las aulas, como talleres, visitas a empresas e instituciones, conferencias, jornadas, congresos o similares.

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El problema de diseñar una estrategia pedagógica

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Abstract

En el marco organizacional de una institución educativa de Educación Superior se adelanta un programa de desarrollo profesoral. Este programa ofrece un espacio de aprendizaje y reflexión acerca de diferentes aspectos sobre Educación y Pedagogía con el fin de generar en los profesores una dinámica de reflexión y mejoramiento permanente en las metodologías de enseñanza y aprendizaje que practican.

Este artículo presenta los resultados de una experiencia de aprendizaje y reflexión de un grupo de profesores participantes en el programa de desarrollo profesoral luego de vivir un proceso de aprendizaje basado en problemas. El proceso inicia con una mirada a las necesidades y problemáticas expresadas por los profesores participantes, encontrándose aspectos en común a pesar de la diferencia de áreas de conocimiento de sus asignaturas. En este grupo participaron profesores de diferentes programas de pregrado, Economía, Administración y diferentes ramas de la ingeniería. Se identificó en común, el interés por desarrollar en los estudiantes un pensamiento crítico, lo que llevó al siguiente paso dentro del proceso. ¿Qué estrategia pedagógica se puede implementar en los ambientes de enseñanza y aprendizaje para desarrollar un pensamiento crítico en los estudiantes? Diferentes estrategias y metodologías didácticas buscan promover el pensamiento crítico pero ya el grupo de profesores enfrentaba un problema, ¿cómo diseñar una estrategia pedagógica que pudieran implementar todos a pesar de la diferencia de asignaturas?, pero visto en la otra dirección, ¿cómo diseñar una estrategia pedagógica que pudieran implementar todos aprovechando justamente esta diferencia? Este estudio presenta dos resultados, primero las percepciones y reacciones de los profesores en el proceso de aprendizaje basado en la resolución de un problema. Y como segundo resultado, una estrategia pedagógica con un diseño basado en Aprendizaje Basado en Problemas (PBL o ABP). Las conclusiones de la experiencia nos muestran que aunque los profesores identifican la estrategia ABP como beneficiosa para sus estudiantes existen resistencias en aspectos como la cobertura de contenidos, la evaluación y el rol del profesor. Estos tres aspectos relacionados con el control que ejerce un profesor en su asignatura, que se ve afectado al implementar esta estrategia. El diseño de la estrategia pedagógica elaborado por los profesores refleja esto mismo, observándose en el diseño un mayor énfasis en estos tres aspectos. La experiencia también nos permite concluir que siendo profesores, cuando actuamos como estudiantes, igualmente esperamos que en un ambiente de aprendizaje el profesor tome el control y nos diga qué hacer.

Keywords: PBL, aprendizaje basado en problemas, pensamiento crítico, enseñanza y aprendizaje, estrategia pedagógica

Type of contribution: research paper.

1 Marco Teórico

El interés por encontrar estrategias efectivas para el logro de aprendizajes es permanente en el ejercicio de la labor docente. Es posible encontrar una extensa bibliografía tanto de las diferentes teorías del aprendizaje como de las estrategias y metodologías utilizadas en los ambientes educativos. El constructivismo de Piaget, la teoría del pensamiento reflexivo de Dewey, el aprendizaje social de Vigotsky son algunas de la teorías más referidas en los ambientes educativos y sobre ella se sustentan igualmente diferentes estrategias de enseñanza y aprendizaje como el Aprendizaje Basado en Problemas (ABP), modelo sobre el cual presentaremos el marco teórico de este trabajo. El marco está organizado iniciando con la fundamentación, componentes y versiones del ABP y luego con algunas experiencias de su implementación.

La estrategia Aprendizaje Basado en Problemas se fundamenta en principios básicos del constructivismo cuando propone que el estudiante aprende durante el desarrollo de un proceso de indagación, experimentación e interacción con el entorno. El constructivismo reconoce el aprendizaje como un proceso (Ordoñez, unpublished) haciendo énfasis en el cómo se aprende por medio de experiencias que permiten alcanzar comprensiones (Savery & Duffy, 2001). También la estrategia ABP se fundamenta en la teoría de Dewey cuando propone que mediante una situación problemática el estudiante se verá desestabilizado e impulsado hacia la consecusión de una solución (Montoya, unpublished). E igualmente el ABP se sustenta en el aprendizaje social de Vigotsky cuando incluye como componente de la estrategia el intercambio de las diferentes comprensiones entre los estudiantes, pues aunque la construcción del aprendizaje sea individual el proceso se estimula mediante la interacción con otros (Ordoñez, unpublished). En un compendio Savery & Duffy (2001) describe el ABP como una estrategia pedagógica basada en propuestas fundamentales del constructivismo como la comprensión a partir de la interacción con el entorno, el conflicto cognitivo como estímulo para el aprendizaje y la negociación con otros como mecanismo para la validación de las comprensiones individuales.

En la estrategia ABP se distinguen tres elementos importantes para el éxito de su implementación, el problema, el rol de facilitador y la actividad del estudiante. ABP requiere que un problema sea apropiado para el nivel de comprensiones de los estudiantes (Wood, 2003), que sea motivador y no esté completamente definido (Restrepo, 2005), que permita el logro de los objetivos de aprendizaje propuestos así como diferentes soluciones y que dirija el aprendizaje (Woods, 2000). Segundo, el profesor en esta estrategia deja de transmitir información a sus estudiantes y pasa a acompañar el desarrollo del proceso de resolución, se convierte en facilitador o tutor (McMaster, n.d.), permitiendo que los estudiantes se apropien del proceso. Y tercero, las actividades que el estudiante realice en la estrategia ABP le deben permitir identificar conocimientos que ya tiene y los que necesita para usarlos en la solución del problema. En esta estrategia la reflexión crítica y la indagación son acciones permanentes en el estudiante para el logro de los objetivos (Boud & Feletti, 1997). Pero el ABP no se limita al contexto de las actividades de una asignatura, la implementación de esta estrategia termina afectando la organización académica, administrativa y física de la institución educativa (Restrepo, 2005), en la bibliografía que la estudia se puede observar cómo la estrategia es el modelo alrededor del cual se organiza y existe la institución (Hernández, Ravn & Valero, 2015).

Aunque la estrategia en general sigue un algoritmo básico de pasos, entre cinco y nueve, se pueden encontrar diferentes versiones para su implementación. Una versión es la de la Universidad de Aalborg en Dinamarca que integra el Aprendizaje basado en Proyectos con el ABP y donde los estudiantes son quienes formulan los problemas. Este modelo determina principios básicos que lo sustentan: el problema como punto de partida, la organización de proyecto que enmarca el proceso de aprendizaje basado en problemas,

el proceso es soportado por cursos, la cooperación permanente es fundamental para el logro de los objetivos, el trabajo de resolución del problema en el marco del proyecto es un modelo replicable en el contexto profesional, los estudiantes son responsables de su proceso de aprendizaje (Aalborg University, 2015). Otra versión es la de la Universidad de McMaster en Canadá donde se destaca el énfasis en el aspecto emocional de los estudiantes involucrados en la experiencia ABP, la preparación de los estudiantes para lidiar con los problemas es necesaria para hacer del ABP una experiencia de aprendizaje (Woods, 2000). En síntesis los pasos de la estrategia ABP son: (a) la presentación de un problema, (b) la identificación de la naturaleza del problema y de los aspectos involucrados en él, identificando qué se conoce y lo que no se conoce, (c) definición de los objetivos de aprendizaje y planeación del trabajo a realizar, (d) el estudio individual, (e) el intercambio de información y el compartir aquello que se ha aprendido con los demás y (f) la evaluación del proceso y retroalimentación de la solución.

Esta estrategia se comenzó a implementar en los ambientes de aprendizaje en la década de 1960 en las escuelas de medicina y luego ha tenido infinidad de aplicaciones en escuelas de administración, de educación, arquitectura, leyes e ingeniería. A continuación se presentan algunas experiencias de implementación de ABP.

Un aspecto que se incorpora en el ABP es el desarrollo del pensamiento crítico pues se busca que el estudiante comprenda y profundice en la solución de los problemas de una manera integral desde diferentes disciplinas y mediante la negociación con pares en un proceso de colaboración. En relación con este aspecto un estudio realizado en la University College Dublin (Gavin, 2011) determinó los beneficios de aplicar ABP en la educación universitaria porque facilita el trabajo en equipo, la resolución de problemas y promueve el liderazgo, todo esto porque los estudiantes toman el control de su proceso de aprendizaje identificando lo que necesitan aprender y decidiendo cómo aprenderlo. También Loyens et al. (2011) en College Quarterly (2015), define como un elemento clave en el ABP la presentación de un problema que no esté completamente definido, donde la solución no sea obvia, de tal manera que se estimule la discusión, la búsqueda de información en una gran variedad de fuentes y se promueva el pensamiento crítico. Por otro lado, un estudio realizado en la Escuela de Ciencias Aplicadas de Singapur en 2006-2007 pudo establecer que el diseño de los problemas es un factor determinante en el éxito de la estrategia ABP. Para los estudiantes la característica principal de un buen problema es que esté orientado al logro de los objetivos de aprendizaje propuestos en el curso.

El ABP es una estrategia pedagógica de gran aceptación en las instituciones de educación superior, la universidad de Maynooth en Irlanda (McLoone, Lawlor & Meehan, 2016), la implementó en un curso de circuitos del programa de ingeniería electrónica y entre sus hallazgos es importante destacar dos aspectos, primero las implicaciones que tiene la estrategia sobre el currículo de los programas que requiere de una planeación adecuada para permitir que los estudiantes cuenten con el tiempo necesario para dedicar al desarrollo de las asignaturas con esta orientación, y segundo, el rol de facilitador que cumple el profesor, que requiere de práctica y preparación, siendo un aspecto que puede afectar de manera positiva o negativa la intervención con ABP. También la universidad de Zagreb (Pažur & Mekovec, 2016) implementó ABP en un curso de administración de tecnología informática del programa de ingeniería informática, en esta intervención se destacó la actitud positiva y entusiasta que mantuvieron los estudiantes durante el curso, así como el cambio en los roles que desempeñaron tanto los estudiantes como los profesores siendo este el aspecto más destacado de este estudio por cuanto les permitió acercarse a las demandas que hacen los empleadores de este tipo de profesionales.

2 La Experiencia

Durante cuatro meses un grupo de seis profesores adelantaron un proceso de reflexión y aprendizaje en pedagogía, indagando sobre aprendizaje y prácticas. El objetivo planteado en este programa profesoral fue ofrecer un espacio para que los profesores reconocieran su propia práctica y encontraran estrategias para superar problemas y necesidades identificadas por ellos mismos. En el grupo participaron profesores de diferentes áreas profesionales, economistas, administradores e ingenieros vinculados con diferentes programas de pregrado. El inicio parte justamente haciendo una primera mirada a la experiencia pedagógica personal, así los profesores identifican sus asignaturas, a sus estudiantes y se reconocen ellos mismos. En el ejercicio por identificarse ellos mismos, los profesores describen sus acciones antes de ir a clase, durante y después de clase. Identificaron igualmente las dificultades que enfrentaban tanto con sus estudiantes, como con conocimientos propios de sus asignaturas y con aspectos personales. No se propuso a los profesores compartir completamente el resultado de este ejercicio pero el objetivo fue llevarlos a pensar en su práctica y hacerla visible para ellos mismos.

Luego el proceso continuó a través de la búsqueda de una estrategia pedagógica que respondiera a problemas y necesidades comunes. Como dificultades resultaron la falta de interés y responsabilidad de los estudiantes por su proceso de aprendizaje y la falta de una actitud crítica frente a la información que reciben. Los profesores participantes estudiaron diferentes prácticas pedagógicas donde los estudiantes desempeñaran un rol activo y les permitiera además desarrollar otras habilidades como autonomía, responsabilidad y pensamiento crítico. Los desempeños auténticos fue un tema de discusión y atención porque para los profesores participantes resultaba muy importante que los estudiantes desde sus aulas de estudio iniciaran un acercamiento con el trabajo “real” de un profesional. Después de comparar diferentes estrategias el grupo decidió que el aprendizaje basado en problemas, ABP, respondía a las necesidades identificadas.

El grupo de profesores inició su acercamiento al ABP. Una primera experiencia fue simular un ciclo de ABP con un problema propio del entorno universitario y del momento que se vivía. Este les permitió indagar sobre ABP y su relación con currículo, evaluación y roles del profesor y del estudiante. Se les propuso a los profesores participantes en esta parte de la experiencia trabajar en parejas dada la dificultad de reunirse el grupo completo por la diferencia de agendas. Esta experiencia de trabajo en parejas funcionó bien pues los profesores en cada pareja tenían afinidades y una relativa cercanía. Una vez los profesores comprendían los aspectos importantes relacionados con ABP vino la última parte que tuvo como objetivo diseñar en equipo una práctica pedagógica basada en ABP que todos pudieran aplicar. La razón de diseñar una única práctica buscaba hacer un trabajo colaborativo, aprovechar el poco tiempo disponible y explorar un aspecto identificado en el estudio sobre ABP, la interdisciplinariedad.

Para esta última parte los profesores trabajaron en un solo grupo donde se pudieron evidenciar las dificultades propias del trabajo en equipo, sin embargo lograron el diseño de un problema con un tema muy amplio que permitía la participación de las diferentes disciplinas y el diseño de una estrategia pedagógica.

3 Metodología

Para estudiar la experiencia se hizo un análisis cualitativo de los datos recogidos en tres momentos, al inicio, durante el proceso y al finalizar. Participaron seis profesores de diferentes programas, Economía, Administración, Matemáticas e Ingeniería. Al iniciar la experiencia se recolectaron datos por medio de un

instrumento diseñado para recoger el resultado de una reflexión personal. Durante el proceso se recogieron expresiones verbales que los profesores hicieron en sus intervenciones durante los encuentros. Las clases discurrían en un ambiente de conversación, donde se formulaban preguntas y los profesores participaban. Al finalizar la experiencia se aplicó una encuesta que indagaba acerca de las concepciones de los profesores sobre la estrategia ABP y las implicaciones en su propia práctica docente. También al finalizar se recogieron datos de la conversación con uno de los participantes a quien se le plantearon de manera repetida cuestionamientos sobre su práctica y sobre sus concepciones pedagógicas.

Los datos recogidos de las reflexiones, intervenciones y encuestas fueron analizados cualitativamente buscando comportamientos y concepciones comunes de los profesores tratando de identificar patrones en sus prácticas y creencias.

De la misma manera el diseño de la estrategia basada en ABP, producto elaborado por los profesores, se analizó de manera cualitativa identificando las acciones propuestas y clasificándolas en las categorías: desempeños del profesor y desempeños del estudiante.

Finalmente estos datos fueron triangulados con los datos recogidos en la conversación final.

Los datos recogidos fueron agrupados en cuatro categorías principales:

1. Mejores aprendizajes.
2. Cómo aprender mejor.
3. Implementando ABP.
    a. Elemento más importante.
    b. Elemento negativo.
4. Yo Profesor.
    a. Los problemas
    b. Mi asignatura
    c. La estrategia ABP

Por medio de estas categorías se buscó:

1. Responder si la estrategia ABP satisfacía las necesidades de lo que los profesores denominaron mejores aprendizajes y cómo lograrlos.
2. Identificar los aspectos positivos y negativos de ABP.
3. Visualizar las concepciones de los profesores frente a los problemas, la manera de abordarlos y el impacto de ABP a su labor docente.

4 La Estrategia

A continuación se presentan únicamente los aspectos a destacar en la estrategia diseñada por los profesores con el fin de ilustrar los resultados del proceso. No se muestra el diseño completo. Tampoco se muestran resultados sobre los efectos en estudiantes y profesores porque la estrategia no se ha implementado.

4.1 Objetivo de la estrategia: Que los estudiantes logren mejores aprendizajes.

Para los profesores participantes lograr mejores aprendizajes significa que recuerden los aprendizajes logrados, que estén interesados en aprender, que tengan una actitud crítica sobre lo que aprenden y, para todos, que sepan aplicar los conocimientos adquiridos.

4.2 El Problema.

Aprovechando la diversidad de disciplinas en el grupo de participantes y teniendo en cuenta las características de un problema apropiado en ABP, se determinó que el proyecto que presenta la planeación urbana de Bogotá para los próximos 30 años era el contexto apropiado para abordar diferentes problemáticas en las que la participación de economistas, administradores, matemáticos e ingenieros es fundamental. Enmarcados en este contexto general los profesores hicieron un enunciado general y diferentes enunciados de problemas, estos últimos más cercanos a cada disciplina.

Los profesores participantes consideraron que el aprendizaje de los conocimientos propios de cada disciplina no se vería afectado negativamente usando ABP. Pero en cambio la interdisciplinariedad fue de manera mayoritaria un aspecto que los profesores consideraron de difícil realización por condiciones como la organización curricular de los programas y las cargas académicas de los profesores.

A continuación se presenta un ejemplo de un problema planteado:

"Se estima que en la intersección del sendero para bicicletas con la estación de Transmilenio *Jardines de Paz*, el tráfico peatonal se incrementará de manera notable. Las personas podrán adquirir y consumir alimentos en quioscos planificados con tal fin. Los ambientalistas están preocupados por las basuras que se generarán. Sin embargo según experiencias en otros lugares del mundo se puede apreciar que cuando las personas encuentran espacios limpios y cuidados procuran mantenerlos así. Otros estudios muestran que las personas arrojan basura al espacio púbico cuando no encuentran contenedores disponibles, de fácil acceso y uso."

4.3 4.3. Título: Propuesta de una estrategia ABP

Se definieron tres momentos en la estrategia, el momento 1 a cargo del profesor que se refiere a la preparación del problema, planeación de las actividades de aprendizaje, diseño de instrumentos de evaluación y recopilación de recursos de aprendizaje. El momento 2, que se refiere a los encuentros en el salón de clase donde se desarrollan de manera presencial actividades grupales para la solución del problema; y el momento 3, que se refiere a las actividades que suceden fuera del aula de clase también con el fin de elaborar la solución del problema.

Igualmente se definieron nueve fases para el desarrollo de ABP:

1. Contextualización. Presentación de entorno y sus problemáticas.
2. Presentación de problema y de la metodología de trabajo.
3. Investigación en el aula.
4. Presentaciones de los estudiantes y retroalimentación.
5. Investigación fuera del aula. Trabajo independiente del estudiante.
6. Presentaciones de los estudiantes y retroalimentación.
7. Construcción de soluciones.
8. Presentación de soluciones.
9. Evaluación de soluciones y retroalimentación.

Para cada momento se definieron los roles que desempeñarán el profesor y el estudiante.

Momento 1

Rol del profesor

Se realizan un conjunto de actividades donde participa un grupo de profesores de diferentes programas buscando un trabajo interdisciplinar que se refleje en los resultados de este momento. Se espera que estas actividades entreguen como productos:

- Un problema cuya solución permita la intervención de profesionales en cada una de las áreas de los profesores. Se propone que cada profesor se aproxime a una solución del problema desde el punto de vista de su profesión o área de conocimiento. Por tal razón se esperan soluciones diferentes según las asignaturas de los profesores participantes.
- La planificación del proceso que adelantarán los estudiantes, determinando la duración del trabajo sobre el problema, número de sesiones de clase y semanas así como las actividades y metodologías que se puedan proponer en el aula.
- Los mecanismos de evaluación que se aplicarán a los estudiantes.
- Los recursos que se pondrán a disposición de los estudiantes.

Como actividades en el aula se proponen:

- lluvia de ideas, que promueve el trabajo colaborativo y la creatividad.
- presentación magistral por parte de expertos, que entrega información actualizada y especializada en poco tiempo.
- trabajo en aulas de computadores, promueve la incorporación de tecnologías de información y comunicación como apoyo para el proceso de aprendizaje, promueve el desarrollo de competencias informáticas.
- estudio de casos, facilita el aprendizaje por imitación, promueve el análisis y pensamiento crítico.
- presentaciones por parte de los estudiantes, promueve el desarrollo de análisis y síntesis de información, habilidades de comunicación.
- trabajo en colaboración, promueve el trabajo en equipo, desarrolla responsabilidad y pensamiento crítico.
- preguntas, incentiva la discusión, la investigación y el debate, despierta el interés sobre un tema o problemática y motiva el pensamiento crítico y reflexivo.

Rol del estudiante

El estudiante debe preparar la sesión con anterioridad empleando como ayudas la información suministrada por el docente y la información investigada de manera autónoma. Adicionalmente el estudiante debe realizar una lista de dudas para ser resueltas durante la sesión.

Momento 2

Dependiendo de la metodología elegida y de la fase en la resolución del problema, profesor y estudiante desempeñarán diferentes roles.

Rol del profesor

En términos generales se espera que el profesor actúe como un acompañante en el proceso de resolución del problema. Desempeñará también el rol de indagador, cuestionador y será también director al mantener a los estudiantes en la dinámica de las actividades propuestas y centrados en el tema de estudio.

Rol del estudiante

En términos generales se espera que el estudiante tenga una participación activa y permanente en las actividades propuestas.

Al finalizar la sesión el profesor propondrá el tema a desarrollar en la siguiente sesión, establecerá tareas o trabajos para realizar después de la sesión, mientras que el estudiante deberá entregar:

- Una hoja escrita por grupo donde presenten evidencias del trabajo realizado durante la sesión. Esta hoja deberá ser similar para todos los integrantes del grupo, es decir todos los estudiantes deberán evidenciar el trabajo que realizan en clase de manera que el profesor puede elegir recoger cualquiera de los escritos de los integrantes del grupo.
- Productos realizados que han servido como material de estudio, o que servirán de insumo para la solución que están elaborando.
- Una hoja escrita por grupo donde presenten de manera organizada las tareas que cada integrante realizará durante el tiempo a transcurrir antes de la siguiente sesión.

Momento 3

Rol del profesor

Se propone que el profesor realice evaluaciones del proceso, de su desempeño, del desempeño de los estudiantes y del avance del trabajo que los estudiantes realizan con el fin de hacer las respectivas retroalimentaciones y ajustes.

Rol del estudiante

Se propone que el estudiante haga las tareas y trabajos propuestos por el docente, investigue de manera autónoma para dar solución a la problemática planteada y evalúe el conocimiento adquirido durante la sesión y su participación en las actividades desarrolladas.

5 Hallazgos y Discusión

Las reflexiones de los participantes nos muestran que en los procesos de enseñanza y aprendizaje el profesor es el actor principal. Éste determina y define el ambiente donde el estudiante actúa siguiendo las indicaciones y usando las herramientas propuestas por él. Esto mismo se ve reflejado en la estrategia elaborada, donde las fases 2 y 3 del proceso propuesto, tienen como objetivo preparar a los estudiantes en la dinámica de la metodología y en habilidades de investigación. Los profesores mencionan que es necesario dedicar tiempo a estos aspectos para asegurar que la estrategia tenga éxito. McLoone et al. (2016) así también lo plantean en su experiencia donde incorporan simulacros para desarrollar habilidades de trabajo en grupo, actitudes de responsabilidad con su propio proceso de aprendizaje y con el de su equipo, habilidades de comunicación y de negociación, habilidades de liderazgo y de planeación del trabajo.

Por otro lado lograr la atención y una actitud crítica y activa son las dificultades que más mencionan los profesores en relación con sus estudiantes. Sin embargo, en contraste, las actividades propuestas en la estrategia diseñada muestran una tendencia a incrementar las acciones del profesor mostrándolo como el actor principal y con mayor número de responsabilidades. Las actividades propuestas para los estudiantes se describen vagamente y tienden a ser dependientes del dominio del profesor.

Se evidencia un consenso entre los profesores sobre las bondades de la estrategia ABP, pero este reconocimiento contrasta con la manifestación mayoritaria y en connotación negativa acerca de las exigencias de la estrategia en términos de tiempo, trabajo colaborativo y cambios en los currículos de las asignaturas. Otro aspecto que preocupa a los profesores se refiere a las capacidades de los estudiantes para adelantar con éxito el proceso de aprendizaje en esta estrategia, justamente los problemas que ellos expresan necesarios superar se convierten en obstáculos para implementar la estrategia que los solucionaría.

La estrategia elaborada evidencia también un arraigo muy fuerte hacia el mantenimiento de un orden y dirección por parte del profesor, en casi todas las fases propuestas el profesor es quien dirige el desarrollo del proceso.

Los profesores consideraron "el problema" como el elemento que requiere mayor atención en la estrategia ABP, pero se encontraron diferentes puntos de vista sobre si permitía el estudio de todos los temas del curso o por el contrario no se podrían integrar todos en un solo problema a tratar.

Para todos los profesores la estrategia ABP les significa un reto interesante, una oportunidad para repensar la asignatura, una oportunidad para reconsiderar el rol profesor, pero también les significa más tiempo, mayor dedicación, mayor acompañamiento a los estudiantes.

6 Conclusiones

Entre los profesores de la experiencia hubo un consenso general sobre los beneficios de la estrategia ABP para la enseñanza y el aprendizaje destacando los procesos de análisis, de investigación y de elaboración. Sin embargo otros aspectos salen a la luz.

Aunque la estrategia basada en ABP puede parecer una secuencia detallada de pasos para resolver un problema, de fondo su implementación requiere un cambio en el pensamiento del profesor sobre lo que es aprender, modificando el propósito del cubrimiento de contenidos por el logro de comprensiones.

Los cambios en las concepciones de los profesores en relación con los procesos de enseñanza y aprendizaje requieren de un proceso constante de reflexión y experimentación donde no es suficiente conocer las bondades de diferentes estrategias pedagógicas pues la actividad cotidiana de los profesores no permite el espacio para que los profesores asuman el riesgo de modificar sus prácticas conociendo que implican una gran inversión de tiempo y cooperación.

Experiencias de reflexión pedagógica como la presentada en este trabajo generan reacciones positivas en general, los profesores se animan a proponer e incorporar cambios en sus prácticas, sin embargo el entusiasmo se desvanece frente a elementos como contenidos curriculares extensos, evaluaciones comunes y unidades académicas muy diferenciadas. Tal vez el problema de diseñar una estrategia pedagógica requiere de salirse del salón de clase e instalarse en todo el campus de una institución educativa.

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"Awareness of the importance of social interaction as part of the Bildung developmental process at Bachelor Civil Engineering program."

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Abstract

Introduction. In 2015 the subject "Engineering Academic Systems Thinking" was established for the bachelor programs in Norway. A need for a more solid Bildung as a base, and to be more skilled in social interaction processes is preferable.

Vision. Jomar Tørset has as a teacher formulated the needs to be:

"The engineers must be more adaptable in tackling unpredictable situations and also be able to do the work in different stages of a project in collaboration with people who have different background/experiences/history without compromising the demanded efficiency and innovation." 3. Theory. The students got a theoretical basis about phases in a project that can be linked to Barrows & Tamblyn "Problem Based Learning" (PBL) theory. Students have also been familiar with team dynamics by use of the SPGR instrument. SPGR is a validated tool for measuring team behavior.

Performance method. 23 new teams got highly relevant but different projects to solve. The performance period is 9 weeks with two SPGR measurements, in week 3 and week 6, respectively. The students had to describe where they are according these theories in week 4 and 7.

Results. Through such process, students acquire a common language of how to describe the situation related to project and team dynamics/processes. They are also familiar with SPGR and have the opportunity to use it in order to get a complete overview of how the cooperation interplay within teams. The students have experienced that team processes during a project do not necessarily follow a fixed pattern outlined in models like Tuckman's.

Keywords: Problem Based Learning, Academic System Thinking, Team Model, Project Performance Model, SPGR, Bildung

Type of contribution: Best practice paper.

1 Introduction and Motivation

"Education is the most powerful weapon you can possibly know if you want to change the world". Nelson Mandela, the first black president of South Africa, based his life on what he believed in. His judgements and deeds are followed by citizens, not only within his own country, but in the whole world. Our patterns of behaviour are influenced strongly by values adapted already from young age, but leading stars like Mandela may

lead to change in mentality and behaviour much later in life. Your behaviour is influenced by your own values and experiences, and also by observations of what others do/have done. In addition, we shall illustrate that behaviour is also influenced by scope and context, and can be trained inside the current setting. Bildung is a German word for the combination of forming and educating human beings in a holistic perspective (Klafki, 2001) many prosperous countries, the Bildung concept has somewhat been faded as we leaned back and enjoyed our prosperity. Engineering university education has for some time focused more on the excellence and marks in the scientific topics, and less on shaping the whole person, including the broader spectrum of perspectives, understanding the interaction and synergy of technology with human relations, society and wider social responsibility (Jon Hellenes, 1969). If covered, these perspectives have in many cases been confined to isolated university courses, and not blended into the practical teaching in the scientific university courses. However, Bildung has in some countries always been an important integrated part, also of the technological education. In many prosperous countries, including Norway, the faded Bildung concept is regaining its momentum, and the universities are redirecting towards a more holistic view of education. At the Norwegian University of Science and Technology, this has been the case for some time now, and each engineering direction has been forming their education, adding elements of Bildung into the individual scientific topics. Problem based learning (PBL) is a crucial element of this Bildung, and human relations another. The work presented in this article, displays an example of combining these; in the topic Engineering Academic Systems Thinking in their last year for Batchelor in Civil engineering. PBL is an excellent arena for Bildung, and we will show how the students are combining their practical problem solving work with learning on many levels and with several perspectives present in an effective and efficient training programme.

In the next sections of this Best Practice paper, we present the university course for System thinking, and the Spin model for teams and its team behaviour measurement instrument SPGR (Systematize the Person Group Relation, described in section 3). In section 4, we show some examples of how the students have worked with technology problems and Bildung in the program. Section 5 discusses our experiences with this scheme, and suggests modifications and continued efforts for educating our students in the multi-level program.

2 Description of the PBL program: Engineering Academic Systems Thinking

Society is changing. The way we do things now is probably not the same tomorrow. How should we think in order to adapt to the times to come, in parallel with learning from experience and tradition? It is more important than ever to focus on the base we act out of, and this is not just about what has traditionally been learned through education. Accordingly, we must focus on Bildung as part of the education. The importance to be more adaptable and flexible has increased. The “Norwegian Association of Higher Education” established the “Bildung Committee” in 2007. They formulated their mandate based on the headline “Bildung Committee – about Bildung Perspectives in higher educations”. The result of their work was presented in June 2009 in the document “Knowledge and Bildung before a new Century” (Bildung committee, 2010).

2.1 NOKUT’s vision

On this basis, the Norwegian Agency for Quality Assurance in Education (NOKUT) in 2010 established a vision for engineering studies: As an engineer, you use both your analytical and creative skills to solve socially useful technological challenges. You must work in an innovative, structured and targeted manner. You must have

excellent skills both for innovation, and for analyses, for generating solutions, for assessing, deciding, implementing and reporting, and hence you must be a good entrepreneur. Alongside Science and Technology, your linguistic skills are important, both written and orally, Norwegian as well as foreign languages. Systems that interact are an important feature of a modern society. You must be able to work independently and to work in interdisciplinary teams. As an engineer, you work with people, you are ethically responsible and environmentally conscious, and you have a major influence on society! (Bildung committee, 2010).

This resulted in the subject course "Engineering Academic systems thinking" at NTNU, the Norwegian University of Science and Technology, based on guidelines from the Norwegian "Ministry of Education and Research" (Lovdata, 2011). For the engineering program, this course was run for engineers at the undergraduate level for the first time in 2015. The subject has 10 ETC and takes place in the 6th and final semester at the bachelor study. J. Tørset taught this subject in 2016 and 2017 at the Department of Building and Environment, Bachelor degree, at NTNU. The expected main learning outcome is: holistic system thinking, project work and project management, quality management, methods of interaction in collaboration, and group dynamics. The main idea is that Bildung is making engineers more adaptable in tackling unpredictable situations, and also enabling them to work in different stages of a project in collaboration with people who have different backgrounds without compromising the required efficiency and innovation. They are trained to handle development projects aiming at sustainable environmental and societal solutions by e.g. carrying out life cycle analyses. In parallel, they are trained as team members, reflecting on the development process and relational aspects. Finally, they are trained in reporting the technical results.

In more detail, students are taught:

1. To <u>solve engineering problem which is bigger and more challenging than they are used to</u>: The students will have to do judgements and decisions based on the limited timeframe and competence they have.

2. To <u>recognize situations</u>. How should the students act in various scenarios? Students are given a theoretical base relative phases of a project that, in principle, can be linked to PBL (Barrows & Tamblyn, 1980). Students must each week submit an interim report with reference to the different phases of PBL.

3. <u>To find and understand your role in a team</u>. How to adapt their own and others' behaviour through understanding the behaviour of - and relationship to -the others in the group. SPGR is a tool that measures behaviour and the relationships between the members of a group over some time. It does not say directly what personal qualities students have, but rather how students rate their own and the others' behaviour in the group. SPGR provides a description of the perceived status quo for the team dynamics, and a language that makes it possible to understand what is happening in the group.

4. <u>SPGR as a tool:</u> Tools that can enable a basic understanding of relations, to plan projects according to the problem characteristics (wrt Level of Purpose, clarity, difficulty, complexity, predictability) and the nature of the participants of the group (wrt trained/untrained, competence, structured/unstructured, motivation, behaviour in the group, and group maturity).

The nine weeks of project work is for each group structured like this:

- Week 1: Collaboration agreement
- Week 2: Description of the assignment with idea and vision
- Week 3: Overview of requirements and solution elements

- Week 4: Choice of concept
- Week 5: Plan and volume descriptions
- Week 6: Interface description
- Week 7: SPGR summary
- Week 8: Technical contents, freeze report
- Week 9: Final report submission
- Evaluation by teacher

Through this process, the students learn how to communicate and to act on issues regarding the collaboration. They aquire a common language for describing relations and behaviour that makes them able to discuss and reflect. They learn the SPGR tool (ref. chapter 3), enabling a complete overview of how the cooperation of a group works. The students learn through the project experience that group dynamics processes does not necessarily follow a particular pattern, such as Tuckman's theory (Tuckman, 1965).

The civil engineering students are assembled in groups of 3-5 in the program; the group size is discussed in Section 5. They are then assigned to concrete projects, where particular cases in or around the City of Trondheim are addressed. It is important that the cases are sufficiently challenging and interesting for the students to be motivated to use the whole spectrum of skills, knowledge and instincts to solve the tasks. The goal is that the students learn to be adaptable. Based on this experience, the students are more skilled in order to handle a less predictable world, according to NOKUT's vision formulated in previous section.

On the technological engineering level, the main purpose of the course is to perform proper research, to develop alternative solutions for the projects, to select and elaborate on the best alternative for the development of the area. The group work is performed for 9 weeks, and results in a development report for the solution strategy. The students address the group dynamics, the group processes and the individual performances in the team. The group dynamics is measured by the SPGR instrument during weeks no 3 and 7 in the work. They are given a short introduction to the team model and measurement instrument, similar to the description in Section 3. They reflect on what was going on in the group processes during the work, and on how these team characteristics influenced the work and the results. The motivation for this whole program is then to learn on a multi-level PBL training arena: the interplay between the real world problem, the technology and methods, the inter-human team relations, and the individual behaviour and performance.

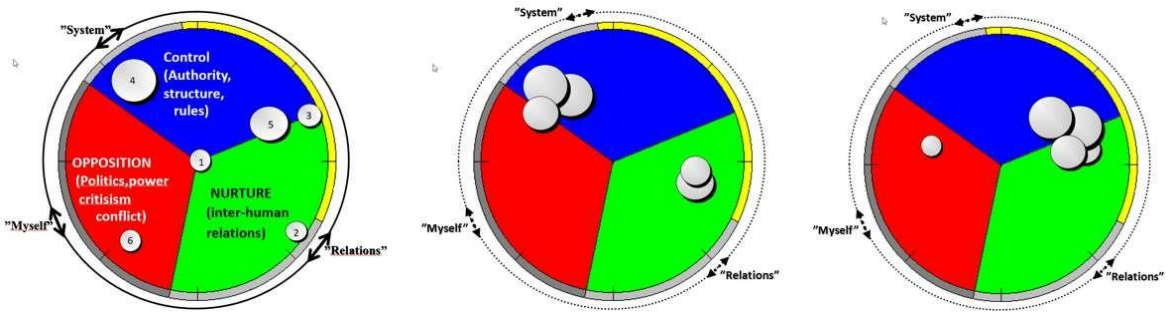
3 The Spin model for teams, a forefront model

The Spin model for teams is a team dynamics model based on behavioural science, presented in (Sjøvold, 2007), (Sjøvold, 2011), and (Sjøvold, 2013). The main concepts in the model are team dynamics, individual behaviour patterns, the Level of Purpose (LoP) of the team, and the context of the team. The Spin model is based on team building and team models resulting from 70 years of research. The main tool for instrumenting the Spin model is SPGR: Systematize Person Group Relations. The tool is well validated and have been used for analysing over one million team members in their team context. A main difference from many other widely used models, is that the Spin model does not focus on personality, but rather on context dependent behaviour. A person will typically adapt behaviour strongly to the context of the team, and this can both be changed and trained, as opposed to the much more stable personality. The tendency to focus on people's personality, and based on this

to assign roles to individuals in a team, has in fact proven to establish stigmatized behaviour, limiting the team dynamics and also reducing the potential for the team's LoP. Implementation of the PBL program include the use of SPGR.

3.1 Behaviour in teams

The Spin model includes four behaviour regimes: Nurture, Control, Opposition and Loyalty. In the spectre of Nurture type behaviour, we find both supportive, compassionate behaviour, and also more spontaneous ad hoc behaviour, that can create some uncertainty and distraction from the task solving team. The Control regime spans from authoritarian instructions to directed and proactive engagement for solving the tasks. The Opposition behaviour regime contains a series of obstructive behaviour, like resignation and irresponsible disregard and unfriendly stubbornness. The Opposition regime also contains useful behaviour for some occasions, like constructive protest. A certain portion of self-centred assertiveness can also assist constructive team dynamics towards top results, given that it is applied with proper timing and care, and in a responsive team culture. Loyalty behaviour is e.g. quietly performing the work agreed upon by the team.



a) b) c)

Figure 1: The Field Diagram from the spin model for teams, displaying examples of teams with different behaviour patterns. Each circle represents one individual; the behaviour is as perceived over some time.

We use diagrams (see Figure 1) from the Spin model to display measurements of the team behaviour, both on the individual level and for the team as an assembly. In the "Field diagram", we can display a collection of team members in terms of the behaviour perceived by their team mates. The position of the resulting circle for a particular person (the grey circles in Figure 1) is the result from adding eight vectors of different types of behaviour, based on 24 questions about how the person is perceived by the respondents. We show some examples in figure 1a. Individual no 1 (circle labelled 1 inside figure 1a) displays an equal mix of the three behaviour types Control, Nurture and Opposition. The small size of the circle implies that the person scores high on Loyalty, indicating that he is not very strong in any type of oral or pro-active behaviour; he will not be a very noticeable member of the team, other than the results of his work. Person no 2 has a strong tendency to act with a lot of empathy, and his behaviour is unbalanced in the sense that he is very little taskoriented. Person no 3 has a good balance between Control and Nurture behaviour, but shows no behaviour of the Opposition type, and is not very visible in the team (small circle). Team member no 4 is very noticeable in the team (large circle), and has a strong tendency to authoritarian behaviour. Person no. 5 has a good balance between all four types of behaviour. In fact, this is the average behaviour pattern when approximately 400 successful Norwegian

managers were evaluated by their surroundings. It is referred to as the "norm" of constructive team behaviour. Finally, the team member in position 6 is in a resigned state. His oppositional behaviour is very silent (small circle), and the person is probably not taking much part of the team as such. He is typically silently annoyed with everything that is going on, without any visible attempt of improvement initiatives. In the case example figure 2d and 2e, nuances of observed behaviour patterns for the regimes Control, Nurture and Opposition can be seen in the text outside the circles.

Analysing teams by measurements as described above, can lead to many hypotheses about the team. In some teams, the team members display a balanced spectre of behaviour, with a good mix of Nurture, Loyalty, Control and Opposition. In other teams, some members tend to favour or disfavour a particular regime of behaviour. A misbalance in behaviour pattern will often affect the effectiveness or effectivity of the team, changing the potential team results.

Figure 1b displays a team split in two subgroups. One subgroup claims that the rules are clear and do not leave any room for discussion, and that the work should be carried out straightforwardly without any discussion. The other subgroup finds the first subgroup too authoritarian, and wants to discuss the matter thoroughly, presumably irritating the first subgroup with a need to take another round on listening to everyone in this discussion. Intrigues, inconclusive discussions, inefficient communication, poor working atmosphere and lack of synergy-creating collaboration may be the result if the polarization is a sustained condition in the team. Finally, figure 1c displays a situation where most of the group members display an assembled behaviour with a proper balance between the different behaviour regimes, and everyone participates. The exception is the outlier, referred to as the scapegoat. The rest of the team will often blame that separated individual for any problems or mistakes in the team, and the situation will most certainly discourage and inhibit optimal teamwork. This situation is sometimes a systemic problem, rather than a particular difficult individual, but this is often not realized. Some very active team members may dominate the dynamics of the team, at the risk of suppressing others. The passive members may then display too much behaviour in the Loyalty regime. Having one or several passive members in the team often comes to the expense of effectivity and quality assurance in the group. The quality of the management behaviour can also be analysed by combining the manager's position in the group picture with the group's (varying) view of the manager's behaviour versus his/her view of own behaviour. The consensus, or lack of such, in the view of how well the group is functioning as a team, is vital information for the team developer.

3.2 Team Level of Purpose (LoP)

The Spin model for teams includes many useful terms, including the team Level of Purpose, which expresses the adaptive capability of the team. We briefly outline the concept here. The Spin model states that the more all team members are capable of flexibly varying their behaviour range, the more mature the team will become. Training the team members, and the team as an entity, on desired behaviour is therefore an important part of the team practitioner's activities. The required LoP is determined from the complexity and variation of the tasks the team is going to solve, and from the complexity and instability of the context inside which the team operates. These factors determine the required LoP for the team, and the idea is to develop the team's behaviour skills and maturity to at least match the required LoP. The LoP is a continuous variable, and the model outlines four LoPs as examples that characterize groups working with very different behaviour patterns. With increasing maturity, they are: Reservation, Team spirit, Production and Innovation. No team will operate on one distinct

LoP all the time; this will vary with the tasks and with time. The team will ideally only perform high-level dynamics when needed and may, if they work under stable conditions, perform simpler dynamics most of the time. The main point is that the team needs to master the LoP required by their context, and that this level is evoked when encountering challenging situations. The LoP concept provide possibilities for analysing, evaluating and suggesting improvements and training towards the level that fits the requirements for the team context.

The Reservation team LoP is also called an "I"-dynamics group. In this lowest of the LoPs, everyone focuses on themselves and on the contribution delivered from me to the group, or just directly to the team leader. Most members show a very restricted spectrum of behaviour, and typically, everyone masters the "Nurture" type of behaviour. In these teams, we will often observe a clear division between individual's roles. The Reservation team is efficient and effective if the tasks and context are highly predictable, particularly if management is performed with strong control, often in an authoritarian style. It is a prerequisite for success that the job is well defined, preferably with strict rules and standard operations that can be trained by drill. These teams do not have the dynamics required for improvements, and they are very fragile to external pressure, internal disagreements and changing conditions.

The Team Spirit LoP is termed a "we"-dynamics group, where all team members share a common responsibility for the team to obtain its objectives. The members are proud of their group, and they often view the team leader as a hero whose opinions are seldom questioned. The team leader usually directs improvements, if there are any. In addition to "Nurture", all members need to fill the "loyalty" type behaviour, sharing and helping the other team members and doing as they are told, and preferably not asking questions on the way they work, or on the leader's conclusions, or the way things are managed. The team often sees itself as complacent, and superior to its competitors, not taking many ideas from the outside, and the members often show a sceptical, or even hostile, view on other groups or external suggestions. The Team spirit group is result oriented and can be efficient under stable conditions, when the task is not too complicated, and it requires full mobilization of everyone's resources over a short time. The team spirit group needs serial short-term successes in order to keep up the spirit. The work is often regulated by procedures and standards, and the team will normally not challenge them by own initiative.

The Production team LoP is also referred to as the "us"-dynamics. The group is not as efficient as the team spirit group, but the team members can work patiently over longer periods towards a future target. An inherent ground rule is that it is fully acceptable to question the way they perform their work. The team members are encouraged and helped by colleagues in order to achieve success for the group and for the company. The Production team extracts much of its energy from open discussions on how the work can be improved and performed with better results. The demand for ideological leadership is no longer prominent, and the management style is open, democratic and inviting. The behaviour pattern is now more adaptive for all team members, and all members master each behaviour type, usually with the exception of constructive opposition. The team is quite adaptive, unless changes in the context are dramatically abrupt.

The Innovation team LoP is termed "Free flow" dynamics. This represents the highest LoP in these Spin model examples. An Innovation team is capable of creating genuinely new modes of working and of developing abrupt innovations in products, processes and concepts. The group dynamics enable a natural curiosity of the outer world, how things are done there, and how the world is developing. It is fully acceptable to question the group's status quo and its reason for being. The membership of the team is inherent for each member, even if he or she

leaves the group. There is no need for a leader in the classical sense. Every member is pro-active, and claims similar attention in the team. All team members master all behaviour regimes, and in a discussion, the behaviour pattern may change so rapidly that it is hard to determine which regime the team is operating at a particular time. In most cases, it will not be appropriate to develop an Innovation LoP in a Lean production group. Firstly, because it may be wasted efforts developing this high level, and secondly because lifting a group to Innovation involves a risk of generating instabilities in the team. On the other hand, the Innovation level may often be the optimal LoP for a leader group in a challenging business. These statements are indicative, however, and we need to consider each case while analysing the context, the stability of the surroundings and tasks, the individuals in the group, the nature of the tasks, etc. Note that research has shown that a team that are able to work on a high LoP can also be able to work on lower LoPs when required, but that this require training also on the lower LoPs, as well as awareness of these aspects.

3.3 Team building

Optimizing the performance of a team inside a particular maturity level is termed “team training”. One of the main aspects of the Spin model for groups is the strategies for lifting a team from one LoP to a higher one. This process is termed “team development”. Note that the Spin model flags some warnings on risks that may damage the teams in the team development process.

Many team-building agents use personality as the basis for analysis and for distributing roles in the team. It is vital to understand that the Spin model for teams addresses behaviour and the development of behaviour, which opens up large new perspectives for the team LoP and dynamics. Furthermore, many team builders work by taking the team out of its normal context and create events and experiences on new arenas. According to the Spin model for teams, this may be pleasant, frightening or inspiring, but research suggests that the possible learnings won during these events, are hard to transfer to relevant and sustainable competences in the normal working context. Team building will therefore be much more efficient when performed within the normal scope of the everyday work.

The team that aims at a high LoP needs to discuss regularly their strategy and general dispositions. A professional team should establish effective procedures to initiate and apply improvement projects. A democratic and involving process for goals and evaluation must be facilitated. We need to develop a culture where the capabilities of the members are utilized in an optimal manner. The team establishes ground rules, where suggestions for improvement are not only accepted, but also encouraged. The team leader must facilitate true teamwork where everyone seeks success, not only for oneself, but also for the other team members, for the team and for the organization. The team manager is responsible for creating arenas and bridges to the rest of the organization. This includes exchanging expectations, asserting that each team member understands their part of the larger game, in which the team in all manners aligns with the company, and that proper communication is flowing freely in the larger scope, like e.g. the company. Criticism and scrutiny is accepted and encouraged, and there are few lasting conflicts. The high LoP team takes action if individual members avoid their responsibility of tasks in the group or alignment towards the organization. The team is trained in broadening and adapting their behaviour pattern. Moreover, the ambitious team can be trained in accepting that continuous improvement is vital for success. In order to achieve this, we work both with culture, team LoP and behaviour patterns on the individual level and on the team level. The team is trained to evaluate itself whether they are properly aligned with the organization values, goals and improvement processes.

The information from the team analysis on behaviour and LoP can establish hypotheses on potential improvements for the group towards a suitable result. As team coaches, we then discuss and reflect upon these hypotheses in a feedback session with the team. The Spin model provides a language, by which the symptoms and consequences of non-optimal team behaviour can be detected and discussed. The team can investigate root causes to the team issues, elaborating possible solutions and select the best one.

4 The 2016 PBL course implementation

Veidekke is one the biggest contractors in Norway and is known for their focus on cooperation processes and their focus on the importance of "social interaction". Veidekke has been an important cooperation partner for this work and has exemplified how to be aware of "social interaction" challenges in projects and how challenges can be solved.

Veidekke has divided their project performance platform into phases "early stage", "implementation phase" and "operation phase". For the "early stage", we know that is difficult to predict the performance process. The "implementation phase" is expected to more predictable but in reality this is not always the case. Experience in Veidekke shows that even if similar jobs have been done many times before, circumstances lead to ambiguity for different process paths, which in turn lead to different cost, time and resulting quality.

They use a process called "obstacle analysis", with 6 topics that need to be addressed: 1. Project basis. 2. Expectations and requirements. 3. Degree of dialog. 4. Decisions. 5. The team skills 6. Methods and tools.

4.1 The student cases

The students were assigned cases, one for each team. The team size has varied from 3 to 5 persons. It is important that the cases are so challenging and so interesting that the students are motivated to use the whole spectre of skills, knowledge and instincts to solve the tasks in addition to the "pass/not pass" criteria for the subject. The challenge is divided in 2 stages:

1. "Early stage". The students have 4 weeks where they have to come up with a concept on a challenging problem.
2. "Implementation phase". The students must then make a plan for the last 4 weeks.

The expectation is that the students should produce more, and be more efficient, in the "implementation phase" than the creative "early stage" phase. The "obstacle analysis" is something that for Veidekke takes place all the way through a project. It is interesting to observe whether this is the case for the student teams.

The team assembly is made by random, and the students of 2016 were divided into 24 teams. The teams were assigned realistic problems concerning the city of Trondheim or surroundings. The case list of 2016 contained different cases, e.g. a local railway circle line, several local freight terminals, a wind turbine park, local transport, the concept of Trondheim centre without cars, floating concrete buildings, and several bridge projects. The assignments are divided into three main areas: "City themes", "Rural themes" and "Marine themes". In parallel with the specific content of the projects, the student teams all assess themselves by the SPGR group dynamic tool, and reflect on the group dynamics, the group interaction, and the work processes that led to the group

understanding, results and deliverance. During the nine weeks of work, they are assessed by SPGR in weeks 3 and 7.

There are some typical issues that repeatedly occur in the teams, that can be observed in a combination of SPGR data and students own observations, and that can be improved. Below, we mention some examples.

One typical situation is that some students are less proactive, and less dominating in the team, seen as small circles in the Field diagram. They are often contributing by loyally doing what is agreed, but they do not take out their full spectrum of potential team contribution.

A typical situation is a team where one or several of the members are separated from the rest of the team in the SPGR Field diagram. This was described as either “polarized team” or “scape goat” in section 3.1. The team should discuss whether this is recognized in the team behaviour, and whether this represents a decrease in effectivity and effectiveness. In some cases, it is discovered that the division is not real, but rather perceived by many group members based on prejudices or beliefs. These issues may be reduced, or even removed, by discussing common expectations and work procedures.

Are all team members displaying constructive team behaviour over time? This is represented by being inside the circle sector that is marked by yellow on the circle circumference. Research show that behaviour perceived outside this sector persistently over some time is inhibiting effective and efficient team work. Note again that this is not necessarily the subject team member’s own fault, but should rather be seen as a system flaw for the group to solve collectively. And note also that the behaviour is subjectively perceived in this manner by the group, which may have many subtle root causes based on the collective team culture. It is also interesting for the group to check whether they act assembled with a behaviour pattern separating significantly from the balanced behaviour expressed by the “Norm” mentioned in section 3. If the group has a tendency to act with too much/little Control, too much/little Nurture or too much or too little Opposition, this may well result in a non-optimal effectivity or non-optimal efficiency for the group work.

In general, it is interesting whether the team members recognize the behaviour patterns displayed in the SPGR diagrams, and whether the team members report similar behaviour patterns, or if they describe the team quite differently in the measurement. This will often lead to very useful reflections and changes towards common expectations and common views on effective group processes.

Finally, it is useful to discuss which Level of Purpose that is suitable in the two main stages in the team work, and how this is reflected by the actual work mode displayed in the group. If the team acts with a low Level of Purpose in the early stage of the project, the result may be that the group misses many opportunities in exploring and developing creative solutions that may be more effective than the straightforward one. On the other hand, if the group continues to behave creatively and discussing and scrutinizing the work methods they use, i.e. operating on a high LoP during the last stage of the work, they risk not being able to finalize their project in time, or they are forced to land abruptly on poor quality and lacking elements in their results.

Although much can be achieved by the students with their own reflections and discussions in the team, the result of the Bildung part will be strongly enhanced by the guidance of an experienced SPGR coach, and by objectivity checks by an external observer, commenting on the team behaviour, and on the team’s own evaluation compared to what the observer himself observes in the team performance. The teacher can take this role for the student teams.

5 Discussion and lessons learned

5.1 Discussion

The teams are selected and assembled by the teacher. This means that some students will feel that they have been let down by destiny, stuck with team members they either did not like in advance, by prejudice, or that they by first appearance perceive as someone that they do not like to collaborate with. First experience meetings create all sorts of stigmatisation, and with so short a working period, there is little time and motivation to straighten out these conditions. For some, this experience works well, and everything goes along a smooth line of project work. We can see this from their SPGR measurements, and by their final report, where they describe a good process with nice behaviour and positive collaboration. For some, the road is more than bumpy, and first impressions and different expectations, and perhaps perceived unclear instructions from the teacher, creates poor team collaboration, somewhat chaotic and slightly anarchistic – in the worst cases – behaviour, on a low team maturity level, where it is everyone for themselves. And some of them stay there through the process. The most interesting type of group is those that had clear problems in the beginning, but where the SPGR reflections obviously displayed to them some challenges, and where the discussions and clarifications made a change, and they worked more constructively and more mature in the second part of the work.

However, the groups for the first year appeared mostly to fall into one of the two first categories, and there was little change between the first and the second assessment. This is an interesting observation that require further comments, but also further work. The reason might be that the stigmas created in the group in the beginning led to static conditions that were either "good" or "poor", depending on the first notes, and on the motivation of the team members. Another reason might be that the groups that really needed to improve would have benefited strongly by closer follow-up by an experienced team coach, and that they did not manage to change although they observed some team challenges – or perhaps they did not even realize that there were problems, which again could have several reasons. A third reason for no positive change in some groups might also be due to poor motivation for the course, the project results, and for doing the job with improving the team. For some it may not seem to be worth the efforts it would take, and for some, they lack the human relation tools and experience to overcome the problems that inhibit better team work. A two hour class on team relations do not suffice for creating good team toolboxes. For some, the project served as a good training arena, and for some it didn't.

On top of this, most groups will have a need for a change of pace from the first to the second stage in the project work. The LoP will as mentioned need to go from high to low. The creativity will have to be surrendered in order to give way for the goal oriented work in the final period. This challenges the team further, urging them to being able to modify their behaviour balance between the stages. This is actually the true definition of team maturity: to be able to balance the behaviour assembled by the different behaviour types, adapting to what is required appropriately in the moment. A proper team maturity demands knowledge of these things, proper training and good common reflections on these issues. A better awareness of this from both the students and from the teacher needs to be a continuous focus, in order to succeed with the Bildung for as many as possible of the students.

Simmel (Simmel, 1955) showed already in 1955 that team over 5 person's use more time on coordinating activities than production. Student teams of 3 to 5 persons is therefore a good choice. When the number rises

to three persons and upwards, synergy effects, relation effects, communication and possible conflicts increase rapidly. This should mean that the more, the merrier - but also the more, the more complex and challenging. It is expected that groups of three demand more motivation and member qualities in order to create synergies and enhancing interaction. The relational part may not be as straightforward to understand as one could expect. Because although three persons is less prone to conflicts due to the low number of relations involved, it is also vulnerable to e.g. the effect of shyness, group think and relational based inhibitors. The last point means that if they match each other's behaviour dynamics well, three persons can be very effective. However, in the opposite case, three persons can probably be very inefficient if they enter a negative spiral of e.g. red (Opposition), grey (Loyal) or green (Nurture) behaviour, lacking the blue pro-active part that drives progress and results. It could be expected that four or five team members would be less vulnerable to such effects. Though we have not studied these effects in the programme, the group size of 3, 4 or 5 is an interesting parameter that could be investigated further in this particular programme.

5.2 Lessons learned

Summing up, we start with a clear observation that this programme is useful for the students' Bildung and understanding of relations in teams, the importance of the work processes in teams, and that training is very important to develop good understanding and skills in team project work.

We also conclude that the process draws the students out of their comfort zones, and that frustration is a word that often surfaces when the students report the project processes. The assignment is complex, as it addresses both scientific, analytical, work process and relational skills and issues. Frustration may be positive to release understanding and learning, but if a line is crossed where confidence towards the fellow team members or towards the teacher is broken, the learning effects may easily evaporate. One major key factor here, is that the teacher must have time to coach the processes to a certain extent, and to enter the team processes with interventions or strong counselling when a group is on the way into anarchy or chaos.

Communication, scope, rules and advice should be communicated clearly in the initial phase of the processes, and the students should be tutored on basic team relation models in the beginning of the process, in order to have tools to evoke when needed in the process.

The ideal for the initial stage is the innovation Level of Purpose, where the students should understand the problem fast and be innovative, questioning their working methods and even their raison d'être. In the final stage, the Team Spirit is probably the best level to work in, working in positive synergy without questioning the methods. In practice, the student groups will often start out in the Reservation level, improving into elements from the higher levels, without mastering fully the aspect of those. Much of the time, the best groups will work within the Team spirit level. Even if the effect of the exercise is limited, in training the teams to operate inside all these LoP's, it is possible for the teacher to explain what the levels are about, and what the students can do to improve. One of the major effects of this PBL exercise is that the students experience these circumstances and understands the challenges and the ideals. It is feasible to coach the students based on what they have done, things they could have done better or worse. The awareness of how social interaction works under different circumstances has been improved. Hopefully this is visible when they later work in multidiscipline and complex projects with many people, and also in simpler projects with less people. The students have got a basis and some tools for handling these challenges – and this is Bildung: The students have developed competence

with respect of project performance processes, teams and cooperation skills and done reflections around development of concepts which is important for the society to solve. It has been a clue during the process that the students have to do their own judgements. The students are encourage to be critical and use trust their stomach feeling in discussion and decision processes. With positive feedback based in what they have produced hopefully the society will see that they have got more adaptable and prepared for a more unpredictable world.

And finally, we will make a claim, that the Bildung is an underestimated part of the students' education, and that the current PBL engineer course is a step in the right direction, but that subjects like team relations, effective work processes, behaviour dynamics, constructive confrontation and conflicts should be given far more attention in future educational programs.

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Conceptualising first-year engineering students' problem-oriented work within the context of their study programme: exemplified by studies in Denmark and Brazil

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Abstract

Problem-based learning (PBL) is a pedagogical approach that has received worldwide recognition, especially within higher education, and it can be found in a large number of diverse models. However, a common denominator among these diverse models is the principle of 'problem-orientation', which is a backbone of PBL. Problem-orientation is the basis for the students' learning process in real-world engineering problems. This paper will conceptualise first-year engineering students' problem-oriented work within the subject context, framework and curriculum of their study programme, as exemplified by the programmes at Aalborg University, Denmark and the Virtual University of Sao Paulo, Brazil.

Keywords: problem-based learning, problem-orientation, first-year engineering students and study programme

1 Introduction

Looking into education in general '*the banking model*', as defined by Paulo Freire (1970), is still prevalent as '*education becomes an act of depositing, in which the students are the depositories and the teacher is the depositor*' (Freire, 2009 p. 72). This educational approach with the teacher as the narrator of a subject and students who listen to memorise the narrated content is anything but problem-based learning (PBL). As Freire argues, this teacher-centred approach must be rejected: '*they must abandon the educational goal of the deposit-making and replace it with the posing of the problems of human beings in their relations with the world*' (Freire, 2009 p. 79). Abandoning the banking model and implementing the posing of problems is one of the backbones of PBL, which is known as the problem-orientation.

This paper will begin with a theoretical definition of problem-orientation in a PBL environment. It will then progress through a description of the individual study programmes of the selected studies, at Aalborg University, Denmark (AAU) and the Virtual University of Sao Paulo, Brazil (UNIVESP). The aim of this paper is to conceptualise the following research question: *'What kind of problems are students able to formulate within the subject context of their study programme?'*

2 Introduction to the Cases

AAU and the UNIVESP are universities with somewhat large differences: they are located on different continents, they are in terms of age 40 years in difference, and one of them is exclusively an on-line university while the other is not. However, they do have many things in common; in particular, they have the same educational model, PBL, which is fully implemented throughout both universities.

AAU was inaugurated in 1974 and right from the beginning it was founded, at that time, on a rather novel educational concept, PBL. In August of 2014, the UNIVESP was inaugurated as the first virtual Brazilian University, it was also based on the educational concept of PBL.

2.1 The Aalborg University Case

Many attempts have been made to define the PBL concept. One of the pioneers was Howard Barrows, who in the late 1960s was involved in the early stages of the development of PBL at McMaster University in Canada. Barrow defined the concept in terms of specific characteristics as being student-centred, taking place in small groups, with the teacher acting as a facilitator, and being organised around problems (Du et al., 2003, p. 657). In Denmark, the PBL model was developed based on ideas from, among others, Illeris, '*who formulated the principles of PBL as problem-oriented, project work, inter disciplinarily, participant directed learning and the exemplary principle and team work'* (Kolmos et al, 2004, p. 10).

The Aalborg PBL model is a problem-based and project organised-model, which has gradually developed at a profession-based level. However, it is important to recognise that the model and its identified principles are by no means static or contextually isolated but should always be interpreted in the light of the broader context in which the model is to be implemented and applied. The principles that are acknowledged by Aalborg University are:

- Problem-orientation: Problems/wonderings appropriate to the study program serve as the basis for the learning process.
- Project organisation: The project stands as both the means through which the students address the problem and the primary means by which students achieve the articulated educational objectives. The project is a multi-faceted and often extended sequence of tasks culminating in a final work product.
- Integration of theory and practice: The curriculum, instructional faculty members and project supervisors facilitate the process for students of connecting the specifics of project work to broader theoretical knowledge. Students are able to see how theories and empirical/practical knowledge interrelate.
- Participant direction: Students define the problem and make key decisions relevant to the successful completion of their project work.
- Team-based approach: A majority of the students' problem/project work is conducted in groups of three or more students.
- Collaboration and feedback: Students use peer and supervisor critique to improve their work; and the skills of collaboration, feedback and reflection are an important outcome of the PBL model.

(Barge, 2010)

All students and staff act out these basic principles of PBL, which is a general characteristic of all studies at AAU.

2.2 The Virtual University of Sao Paulo Case

UNIVESP was the first truly virtual Brazilian University and it offers free Bachelor's degrees in engineering. All of the public Brazilian universities offer free degree courses. It opened in 2014, enrolling 1,296 students in the freshmen year, distributed in 19 cities of the State of Sao Paulo.

Although spread out in many fields and in different perspectives throughout Brazil, a complete problem-oriented curriculum in engineering had not been implemented in any Brazilian University before the creation of the UNIVESP. Since its initial conception and opening, the principles of a project and PBL curriculum has underlaid all of the discussions as a way to form engineers who have the skills and abilities that are required by modern society and education. The case that will be presented shortly will demonstrate how PBL has been concretised in the curriculum of this two-year old Brazilian university.

The five year programme of the engineering curriculum, adopting a project-based model, requires that during every semester the students should work collaboratively to identify, prototype and solve problems in their local communities. The didactic-pedagogic model of the Bachelor's degree at UNIVESP incorporates five complementary principles that seek to ensure that students have an education that is solid, creative and focused on personal and professional innovation, as follows:

1) Knowledge transmission: this is accomplished through pre-recorded video lessons with some of the leading experts in Brazil on the issues addressed in the courses.
2) Problem resolution: this solves real problems similar to those faced in the professional labour.
3) Interdisciplinary perspective: the students have to develop solutions for non-disciplinary problems through a project-based approach.
4) Collaborative and cooperative work: this is anchored on the importance of social learning, group learning, as a fundamental aspect for the co-creation and preparation to work in the professional.
5) Learning by doing: this relies on the design thinking methodology, problem and project-based learning and the *Maker* movement, which work together as an effective approach to solve complex problems and create innovations, articulating theory and practice.

All of these principles are supported by an e-learning platform that is designed with multimedia features that can integrate the convergence of different languages and is able to foster different students' abilities to participate, to interact, and to collaborate. Many ICT tools are used to implement the didactic and pedagogical model. They are chosen to support the academic principles adopted at UNIVESP and may vary according to the needs and demands of the courses and projects.

3 Methodology: Research Approach

The research approach in this paper will begin with a literature review of PBL, with special focus on problem-orientation. A review of the study programmes that have been selected as subject context for the investigation will also be included. The literature review is supported by empirical data consisting of problem formulations (student projects), which were collected among first-year students demonstrating problem-orientation through their project work.

Beginning in a theoretical definition of problem-orientation in a PBL environment, this paper will continue through a description of the individual study programmes (syllabuses and curricula) of the selected studies in AAU and the UNIVESP. Subsequently, some examples of the student's problem-oriented project work will be exemplified through the student's problem formulation (research questions). This paper will conclude in

a discussion of the student's ability to draw up real-lift problems as a means for learning within the subject context of their study programme.

4 The Theoretical Definition of Problem-orientation

The PBL concept is based on a dialectic interaction between the subjects that are taught in a lecture and the problems that are dealt with in the project work. The project-work may be organised by using a "know-how" approach for training professional functions, or it may be organised by using a "know-why" approach for training methodological skills of problem-analysis and application (Kjærsdam et Enemark, 1994, 2008). Furthermore, Mayo et al (1993) argue that PBL is a pedagogical strategy that can be used to pose significant, contextualised, real world situations, and which can provide resources, guidance, and instruction to learners as they develop content knowledge and problem-solving skills.

But what does '*problem-orientation'* mean in the context of a problem-based and project-organised approach? It essentially means that the starting point for the students learning process is a problem (Kjærsdam & Enemark, 1974; Quist, 2004; Kolmos, Fink & Krogh, 2004; Barge, 2010; Holgaard et.al., 2015; Guerra & Bøgelund, 2014).

There have been many academic discussions about 'what is a problem'. Overall, Kolmos (2004) argues that definitions of problems are diverse in different professional areas. Quist (2004) has located a variety of understandings from a literature review of diverse problem formulations. Basically, there is consensus that a problem can be initiated by a w*ondering, a problematic situation* (Quist, 2004; Guerra & Bøgelund, 2014) or an *un-explored potential* (Guerra & Bøgelund, 2014 with reference to Borrows & Tamblyn, 1980; Quist 2004; Jonassen, 2011):

- A wondering means is an observed phenomenon creating (qualified) curiosity (Quist, 2004), which can include situations, events, persons or a thing (Guerra & Bøgelund, 2014) that happened or happens, something heard and seen (Quist, 2004), or an uncovered need or wish (Guerra & Bøgelund, 2014; Quist, 2004).
- A problematic situation can, according to Quist (2004), be 'something you find, a scandal', 'a lack of knowledge' or 'a lack of function' and it can be caused by contrasts; that is, between a wish and reality, conflicts, contradictions (Guerra & Bøgelund, 2014; Quist, 2004). In the definition of a problem, Guerra and Bøgelund (2014) explain the understanding of a problematic situation as also comprising the students' sorrow and/or indignation, frustration or stress, making them act to change this problematic situation.
- An un-explored potential or an idea is also a possible starting point for the problem formulation.

Consistent with the Aalborg PBL model, the problem can be defined as theoretical, practical, social, technical, symbolic-cultural and/or scientific (Barge, 2010, p. 7). Depending on the type of problem and its starting point (a w*ondering, a problematic situation* or an *un-explored potential*), there is also a distinction between 'retrospective' or 'prospective' problem formulations (Holgaard et.al. 2015, p. 37), which can be characterised by:

- The retrospective problem formulation wants to find justifications and explanations for something that has already happened.
- The prospective problem formulation is designed to solve practical problems and to produce concrete solutions.

Besides the three defined starting points of the problem-oriented project work (a w*ondering, a problematic situation* or an *un-explored potential*) there is also the influence of the teacher, the framework of the study

programme, the academic discipline and the topic of the semester—the 'Semester Catalogue' and so on. All of these factors influence how the students identify real-life problems and how they document this through their project work. Different types of projects have been identified by (Kolmos, 1996; Graaf & Kolmos, 2003; Kolmos et.al., 2008; Holgaard et.al., 2015):

- Task projects: These are 'teacher selected' and the problem, method (an academic discipline), and possibly subject are chosen beforehand.
- Discipline projects: These are 'teacher directed' and the method, discipline and subjects are given beforehand. The students might have the possibility to choose subjects (themes) from a Project Catalogue. The students define their own problems within one of these given subjects, which fulfil the requirements of the study programme.
- Problem-based project: This is a problem-oriented project: *"The problem will determinate the choice of disciplines and methods"* (Kolmos et.al., 2008, p. 30) and the choice of subject (Kolmos, 1996, p. 142.) The students themselves choose the problem.

In summary, problem-orientation, as one of the pillar principles of PBL, cannot be described and categorised as one and only type of problem. Problem-orientation is a concept that relates to various different types of problems with different points of departure, implementing distinctive theory and methods, which are the means for solving the problem. This is documented by the students in their project work. Problem-orientation can be derived from:

- Different types of problems: theoretical, practical, social, technical, symbolic-cultural and/or scientific (Barge, 2010, p. 7).
- Different starting points of problem identification, such as a wondering, a problematic situation or an un-explored situation or idea.
- Problem formulations, which either look for explanations (retrospective) or solutions (prospective).
- Types of projects: such as task, discipline and problem-based projects.

A discussion on problem-orientation and how it can be identified from the cases will follow the description of the cases from the two universities (see Sections 4.1 and 4.2).

4.1 Problem-orientation in the Aalborg University Case

The Bachelor's degree in computer science at AAU begins with the students getting an insight into basic computer science, mathematics and the completion of a problem-oriented project.

In the first year, the students, in project teams, analyse and solve a problem within the subject field of software. They draw up a problem-formulation and qualify a research question where software programming can be included as part of the solution. The students must create a model of the problem and include relevant concepts, theory and methods for analysis and assessment of possible solutions. As part of the solution, the students must develop a small software program of high quality, which has to be documented in the project report.

The Study Programme of Computer Science

The overall learning outcome for the computer science students of the first semester project work is to achieve experiences with PBL related to programming and program understanding in order to build both software and project competences.

To get started, the first-year the students are introduced to the Semester Catalogue, which contains formal information on the study regulation and learning outcome of the project, this has an extent of 15 ECTS (ref.). The catalogue contains seven elective real-lift problems areas, of which the students can choose one as their problem to solve within the timeframe of the semester.

The students' learning outcomes from the first semester project are as follows. The student must be able to:

Knowledge:

- Understand and explain the theories and methodology applied for the analysis of the problem,
- Especially understand and explain the concepts of programming and modelling, which has been used for the project,
- Understand and explain the project's contextual circumstances.

Skills:

- Choose, describe and apply any of the PBL-course proposed methods of organising group cooperation and in resolving group conflicts,
- Apply concepts and tools for problem-based projects and reflect in writing to the problem-based learning in the context of the project,
- Disseminate the project results and the work in a structured and understandable way, as well written, graphic and orally.

Competence:

- Analyse a software problem and within this context draw up a problem formulation, where programming can be included as part of the solution.
- Create a model of the problem.
- Include relevant concepts and methods for analysis and assessment of project solutions in relation to the problem context. (Studieordning for Bacheloruddannelsen i Datalogi, 2013)

The seven possible areas of problems that the students can choose among are described as 'problem area, goal and examples of contextual questions and problems'. To exemplify the elective real-life problem areas 'Automating Visit Planning in Homecare' has been chosen as an example:

Automating Visit Planning In Home Care

In Denmark, many resources are spent to maintain and improve our welfare in society. Electronic systems can, in many cases, provide a more economic and timely service, therefore the services that are being offered citizens, are streamlined and modernised. Thus in recent years, the public sector has stepped up efforts to digitise public service offered in e.g. elderly care and health care.

The Problem

According to the Social Board the home care conducts more than 200,000 visits to the Danish citizens. Today home care staff plans most visits manually, which means a lot of work hours are spent on transport in between visits. Is it possible to automate the route planning, in order to optimise driving between visits? Here it is important to take into account knowledge of the needs of the individual citizens, the home carers work plan and transport, as well as the geographic landscape.

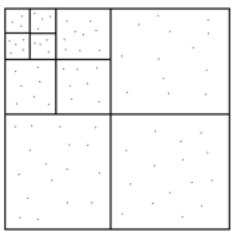
Goal

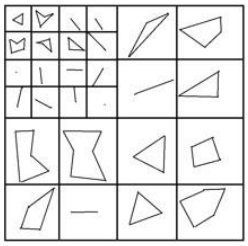
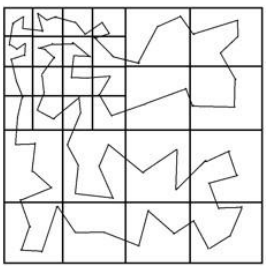
The goal is to develop and implement a model that automatically can establish an effective driving list (rout plan) for the home carer from the parameters that will be added to the system. These parameters could be employees of service of transport and skills, or the road journeys used in between visits. (Nørmark, 2013)

Based on this semester catalogue, a group of six students selected the Automating Visit Planning but they were not interested in the homecare area, instead they were interested in Post Danmark and their packages delivery system. With an increase in private persons shopping on the Internet, the amount of packages to be delivered is rapidly growing. The students wondered how Post Danmark was handling route planning and how well they were prepared for the rapid increase of packages. The students went to interview the director of the local Post Danmark and learned that what they had been wondering was a real-life problem occurrence every morning when the postmen were planning the routes of the day.

Package distribution at Post Danmark (Frandsen et al. 2014)

Initial problem	The problem in the present system at Post Danmark is that the software they have is only used to calculate routes for mail delivery. Routes for package delivery are handled manually according to the quantity of packages, which makes a route change from day to day. The postmen stubbornly make themselves accountable for the route planning because they are the ones loading the trucks in the morning. The packages are thus put into the truck in the order, which makes the most sense in terms of having to make a maximum effective route. When the individual postmen are managing routes plan, this can easily lead to someone choosing a route by habit. This often results in that a route that may be unnecessarily long. It also requires experience to be able to plan a route when the postmen reasonably should know the area to be able to do it properly. This manual route planning also results in the postmen having to work more hours and thus spend more time on the sorting of packages, which can result in delay. The longer routes also result in a higher fuel consumption, resulting in poorer economy for the postal service and negative influence on the environment.	
Context (Problem analysis)	Post Danmark packages delivery department The individual postmen responsible for the rout planning Stakeholder analysis	Interview with the local director of Post Danmark: Because the amount of packages differs from day to day, Post Danmark believes that is not possible optimised routes with a software solution, it simply takes too long to calculate the optimal route. Moreover, Post Danmark assumes that in about five years, Post Danmark will mainly deal with packages delivery, since packages are increasing rapidly as their main business. From the interview it can be concluded that Post Danmark lacks a method to plan an optimal route for packages delivery, in a very short time.
Problem	Research question	How can a (software) model be used for route optimisation in Post Danmark's packages delivery be prepared? This takes into account that it only applies to 100 addresses and is also considered for the route between two points being designed and

	Requirements specification:	directed elsewhere. • A package truck holds about 100 packages and, therefore, the calculated route could contain up to 100 points. • We take into account that the addresses on the packages are scanned into the program as coordinate points, and that they do not have to manually enter the information. • The program should come with a readable list of what order packages must be delivered so that the truck can be packed from this list. • The geographical breakdown occurs from Post Danmark. • The program should not guide the driver between two addresses, but must only take into account the travel time between the two addresses. • The program does not have to provide the fastest route, but just one that is close enough to the optimal route so that it will not give significant difference. • The program must find the route in less than one minute, so that Post Danmark will not experience delays.
Solution developed	Travelling Salesman Problem Graf theory Brute-force algorithmic	The first part of the Cluster Brute Force consists of a function to be split all the items in smaller groups so that there may be the shortest route within each group. We have chosen this feature to find the individual groups, one that divides the points according to their physical location. By dividing the area into four equal parts, in which points are located, until there are groups of 6 or less. The number 6 is selected as 6! = 720 while 7! = 5040 which are the calculations required to find the shortest route within each group. This can form groups where points are almost optimally close to each other that one can get the most optimal route.  Brute Force Function If the points are divided into groups, there must be the shortest route between the points of each route, as then to be put together to a greater route, the "snake" consisting of all the routes (see the figure). In this way, the calculation time for entire routing can be minimised, compared to if one would let a Brute Force be an example. 100 points, it is now only clearly 5 points 8 times, depending on the size of the groups, and the number of points.

		 When all the groups have found their internal shortest route, all of the groups are put together for a long route, which is based in the Post Danmark distribution centre (see the figure). This method has a 'lower driving a brute-force' but is not necessarily the most optimal route, although it is nearly optimal. 

4.2 Problem-orientation in the Virtual University of Sao Paulo Case

As stated previously, the project at UNIVESP is a mandatory semester curricular activity developed by groups of six students under face-to-face guidance by a tutor who is specially trained for this function by the pedagogical coordination and supervision of the major.

UNIVESP's academic coordination defines a theme for all of the students and this general theme will orientate the problem elaboration of each group. In the first year, in 2014/2015, the theme was: climate, environment and society.

The main goal of the project development in the first year is to lead the students to comprehend the engineer's role in understanding society, and to propose actions and strategies according to the reality experienced. To do so, in a central theme like climate, environment and society, we aimed to make them understand how environmental and climate changes have gained importance in today's society, at the same time as promoting the development of skills and abilities to find solutions for real problems that they identify in their surroundings.

Following the steps of the design thinking methodology and principles of the problem and project-based learning, the project development basically involves the following three essential phases:

1) Approach to the theme, elaboration and analysis of the problem.
2) Development of actions that lead to the resolution of the problem, through the creation of prototypes.
3) Socialisation of the knowledge produced, aiming to obtain feedback before the implementation of the prototype, and the production of a written report.

The groups organise weekly action plans of the project development under the reference of the three steps of the design thinking method, which are: listening, creating, implementing.

In the first stage—listening—, during the first three weeks, the groups choose a place to conduct their fieldwork and visit it to interview individuals and groups of people about the central theme of the project, which is: climate, environment and society. At this stage, they also observe people and their routines and bring all of the information to the tutorial session at the university. To identify the local situation and possible problems, in the third week the groups have to define the problem that they will work on to find a solution for the next 12 weeks.

In the second stage—creating—, sessions of brainstorming and discussions are performed; for example, to design solutions for the problem analyzed. Groups have up to the seventh week to create the first prototype of the solution.

At UNIVESP, in the eighth week we have a session called "Fishbowl", which is a method developed by Prof. Renate Fruchter at the Stanford University PBL Lab. In this session, two experts are invited to discuss the first prototype and mentor the groups to the further development of the solution. There is an iterative process in the next weeks, where the groups have to go to the fieldwork to show and discuss with the community the prototyped solution, aiming at its improvement.

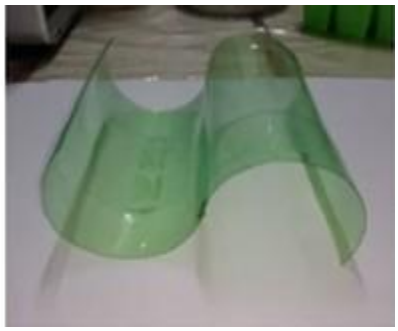
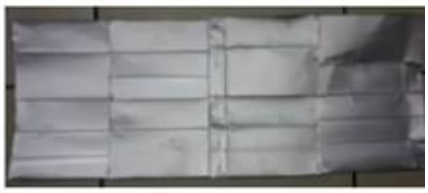
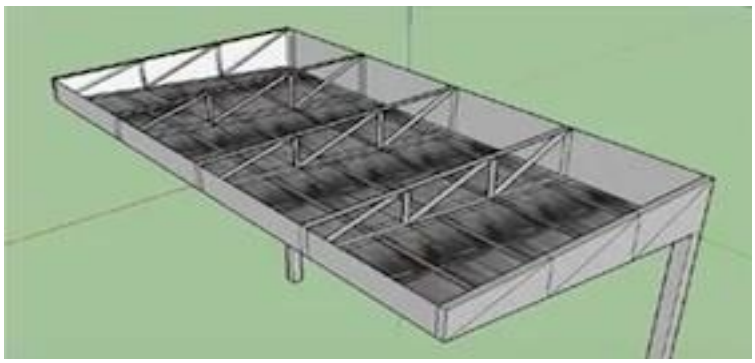
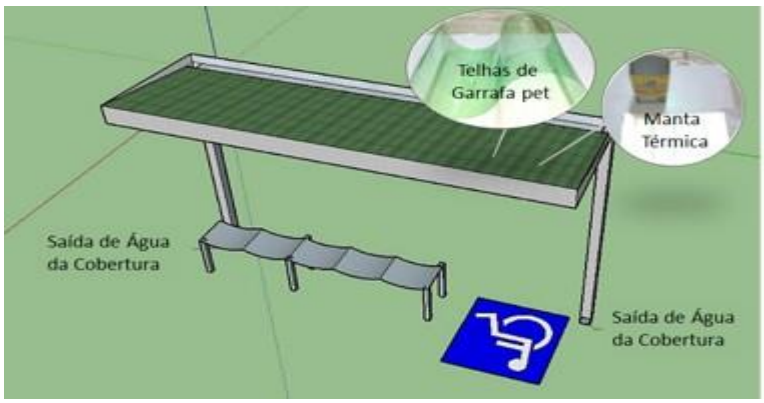
In the third stage—implementation—, the groups prepare prototypes of the best solutions created and carry out tests with the stakeholders. In this way, the solutions are fine-tuned and improved to meet the expectations and needs detected in the previous steps.

To evaluate this academic activity, at the end of the semester the groups deliver qualitative scientific reports that describe the development of the whole integrating project and the prototyping processes carried out in order to respond to the problems that have been studied. In addition, the prototypes that have been created are socialised by the group with other students and the community through videos that they have to produce and publish on YouTube (https://www.youtube.com/watch?v=r_dno3_BVOQ&feature=youtu.be).

We will next present one of the projects that the students developed to demonstrate how these students reached the goals of the project discipline, and how they could better understand the role of engineering in society and learn new skills and abilities:

A sustainable bus stop (Carvalho et al. 2014)

Problem	How to improve the conditions of a bus stop in order to bring convenience to the users of this public service?	
Context	The group identified that the biggest problem for bus users was the lack of coverage or a place to sit. Figure: Original bus stop	 

Solution developed	The group created a bus stop project consisting of a rectangular profile made of iron plate and a sustainable cover prepared with thermal blanket made of TetraPak® boxes, and tiles made with pet bottles Figure: Sustainable bus stop	     

5 Discussion

This article presents two different perspectives on a problem-orientated curriculum that is implemented in first-year engineering Bachelor's degree programmes. As the cases demonstrate, the students from both UNIVESP and AAU are very innovative in the identification of real-life problems. Even though their culture and subject contexts are very different, the problems that they develop are real-lift problems that they have identified in a social setting.

UNIVESP's curriculum is broad and open for the students to select problems within the field of sustainability and engineering. Aligned with Kolmos et al. (2008), this type of project is a 'problem-based project' that is based on problem-orientation where the problem will determine the choice of disciplines and methods, and where the students themselves choose the problem. At AAU, PBL subject knowledge is also part of the learning outcomes along with (software) subject knowledge. However, in the case of AAU, the problems that the students come up with are much more narrow and within the subject field of their study. This calls for a type of problem defined by 'discipline projects' where the method, discipline and subjects are given beforehand and where the students have chosen the subjects from a project catalogue. Even though the project catalogue inspires the students in the AAU case, they define a problem by themselves and the problem should meet the requirements of the study programme.

The problem formulation drawn up by the engineering students at UNIVESP (*How to improve the conditions of a bus stop in order to bring convenience to the users of this public service?*) has a starting point as a '*a problematic situation'*—the students have located a lack of functions or no function at the local bus stop. This led them to act to construct a sustainable bus stop. In the AAU case, the students draw up a problem formulation (*'How can a (software) model for route optimisation in Post Danmark's packages delivery be prepared?'*) that has its starting point in between 'a wondering' and 'a problematic situation' since the students, inspired by the elective problem in homecare, are wondering how Post Danmark manages to handle their everyday route planning. Based on this initial wondering, they identify 'a problematic situation' in Post Danmark who use entirely manual route planning. With a predicted increase in the number of packages in the coming years, the problematic situation seems likely to become worse in the near future. The lack of automation in route planning made the students' act to prepare a software solution to optimise route planning in Post Danmark's package delivery.

The two cases demonstrate that the students' enrolled in both study programmes show great abilities to identify real-life problems and solve them. Both cases can be recognised as 'prospective' problem formulations (according to Holgaard et al. 2015) because they are both designed to solve practical problems and to produce concrete solutions.

6 Conclusion

In this paper, we presented first-year engineering student projects in the context of their study programmes from both AAU and UNIVESP. The aim was to answer the question: 'What kinds of problem are students able to formulate within the context of their study programme?' In conclusion, the students' projects in UNIVESP are broad and open, and can be categorised as a 'problem project'. The AAU project can be categorised as a 'discipline project'. In both study programmes, the students are able to use their problem-orientated study to focus on identifying, prototyping and solving problems in their local communities, despite notable differences in the frames of the study programmes. The students are able to act out problem-orientation through identifying problems that can be recognised as 'a problematic situation' that emphasises a lack of functions in a social setting.

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Investigating students' perceived autonomy support, competence and relatedness, and the relationship to students' motivation to learn

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Abstract

It has been shown previously and for various contexts, that Project-based Learning (PBL) has potential to increase student motivation. In order to gain a deeper understanding of engineering students' motivation at an institution of higher education in the GCC (Gulf Cooperation Council) region, when exposed to PBL for the first time, a framework based on the self-determination theory (SDT) was chosen. This theory considers comprehensively the relationship between the motivation to learn and the satisfaction of perceived needs.

The aim of this study is to analyse students' perception on the three psychological needs of the SDT, namely, their learning autonomy, competence and relatedness, to fellow learners, when exposed to PBL for the first time. Furthermore, the relationship of the students' perceived needs to their learning motivation is analysed in order to improve further the application of a PBL approach within the socio-cultural context of the GCC region.

Based on validated survey instruments, students' perceptions are measured using a 7-point Likert scale, at the beginning and at the end of their first PBL experience. Descriptive and inferential statistics, as well as an analysis of correlations between the constructs of the framework and students' performance, are used to analyse students' motivation.

All constructs of the framework are perceived less positive at the end of the semester, except students' perceived competence that did not change during the exposure to PBL. Confirming Kübler-Ross's grief cycle, students seem to experience the frustration phase of the change to their learning environment. Recommendations to guide students through this challenging phase are given.

This study is part of an ongoing research effort related to novice project-based learners in the GCC region.

Keywords: Motivation, self-determination theory, project-based learning, first time exposure, GCC

Type of contribution: Research paper

1 Introduction

There is a lot of evidence that indicates that a PBL approach increases engineering students' motivation to learn (e.g. Davies *et al.*, 2011, Surif *et al.*, 2013). Also assessment approaches typical for a PBL environment, namely portfolio assessments, were found to increase student motivation (Linnakyla, 2001). However, much less evidence exists regarding students' motivation when exposed to active learning approaches in engineering programs in the region of the Gulf Cooperation Council (GCC).

Although a blended learning environment of a computer programming course at Qatar university was found to have a positive impact on students' motivation (AlHazbi, 2016), it was also found that students in

the GCC region prefer to be directed (versus self-directed). "In the early stages of tertiary education, students require or expect a 'spoon-feeding' approach to learning, with little or no critical thinking and no effort beyond the limits of what has been stated by the instructor" (Randeree, 2006). Students' rote-learning background seems to be a major challenge (Webb 2008).

Anecdotal evidence seems to indicate that, in general, a PBL approach in educational institutions in the GCC region is increasing the learning motivation of engineering students. However, how is their learning motivation affected when exposed for the first time to PBL? Does the change from a familiar learning environment to an unfamiliar learning environment affect their motivation? And what is the relation between learning motivation and influencing needs such as learning support, competence and relatedness with other students and learning performance? This study is aiming at answering these questions.

2 Research Background

Although acknowledging the positive impact on students' performance, it has been found that a change of learning environment towards a more student-centered learning is usually met with student resistance (Keeney-Kennicutt *et al.*, 2008; Maceiras, Cancela, Urréjola, & Sánchez, 2011; Smith-Stoner & Molle, 2010). However, it was also realized that the resistance can be resolved over time (Keeney-Kennicutt *et al.*, 2008). Douglas and Chiu (2012) explained that students assume their instructors to be experts and to be their main source of knowledge, and that this leads to a tendency to resist active learning.

In order to assess students motivation to learn during a period of change, the Self-Determination Theory (SDT) has been chosen as a framework since it has been shown that meeting the human needs for autonomy support, personal competence and relatedness to other humans, increase students' motivation to learn (e.g. Ryan and Deci, 2000; Koh *et al.*, 2010). Furthermore, the cross-cultural generalizability of the theory has been shown by a study carried out in South Korea (Jang *et al.,* 2009). The SDT distinguishes different types of behaviour regulation based on the degree of self-determined (i.e. autonomous) versus controlled behaviour. When humans are self-determined in their behaviour, this is considered to be a consequence of their intrinsic motivation; whereas a less autonomous and more controlled behaviour reflects a stronger extrinsic motivation. The SDT suggests that stronger internalized motivation leads to more self-determined behaviour.

Four different types of behaviour regulation have been defined (Ryan and Deci, 2000) and reflect a tendency from least internalized behaviour to fully internalized behaviour: external regulation, introjected regulation, identified regulation and integrated regulation. External and introjected regulation reflect relatively *controlled* forms of extrinsic motivation, whereas identified and integrated regulation reflect relatively *autonomous* forms of extrinsic motivation. For more details and background on the SDT, as well as the fact that amotivation (i.e. behaviour is neither intrinsically nor extrinsically motivated) is included in the SDT, the reader may refer to Ryan and Deci (2000).

3 Purpose and Methodology

The purpose of this study is to answer the following questions:

1) How does first time exposure to a PBL approach impact the learning motivation of engineering students?
2) How does the exposure influence students' perceived needs, such as perceived autonomy support, perceived competence and relatedness to other students?

3) Is there any correlation between a student's GPA, their perceived needs and their learning motivation?
4) If there is a correlation between a student's GPA, perceived needs and learning motivation, how is it affected by the first time exposure to a PBL approach?

In order to answer these questions, a survey tool was developed and administered at the beginning and at the end of students' first course utilizing a PBL approach. The tool and its application are further explained in the following sub-sections.

3.1 Perceived Autonomy Support

In order to collect data showing students' perceived autonomy support (PAS), the Learning Climate Questionnaire (LCQ) was used (LCQ, 2017). The short form of the questionnaire, with a scale containing six items, has been applied here in order keep the number of questions as low as possible, since experience with previous data collection has been shown to reduce reliability with increasing number of questions. This questionnaire is an appropriate tool for the purpose considered here since it was developed for specific learning settings (i.e. here: the first PBL experience of students) at the college level. The questions had to be adapted slightly in order to assess the perceived general support by instructors during the previous two years of students' studies (versus only one particular instructor) and are shown in Table 1. All of the subjects students studied in the previous two years of their studies were not based on a PBL approach. The score is calculated by averaging the individual scores of the six items, and a higher score reflects a higher level of perceived autonomy support.

Table 1: Survey questions related to the perceived autonomy support.

1.	I felt that my instructors provided me choices and options
2.	I felt understood by my instructors
3.	My instructors conveyed confidence in my ability to do well in the course
4.	My instructors encouraged me to ask questions
5.	My instructors listened to how I would like to do things
6.	My instructors tried to understand how I see things before suggesting a new way to do things

3.2 Perceived competence and relatedness

In order to measure students' perception of competence and their relatedness to other students, the two subscales "perceived competence" and "relatedness" of the Intrinsic Motivation Inventory (IMI) have been used (IMI, 2017). This inventory was developed to assess subjective experiences (IMI, 2017) and the validity of the IMI has been confirmed before (McAuley, Duncan and Tammen, 1989). Previous research suggested that including or excluding specific subscales from the IMI has no impact on the other subscales which allows to utilize only the subscales of interest for the purpose of the study (IMI, 2017). Although the original subscale "perceived competence" consists of six item scores, it was decided here to merge the items "I am satisfied with my performance at this task" and "I was pretty skilled at this activity" to "I am satisfied with my performance" since the survey was not aiming at one specific task. The subscale "relatedness" consists of eight item scores, and the wording of all items of both subscales was adjusted slightly in order to make the questions relevant for the context considered here, and they are shown in Table 2. Item scores of both

scales are to be averaged in order to receive the two subscale scores. For more details, as well as the requirement of reverse scoring some of the items shown, the reader may refer to IMI (2017).

Table 2: Survey questions related to perceived competence and relatedness

Perceived competence:
1. I think I am pretty good in engineering
2. I think I am pretty good in engineering, compared to other students
3. After studying engineering for a while, I feel pretty competent
4. I am satisfied with my performance
5. I could not do very well in my learning
Relatedness:
1. I felt really distant to one (or more) of my colleagues
2. I really doubt that one (or more) of the colleagues and I would ever be friends
3. I felt like I could really trust one (or more) of my colleagues
4. I would like a chance to interact with one (or more) of my colleagues more often
5. I would really prefer not to interact with one (or more) of my colleagues in the future
6. I do not feel like I could really trust one (or more) of my colleagues
7. It is likely that one (or more) of my colleagues and I could become friends
8. I feel close to one (or more) of my colleagues

3.3 Learning motivation

In order to collect data reflecting students' motivation to learn (i.e. the reason for learning), the Learning Self-Regulation Questionnaire (SRQ-L) was used (SRQ, 2017). This questionnaire was developed for older students (versus children), and consists of two subscales "controlled regulation" and "autonomous regulation". The questionnaire was validated earlier (Black and Deci, 2000). The wording of the questionnaire had to be adjusted slightly in order to match the purpose considered here, and the adjusted questionnaire is shown in Table 3. The scores are calculated by averaging the scores of the five items reflecting the autonomous regulation (i.e. items 1, 4, 8, 9, 10), averaging the scores of the seven items reflecting the controlled regulation (i.e. items 2, 3, 5, 6, 7, 11, 12). Subtracting the average scores of the controlled subscale from the average scores of the autonomous subscale provides the Relative Autonomy Index (SRQ, 2017).

Table 3: Survey questions related to students' learning motivation

I will participate actively in my engineering learning:

1. Because I feel like it's a good way to improve my understanding of engineering
2. Because others might think badly of me if I didn't
3. Because I would feel proud of myself if I did well
4. Because a solid understanding of engineering is important to my intellectual growth

I am likely to follow my instructor's suggestions for learning engineering:

5. Because I would get a bad grade if I didn't do what he/she suggests
6. Because I am worried that I am not going to perform well in learning
7. Because it's easier to follow his/her suggestions than come up with my own learning strategies
8. Because he/she seems to have insight about how best to learn

The reason that I will work to expand my knowledge of engineering is:

9. Because it's interesting to learn more about engineering
10. Because it's a challenge to learn engineering
11. Because a good grade in engineering will look positive on my record
12. Because I want others to see that I am intelligent

3.4 Survey administration and context

The same survey was administered two times to students of the same subject by using Survey Monkey during students' scheduled class time. The first administration (pre-test) took place in week two of the semester, with 182 students participating, and approximately 70% male students and 30% female students. The second administration of the survey (post-test) took place in week twelve of the semester, with 149 students participating, of whom 139 students participated in the pre-test in week two. Questions related to the perceived autonomy support, perceived competence, relatedness and learning motivation were to be answered on a 7-point Likert scale, and in addition demographic data was collected.

The course considered here is the "Engineering Skills" course at a private university in the GCC region. It is a mandatory course for all civil and mechanical engineering students during the first year of their degree level studies after finishing a 2-year diploma level engineering program. The Learning Outcomes of the course are shown in Table 4.

Table 4: Learning Outcomes of the considered "Engineering Skills" course

1	Discuss the role of a professional engineer within a business environment, showing an appreciation of the interactions between the technical aspects of the role and the social, cultural, environmental, economic and political contexts.
2	Investigate and select materials and processes for engineering applications and justify decisions made.
3	Apply information literacy skills and information technology skills to engineering projects.
4	Use drawing, modelling and simulation tools to analyze and present project outcomes.
5	Describe, apply and justify risk assessment and workplace health and safety in engineering activities.
6	Design, conduct and report on practical activities, including devising appropriate measurements and procedures, analyzing and interpreting data and forming reliable conclusions.
7	Articulate an appreciation of the complex nature of engineering activities including ill-defined situations and problems involving uncertainty, imprecise information, and conflicting technical and non-technical factors.
8	Articulate and demonstrate personal application and development of the practice of professional engineering, including a professional attitude, problem solving skills, relevant technical knowledge, productive work practices and a commitment to lifelong learning.
9	Provide evidence of a professional capacity to communicate, work and learn; individually and in peer learning teams.

Students worked and learned in multidisciplinary teams of 4-5 civil and mechanical engineering students, based on an ill-defined project brief that described client requirements for the design and building of a flume ride model. Students' learning and working was facilitated by learning facilitators during six scheduled class and workshop sessions per week, and a competition in week 13 identified the most successful design and production of the flume ride model. In addition to formative assessments (feedback) throughout the semester, students were required to submit an individual portfolio at the end of the semester for summative assessment. Students' portfolios included a Reflective Journal, Workbook, Technical Drawings, Peer Assessment and an Individual Grade Nomination.

The following section will present the survey results and results analysis.

4 Results

The descriptive statistics of the five sub-scales, as well as Cronbach's Alpha, are shown for both the pre-test and post-test in Table 5. Cronbach's Alpha was calculated to investigate the internal consistency of the used sub-scales (Santos, 1999). The correlations between each sub-scale and the sum of the remaining sub-scales was for both tests larger than 0.6. This means, the internal consistency of all five sub-scales are at least marginally reliable; according to Cohen, a coefficient of smaller than 0.6 would be considered unreliable (Cohen 2011, p.640). The high dependency of Cronbach's Alpha from the outliers of a specific sample has been shown before (Liu *et al.*, 2010).

Table 5: Mean, standard deviation and Cronbach's Alpha of sub-scales.

	Perceived Autonomy Support	Competence	Relatedness	Autonomous Regulation	Controlled Regulation
Pre-test:					
Mean	5.2	5.1	4.9	5.8	4.7
SD	1.1	1.0	0.9	0.9	1.0
Cronbach's Alpha	0.795	0.686	0.608	0.676	0.648
Post-Test:					
Mean	4.8	5.1	4.7	5.6	4.6
SD	1.5	1.0	1.1	1.0	1.2
Cronbach's Alpha	0.903	0.704	0.736	0.694	0.783

A comparison of means between the pre-test and the post-test shows that the perceived autonomy support, relatedness, autonomous regulation and controlled regulation are perceived to be lower than at the time of carrying out the pre-test. However, in order to test if there are significant differences between pre- and post-test results, a two-tailed *t*-test for two samples was carried out. Following common practice for situations where effect size and sample size cannot be increased and a low risk of error is aimed for, it was decided to set $\alpha = 0.1$ (Lipsey 1990). The result of the *t*-test is shown in Table 6. Row one of the table shows the sub-scale, row two the degrees of freedom, row three the *t*-value, row four the critical value for alpha = 0.1 that the *t*-value has to exceed to be statistically significant, and row five shows the associated *p*-value. It is apparent that only the perceived autonomy support, relatedness and autonomous regulation sub-scales reflect a statistically significant difference between the pre- and post-test, although, confirming the mean values in Table 5, all three aspects are perceived less pronounced (negative *t*-value) than during the pre-test.

Table 6: Results of two-tailed *t*-test for post- versus pre-test

	Perceived Autonomy Support	Competence	Relatedness	Autonomous Regulation	Controlled Regulation
df	267	315	282	300	293
t-Value	-2.48	-0.1	-2.23	-2.06	-0.88
Crit $t_{0.90}$	1.65	1.65	1.65	1.65	1.65
p-Value	0.01	0.92	0.03	0.04	0.38

Since one purpose of this study was to identify if there is a correlation with a student's GPA, correlations of learning motivation (here reflected by the Relative Autonomy Index, c.f. section 3.3), perceived needs (i.e. perceived autonomy support, perceived competence and relatedness) and students' GPA are shown in Table 7 for the pre-test results. When considering only values larger than 0.3 as indications of moderate correlations, it is apparent that a student's GPA correlates only moderately with students' learning motivation, but not with perceived autonomy support, perceived competence and relatedness. In addition, there are moderate correlations between perceived autonomy support and perceived competence, perceived autonomy support and relatedness, and between perceived competence and relatedness.

Table 7: Correlations between perceived needs, GPA and relative autonomy (pre-test)

	Perceived autonomy support	Perceived competence	Relatedness	GPA	Relative autonomy
Perceived autonomy support	1				
Perceived competence	0.338289	1			
Relatedness	0.306669	0.312806	1		
GPA	-0.00494	0.110187	0.166196	1	
Relative autonomy	0.059019	0.265426	0.268277	0.295703	1

Correlations of the post-test results are shown in Table 8. Comparing with the results of Table 7, it is apparent that the correlation between perceived autonomy support and relative autonomy increased from 0.06 (i.e. virtually no correlation) to 0.24 (weak correlation). The correlation between students' perceived competence and relative autonomy increased from 0.27 (weak correlation) to 0.35 (moderate correlation).

Table 8: Correlations between perceived needs, GPA and relative autonomy (post-test)

	Perceived autonomy support	Perceived competence	Relatedness	GPA	Relative autonomy
Perceived autonomy support	1				
Perceived competence	0.333653	1			
Relatedness	0.142321	0.322067	1		
GPA	0.011379	0.147195	0.082149	1	
Relative autonomy	0.238508	0.345554	0.114741	0.29254	1

These and the previous results shown above will now be discussed in the following discussion section.

5 Discussion

The first research question to be answered is related to the impact of the PBL approach on students' learning motivation. The results shown above seem to indicate a significant decrease of perceived autonomous regulation which may be related to students' definition of learning. Obviously, students did not memorize as many facts as in traditional courses and the lack of written assessments such as exams may have contributed to a perception that they did not improve in understanding engineering concepts or intellectual growth. The perception of reduced learning may have contributed to students' perception that

their interest in engineering did not increase. The students of this study did not perceive the challenge of engineering work as a reason for expanding their knowledge of engineering, which might be a consequence of being unfamiliar to the PBL approach. Furthermore, the self-directed learning approach may have caused students to perceive their facilitator as not having insights into how best to learn. Students' statements along the line "You are the teacher, you should tell us" confirm this interpretation. Finally, the result of decreased perceived autonomous regulation seems to confirm earlier findings of decreasing learning motivation and higher a-motivation of low achievers among first year STEM students (Van Soom et al. 2013).

Regarding students' perception on how their PBL experience influenced their needs for perceived autonomy support, perceived competence and relatedness (second research question), the following can be said. Students' perception of autonomy support and of relatedness decreased significantly. Both aspects were clearly more pronounced than in previous traditional learning approaches, but the open and self-directed learning process may have confused students. The self-directed learning approach incorporated much more autonomous learning and decision making, and their team work included much more relatedness with other students. Also, in line with some individual feedback that was received from some students, students may not have seen their facilitator as "encouraging mentor". This interpretation is in line with results of a previous study analysing students' needs among engineering students when learning based on computer simulations; it showed that perceived lower autonomy support leads to lower intrinsic motivation (Tan et al. 2009). The result may point towards a clear need for more preparation of students for the PBL approach and more professional development of PBL facilitators. Regarding the need for relatedness, team conflicts and frustrating experiences with peers may also have contributed to the perception of students to have a lower need for relatedness towards the end of the semester. Another reason may have been the fact that the facilitators assigned randomly students into teams in order reflect workplace situations in which superiors usually assign engineers to project teams. However, being "forced" to work with unfamiliar colleagues may have increased students' need for relatedness, which was also found by a previous study (Herman et al. 2015).

Regarding the third research question, an increase in correlation between perceived autonomy support and relative autonomy was observed. This may be again a consequence of the common perception that the instructor is responsible for students' learning. Since students perceived a decreased autonomy support during the semester, they also perceived a reduced regulation of their learning behaviour (i.e. reduced learning motivation). At the same time, the correlation between students' perceived competence and relative autonomy (i.e. the difference between autonomous regulation and controlled regulation) increased slightly. Looking at the mean values in Table 6, this may be explained with a virtually constant perceived competence and an almost constant relative autonomy. Since both the autonomous regulation and the controlled regulation decreased, the relative autonomy is almost the same as at the beginning of the semester.

Regarding the fourth research question, no moderate correlation could be identified and, therefore, no interpretation is attempted here.

Of course, since students reported their own perception, caution is required when interpreting these results. Influences such as reactance or other psychological dynamics may have had a strong impact (IMI, 2017). However, from the data collected and analysed here, neither an improved learning motivation, nor a perception of an increase in needs being met can be derived.

A summarizing interpretation would be that students considered here are still in the earlier phases of the change process from traditional teacher-centred rote-learning to PBL. Based on her work with terminal ill patients, Kübler-Ross (1969) identified five phases of emotions prior to death: Denial, anger, bargaining, depression and acceptance. These phases appear more or less pronounced in many change processes and have been adjusted for numerous contexts since then (e.g. change management, Figure 1). Since the change of learning environment requires from all involved stakeholders to go through a change process, it can be expected that engineering students follow a somewhat similar change curve when changing from traditional learning approaches to PBL.

Figure 1: The Change Curve (Source: National Leasing, 2017)

It was shown earlier that students within a cultural context as the students studied here need sufficient time to experience and to get familiar with a PBL approach (e.g. Jaeger and Adair, 2016). In his study about introducing process-oriented guided inquiry learning (POGIL), Radhi (2013) summarized the following recommendations in order to improve student acceptance of the learning approach:

a) More involvement of the communication department in the marketing of educational goals may be required, as faculty may not have the time or capacity to do that effectively;

b) More engagement of class representatives might help in establishing a common understanding and facilitate good informal communication with students;

c) Students need be trained on the requirement of the POGIL classes (e.g. writing reflection) before these classes are delivered;

d) To attend the limitations and lack of resources, POGIL classes should be integrated within the existing compulsory teaching events;

e) POGIL activities, setting and incentives should address the individual differences in students' cognitive skills; and,

f) More frequent project review meetings and institutional-wide action learning sets are needed to promote change agents' innovation and productivity. (Radhi, 2013)

The same recommendations seem to be adequate in order to guide students through the early phases of the change process from traditional learning to PBL.

Knoster showed that six elements are necessary for successful change: Vision, Consensus, Skills, Incentives, Resources and Action Plan (Thousand and Villa, 1995). If one of these elements is lacking, it will have a negative impact on the change process. For the context considered here this may mean that opportunities to strengthen these elements among students and PBL facilitators should be investigated. Jaeger and Adair (2013) provided evidence for the importance of repetitive explanation of learning outcomes to PBL students throughout the semester. From the findings presented here, the same might be true regarding vision and incentives.

In addition to the recommendations above, curriculum changes towards earlier exposure to PBL as well as changing towards an institutional PBL model should be investigated. However, this would require that existing constraints and regulatory requirements allow for such changes.

6 Conclusion

Engineering students' perceived needs (perceived autonomy support, perceived competence, relatedness) as well as their perceived learning motivation (autonomous regulation, controlled regulation) were collected through a survey at the beginning of a course utilizing PBL and at the end of the same course. A decrease in both constructs was observed. Since the collected data is only covering the first semester of students being exposed to PBL, it is not sufficient to present a more encompassing conclusion. It can only be speculated that, first, there is a need for both, training for PBL facilitators and a better explanation of the PBL approach to students and, second, that the negative trend is part of the early phases of the change curve described earlier. This study is part of an ongoing investigation of motivation of engineering students in the GCC region when exposed to PBL. A future study will investigate the trend when students experience PBL during the remainder of their undergraduate studies.

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Student challenges when learning to become a real team in a PBL curriculum: Experiences from first year science, engineering and mathematics students

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Abstract

This paper analyses the Process Analyses of student groups from three engineering, science, and mathematics programmes to detect the issues students find challenging, how they either have coped with or solved them during the project work, and how efficiency and effectiveness have evolved over the semester. Additionally, we use the Process Analyses to measure the quality of the group work undertaken to identify issues worth addressing e.g. in the PBL course taught during the first semester. We apply the theory of Katzenbach and Smith (1993) to analyse and describe the groups. Based on the analysis, we identify four different types of groups ranging from pseudo teams to high performance teams spanning across all the programmes. Overall, all groups experienced issues such as lateness, distribution of work, different personalities and abilities, conflicts, overview, time management, distribution of work load, knowledge sharing, long time absence due to illness, or drop-out. We also found that some groups could take advantage of their mutual differences, reflectively apply the project management tools they learn in the PBL course, solve the conflicts they experience, and develop their knowledge sharing.

Keywords: PBL, process analysis, student challenges, real teams, high performance teams

Type of contribution: Research paper

1 Introduction

The teaching at Aalborg University (AAU) is organised around the principles of project- and problem-based learning (PBL), and each semester the students spent half the time in groups of usually three to eight students (in the first year, six to eight students) working together on a PBL project relevant to their subject. To aid the students' project work, each group is assigned a supervisor, who acts as a facilitator during the semester and as internal examiner at the exam. The other half of the time, the students attend more traditionally organised courses. The projects are assessed by the end of each semester. As part of the assessment at the first year of study, the groups are obliged to submit a Process Analysis, which is a five-to-ten-page document mainly reflecting on group collaboration, project and knowledge management, and collaboration with the supervisor. This Process Analysis is taken into consideration when determining the students' grades. During the first semester, the students have a 5 ECTS course in PBL providing them with tools for management and reflections regarding the issues mentioned (Mosgaard and Spliid 2011). In this sense, the teaching at AAU is unique. Aalborg University has been an innovator and world leader in problem- and project-based learning in engineering, science and mathematics ever since the beginning. Henceforward, it is of broader interest to scrutinise and reflect upon the educational teamwork experiences that can be extracted from the AAU PBL approach (Kolmos et al. 2004, de Graaff and Kolmos 2007, Barge 2010, Askehave et al. 2015).

The three authors teach the above-mentioned PBL course and act as co-supervisors for student groups from several programmes. Our experience told us that student groups often struggle with challenging issues during the first year of study, although all groups manage to complete and deliver a technical report. Issues are manifold such as students not keeping a deadline or being late for group meetings; dominating students or the opposite, passive or overly social students; conflicts that are not addressed; and working conditions that maintain a high pressure on the group, leading to stress management issues. There are also sometimes problems with supervisors; typically, if students find the supervisor not active enough or too 'bossy'. Another typical group issue is lack of awareness that time management and the ability to prioritise tasks is essential for an efficient group. The students usually learn the hard way that this is essential even though the above-mentioned course introduces them to useful practical and managerial tools. However, the issues mentioned are based on anecdotal evidence and did not provide us with a framework for determining a natural progression in teamwork behaviour for groups.

Therefore, the paper will aim to identify and discuss what kind of issues and challenges student groups experience during the first semester of their university education, and measure the quality of the group work by analysing the Process Analyses of student groups from three engineering, science, and mathematics programmes. The paper will apply the theories of Katzenberg and Smith (1993) concerning high performance teams.

2 Five stages of team performance and their characteristics

For team members and teams – as well as for supervisors – recognising when a team is doing well is important, especially since the workings of a real team, let alone a high performance team, are not always obvious or intuitive to everyone. Katzenbach and Smith (1993) identify five different types of teams of which the first two are not really teams, but either a group of individual people collaborating on a shared issue or

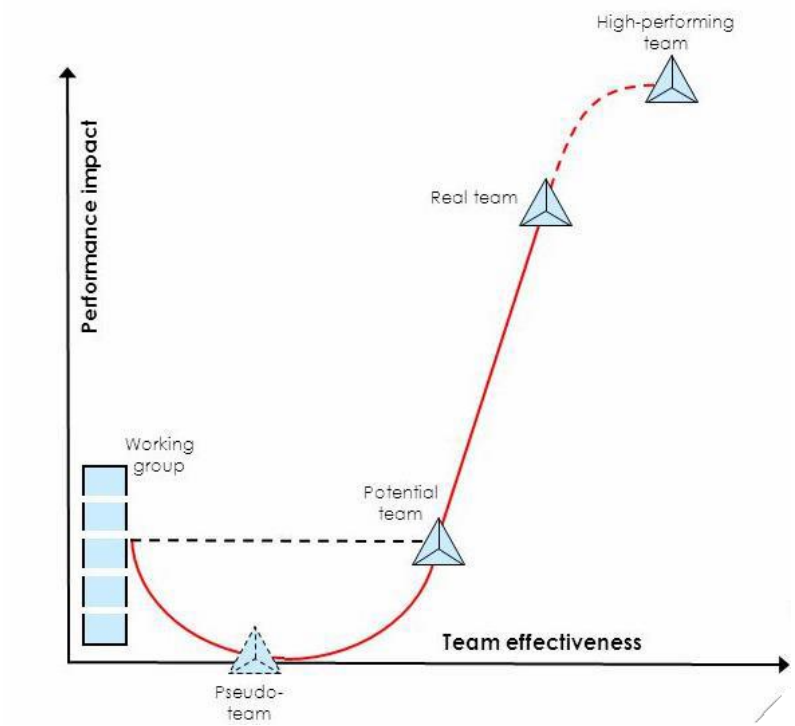

Figure 1: Five stages of team performance (Katzenbach and Smith 1993).

a group of individual people, who speak and act as if they are committed to the same goals without being truly united on the performance goals (see Figure 1). The third kind of team is a potential team, which is a group of individual people who are on the cusp of having a common purpose and goal. They also recognise the need for collective activities and achievements, and acknowledge and accept the collective need for mutual accountability, conflict resolution, and negotiation from a shared point of view. That is, they are following the conviction "we are all in this together".

Only the last two categories – real teams and high performance teams – can be identified as actual teams from an effectiveness and performance point of view. Katzenbach and Smith (1993) identify 5 + 2 characteristics that identify real and high performance teams: (1) Real teams have a common purpose and goal; (2) apply collective activities; (3) produce collective products; (4) hold each other mutually accountable; and (5) dare to go into conflicts. High performance teams, in addition, also have (1) an *explicit* focus on continuous learning and (2) mutual trust and respect.

In the following sections, we will go into details with the different types of teams as described by Katzenbach and Smith (1993), while also referring to some of the tools and management perspectives we teach in the related PBL course.

2.1 The working group: No performance need, no common purpose, and an individualistic approach

The working group is characterised by a lack of performance need that would otherwise require it to become a team. The members work together as individual entities with individual purposes and goals, primarily interacting to share information, align tasks, and support the performance of each individual within a designated area of responsibility (Katzenbach and Smith 1993, p. 91). A working group will typically consider a project work as something that can be divided into different sub-tasks and handed out to specific individuals. Each individual is then expected to know how to deal with the matter at hand and is held independently accountable for the production of specific deliveries. Conflicting issues are avoided, neglected, handled by rules, control, or pseudo consensus (Bøgelund 2014). Knowledge sharing and learning is implicit and not a goal in itself.

2.2 The pseudo team: A performance need paired with the lack of common purpose or goals

The pseudo team is characterised by the presence of a performance need, which would call for teamwork, but the team is unable or unwilling to gather around a common purpose and performance goal. In terms of performance, the team is worse off than the working group. There is not even an individual purpose or goal to adhere by and there is certainly no joint benefit (Katzenbach and Smith 1993, p. 91). Pseudo teams lack the skills or the motivation to find common ground, to set a course, and to muster the effort to follow it. Conflicting issues are mostly ignored, avoided, neglected, or dealt with in a half-hearted manner. Pseudo teams are teams who avoid taking risks regarding conflicts, joint work-products, collective action, or the pursuit of common goals. Working on motivation and acquisition of basic skills – be it problem solving, interpersonal, technical, or functional – is of importance.

2.3 The potential team: Acknowledging the risks – taking the first steps towards team work

Similar to the pseudo team, the potential team is characterised by the presence of a performance need. The potential team, however, sets out to rise to the occasion and therefore acknowledge and accept that becoming a team involves risk taking and efforts to invest in the course, in each other, and in the development of skills. Potential teams seek to establish a common purpose and goals without much success. As Katzenbach and Smith (1993, p. 91) puts it, the potential team typically "requires more clarity about

purpose, goals, or work-products and more discipline in hammering out a common working approach" and "has not yet established collective accountability".

2.4 Real teams: Common purpose, performance goals and approach; accountability and courage

Real teams "are equally committed to a common purpose, goals and working approach for which they hold themselves mutually accountable" (Katzenbach and Smith 1993, p. 92). Even when people are working on different aspects of a project, effective teams understand the end goal. They understand the purpose. Habit 2 of Stephen Covey's *The 7 Habits of Highly Effective People* is "Begin with the End in Mind". Covey was writing about making powerful changes for personal leadership, but the principle is still relevant to a team (Covey 2005). Making a team consider questions like, "What are we creating?" and "How do we want to make a positive contribution to our team and to our education?" can have a profound effect.

In the face of a performance need, real teams apply collective activities and produce collective products. They share knowledge and hold each other accountable – when they discuss, when they plan and when they carry out the plans. When they disagree, they dare to enter the conflicts. Real teams debate and the debate is an invaluable exercise to flesh out ideas, concepts, and strategies; debating, challenging, and defending ideas results in better ideas. It may feel uncomfortable to argue, but that is why it is so important to create a safe and trusting environment.

2.5 High Performance Teams: Mutual trust and respect along with a focus on explicit learning

Over time, a real team has the opportunity of becoming a high performance team. A defining characteristic of this team is mutual trust and respect. High performance teams operate in an environment where they have each other's backs; members are deeply committed to one another's personal growth and success. High performance teams seek to learn and improve at all times both to reach their common goals and to let individual members strive and prosper. For the common good, the team takes risks, shares successes and praise, and is quick to reveal missteps. This is important because highlighting mistakes at an early stage makes them much easier to fix, while the team is learning relatively more at a faster pace. Operating in a trust-filled environment breaks down barriers and allows people to be more vulnerable.

Ultimately, high performance teams come to work in a communal culture. This is when team members are not worried about who gets the credit, and they go out of their way to serve each other. When a team has a communal culture, it is not about the individual team member, it is primarily about the team exerting ownership of the work while supporting each other, because they want both the team and the individuals to be successful.

3 Case: Process Analyses at Aalborg University

Methodologically speaking we examine Process Analyses from three different clusters of programmes taught in the 5 ECTS PBL course during the first semester of 2016. This course is taught by different teachers and the students are clustered in different cohorts of somewhat similar programmes, usually having around 100-200 students. The three programmes analysed were from three different cohorts taught by each of the authors. That means the PBL courses had similar learning objectives, but the exact teaching and learning activities varied. Specifically, we selected 13 Process Analyses from the Mathematics programmes, eight from Mechanical Engineering, and eight from the Chemistry Technology programme. We performed documentary analysis of these Process Analyses both bottom up and top down, applying the framework of Katzenbach and Smith (1993). While we used the framework of Katzenbach and Smith (1993), acknowledging it as a

recognised framework used to describe effective teams, we also need to acknowledge that the framework belongs to the world of business life. Consequently, it might need to be adjusted to adequately describe teamwork in a university setting. Therefore, we cannot apply it without, at the same time, reinterpreting it for a university framework. In practice, we therefore analysed the Process Analyses by first exploring and identifying statements describing issues and challenges the students experienced as well as statements reflecting efficient and effective performance. These statements were then compared to the framework of Katzenbach and Smith (1993) to search for best fit – a comparison that generated discussions on how to distinguish between the types of groups, hence triangulating our approach (Titscher et al. 2000). This also facilitated a more detailed description of the stages of performance by Katzenbach and Smith (1993). As seen below, the process led to a more detailed description of, for instance, what it means to have a common purpose even when group members are very different; e.g. Is this difference something the students learn to cope with or is it something they cherish?

4 Findings

A Process Analysis from Mechanical Engineering was deselected due to insufficient content to make assessment of any team stage. From the remaining 28 groups, two were labelled pseudo teams, 16 groups were potential teams, nine groups could be labelled as real teams, and two groups were high performance teams at the time when the first semester finished (see Table 1). Each team developed during the project period as some teams might have started out in an earlier category to end up in the next one, or the next one again. The real teams and high performance teams obviously did not pass through the pseudo-team stage but developed directly from a potential team. In general, we did not find patterns of programmes only consisting of certain teams and not others. It would furthermore have required many more groups in each programme to determine such a pattern in any statistical way.

	Pseudo team	Potential team	Real team	High Performance team
Mathematics	0	9	4	0
Mechanical Engineering	2	2	2	1
Chemistry Technology	0	5	2	1
Total	2	16	8	2

Table 1: Overview of categories of groups in the three programmes.

In the following sections, we will go into detail about how the theory of Katzenbach and Smith (1993) is played out in a university setting. What kind of strengths and challenges do we find in each category? We exemplify each category with some quotes from the Process Analyses, translated from Danish by the authors. The brackets indicate the programme as well as the group number.

4.1 Pseudo teams' characteristics

Overall, according to the theory, pseudo-teams are struggling to find a common ground and the motivation or the skills to pursue unified goals in an effective and efficient manner. They have very little performance impact. This is certainly true of the two groups characterised as pseudo teams, both found in the Mechanical Engineering programme. Taking the two pseudo teams together, the challenges outweigh the achievements throughout much of the project-period. However, towards the end, the teams managed to define and handle

tasks and issues to deliver the required project report. Having been unable to establish and adhere to common and transparent values and norms, the groups' work efficiency and effectiveness is generally low prior to the status-seminar, and in combination with a fragmented structure (project and time-wise), the individual efforts do not overcome the many discrepancies nor make up for increasing uncertainties:

> The reason it went a little awry from the beginning was that even though someone tried to take initiative to take the lead, it was not respected by the other group members since the group often quickly lost focus. This, combined with the fact that the group had difficulty reaching an agreement about the direction of the project, was an inefficient combination. Our work was very marked by us all having very different ways of how we wanted to work (ME B206).

Despite regular meetings with supervisors, the pseudo-teams struggled with keeping an overview of the project, academic standards, sharing information, seeing things through, and following a strict line of focus – and accepting these struggles as part of the learning trajectory. Collaboratively, they found it challenging to manage time and deal with diversity. People opted out. Seldom was the full team present and the tone could be harsh or too frivolous.

> The fact that people came late all the time meant that it was difficult for the rest of the group to make sound and lasting decisions. The reason was that there were only a few people behind the decisions, and the decisions were therefore changed. It also made it hard to start a day's work since there never was a real starting point for the day and it was therefore not possible to plan the day efficiently (ME B207).

As mentioned above, the two pseudo-teams did complete a project report, ultimately because of deliberately diminishing distractions and irrelevant activities, reaching consensus on needed goals and tasks, and accepting distributed leadership-roles guiding and helping team members. Both teams attached great importance to the application of short-term planning and management (visualised on boards) during the last few weeks, however, collective accountability and risk taking appears to have been avoided.

4.2 Potential teams' characteristics

As stated above, the potential team is characterised by the presence of a performance need and they accept that becoming a team involves risk taking and trust in each other. For the university students, we notice that some groups are characterised by having a variety of challenges, which first are left unsolved, but after some developments the groups change their behaviour and succeed. Partly, this is a consequence of groups developing a clearer purpose as well as developing their mutual and collective accountability. Some groups learned through the semester that they needed to distribute the responsibility of different tasks to different group members; not everybody could do all things. They learnt that they needed to develop mutual trust in each other. Other groups in this category learnt that when they had distributed the responsibility of different tasks, they could also successfully use each other as sparring partners to discuss issues. Some groups stated that the status seminar halfway through the semester was a real wake-up call.

Some quotes from the Process Analyses illustrate this:

> In the beginning, the project had many loose ends. In relation to the tasks, the lack of overview, the group work was sloppy and it was actually very

> demotivating not to know how far we were and all the loose ends we had which seemed impossible to gather. Some days seemed like there was no contribution to the project. But after the introduction of the scrum board, the work morale increased, and you could see how the work moved forward and you realized what was done and what it took to finish the project … It really increased the work morale to implement a project management tool that worked for us (ME B209).

Another group:

> The collaboration was very individualized as the group members often sat alone and worked on specific topics … This was something that in the previous project's Process Analysis had been taken note of, and it had then been concluded that it might be a good idea to make people work more together on a topic. Especially if there was one who had more knowledge of a topic, then it could be good to put them together with others who at this topic knew less. Otherwise the whole idea of group work disappears and then the group might just as well sit at home and once in a while write to each other. When everybody was working in the group room, it was also possible to discuss individual tasks, which often happened. Usually this led to good scientific discussions, when one did not get side-tracked (ME B208).

A group also argued that, after some difficulties in the beginning of the project work, they began to help each other and be considerate of each other's learning styles (the PBL course had included the topic of learning styles). They then concluded in their Process Analysis: "In this way we experienced that jointly we were able to achieve the best product" (Math A218a). Another group stated something similar: "The group showed understanding for the fact that they were different so no one felt under pressure to work in a certain way" (Math A213). However, the group did not go into any details about to what extent it was an advantage that the members were allowed to work in own way or that the differences were an advantage. Nevertheless, they show that they could manage the different types of people. One group wrote: "The group members complemented each other well and when one stops another is ready to take over" (Math A217b). Another group stated that they at some point realised that the members had different levels of ability, "We have chosen to perceive this as something positive since our different ability levels can help us cover for each other's weaknesses" (Math A221a).

What we see here are groups that are having their first experiences with the realisation that being different is not necessarily harmful or wrong but can be turned into an advantage. They are making the first steps towards becoming a real team.

4.3 Real teams' characteristics

Real teams are characterised by participants all being committed to a common purpose to which they hold each other accountable. They think of themselves in terms of "we" and perceive the product as a collective product. They appreciate that they are different and they dare to enter into conflicts.

For instance, we found groups who stated that when they realised they were on a wrong track or stuck, or conflict began emerging, they discussed it and moved forward. We also identified groups that used communication in frequent meetings for knowledge sharing and they found it beneficial that group members

revised each other's sections in the report: "Furthermore the group members revised each other's written parts of the report and in this way the sections were improved and each group member got updated on what the others had worked on and which parts were finished" (ME B205).

We also found groups that directly stated they perceived that being different was an advantage. One group stated: "For this reason, the different learning styles actually complemented each other and the group was rarely caught for too long in the same track" (Math A214). Other groups were also very proactive in conflict management and worked towards preventing that conflicts should even emerge, which is illustrated by the following quote: "The group has had huge focus on making the collaboration work at an optimal level by preventing possible conflicts and solve them as quickly as possible" (Math A217a). This is stated by a group who also writes that they sometimes have problems with members not being on time, being unprepared, and unequal distribution of workload. This group consisted of eight students, of which three were studying other topics alongside the mathematics project. Two other groups directly state that: "The fact that we were different has meant that we in the group have complemented each other well during the writing process" (Math A220a) and "We have taken advantage of our different competencies. So we supplemented each other to achieve the best result" (Math A221b).

Other groups stated that despite challenges with time management, the direction of the project, and some people being late, they were good at sharing knowledge and solving problems. They stated that they had a common spirit, helped each other, and distributed work.

There were also some groups that found themselves to be a high performance team, writing, "as we were gathered towards a common purpose, had the same ambition for the project and a common approach to the final product … help each other in all ways and not just in the project work" (ChemTech B343). This group was also good distributing work, ongoing planning, revision, discussion, and knowledge sharing. However, they still had challenges with proper preparation for meeting with supervisors and clarity of mutual expectations. Consequently, they were not yet perceived as a high performance team, but certainly on the track to becoming one.

4.4 High performance teams' characteristics

High performance teams seek to learn and improve at all times both to reach their common goals, but also to let individual members strive and prosper – for the common good: the team takes risks, share successes and praise, and is quick to reveal missteps. One group explained it this way:

> The reason why the group actively chose to apply the tools from the course was to ensure gaining the optimal from the project and the process. It was here the group could test which tools worked best for them, as well as force them to use other arguments than "common sense" and hereby ensure that new learning took place in the group (ME B203).

Here we saw that the group was willing to take risks applying different tools and reflecting upon them to prosper. Among the evidence in support of characterising the two groups as high performance are deliberate efforts of ongoing monitoring and improvements backed by systematic approaches to apply methods and tools. Uncertainties and challenges were acknowledged, prioritised, and dealt with daily throughout the project period. The groups prioritised discussion over voting by majority ruling. Activities and role-functions were coordinated as consequence of responsibility and ownership – based on shared intentions to apply tools offered, avoid misunderstandings, and wasted resources while learning as much as

possible. These groups proved that foresight, awareness, and attention to detail pays off. Apparently, nothing had been left to chance.

The Process Analyses document how the two groups' ongoing reflections incorporate more aspects of project-work (including how course-work interacts with project-work), thus testifying how transparency fosters efficiency and effectiveness. We also saw they had a well-structured knowledge sharing and time planning. Although the groups have succeeded, they still point to areas of potential improvements that will allow them to fulfil the increased requirements of the following projects.

5 Discussion of findings

5.1 What types of groups were found

Two groups proved to be pseudo teams, 16 proved to be potential teams, nine could be labelled as real teams, and two as high performance teams by the end of the first semester. As seen above, it was possible to apply the different concepts to each group. However, a question that arose during the analysis was: If a group experienced problems, was that an indicator that the group was not a Real Team? We argue that all groups will experience problems but what distinguishes the groups from each other is how soon they solve the problem, how they solve it, how well they solve it, how they reflect upon the causes and cures – and, to some extent, the types of problems experienced. This means that groups experiencing repeated problems of members being late (as well as several other problems) are at a lower stage than groups where lateness was a minor issue and something that was settled early in the semester.

Although the two pseudo teams did perform at the very end – supposedly as a result of pressure for performance and an emerging critical mass of knowledge – we argue they did not develop into potential teams. Their Process Analyses avoided identifying root causes and factors and only vaguely pointed to future improvements (ME207). What is more, the Process Analysis documents showed a consistent lack of social integration as well as a lack of collective trust and accountability (ME206).

The feedback and feedforward provided during the status-seminar (normally halfway through the project-period) appears to function as wake-up call for the lower level teams. Suggestions and impressions from other groups led to immediate initiatives to improve procedures, resulting in increased efficiency and effectiveness.

Some groups were able to *handle* differences while seemingly still being annoyed by those differences while others saw the differences as an *advantage*. We argue this is something that distinguishes Potential Teams from Real Teams. Another thing that distinguishes these two is whether the groups dare enter into conflict, i.e. addressing the problems upfront and not steering away from the problem. Other important factors characterising a group as being a Real Team is common values and ambitions, a common strategy, a good structure for planning, deciding on team roles, and demonstrating the ability to share and coordinate knowledge. However, we also needed to judge and balance different comments written in the Process Analyses since different comments might point in different directions.

Considering these were first semester students, it is remarkable that two groups can be characterised as high performance teams, which is a very advanced stage. The seven students in the group from the Mechanical Engineering programme originated from four of the initial groups in the pilot-project during the first month of studies. This verifies the common practice of students to identify, negotiate, and select preferred group members prior to official group formation. In the Chemistry Technology programme, the students could also

change groups at this point, but they usually remained in the initial groups. All groups in all programmes were designed at random by the administration at the very beginning of the first semester, as the students did not know each other when they began their university studies. Furthermore, the students in Chemistry Technology were explicitly introduced to the theory of Katzenbach and Smith (1993), which might have had an impact on the groups' awareness and choices – including the reasoning used in the Process Analyses. The other students were also introduced to conflict management and types of groups, but with a different framework than the students in Chemistry Technology. One might form the hypothesis that the teacher's prioritisation of course activities can support the students in developing team function, but such conclusion is beyond the scope of this paper.

5.2 The usefulness of the theory of Katzenbach and Smith (1993)

The aim of the paper was to identify challenges the students meet when they start working in a PBL group during their first year of study. We have applied the theory of Katzenbach and Smith (1993). As seen above, the theory was suitable for describing the stages of the groups. However, the theory also has some limitations when applied to a university setting. One limitation is that at AAU we would not meet any working groups due to the pressure of performance stipulated in the study regulations of the programmes investigated: students *must* work in groups and submit a joint project report in which all students are accountable for everything in the report, even parts they did not produce themselves. Students beginning their university study might have had a perception of a "good" group as something that functions like a working group, but they would have to change this attitude and behaviour to fulfil all requirements of the study. Some students left the university during the first year. Some could not adjust to the organisational and social obligations, and some did not like working in large groups.

Since this study assesses the Process Analysis after the first half-year of study, one might anticipate that some students might still see the working group as an ideal, and thereby fail to recognise the importance of having "to take responsibility for results other than their own" (Katzenbach and Smith 1993, p. 89). As working group members tend to "pay attention to individual outcomes and results" (ibid.), such groups will be characterised by an individualist approach and dominance aiming for optimising individual performance in the exam.

One might also argue whether high performance team function is a realistic goal to set for the first year at university. Students are new to university study; do not know each other, and they usually select their own groups each semester. This is different from the settings in professional life, where people usually do not choose their colleagues and usually people in business life work together for a longer period than half a year. The student groups also had supervisors to assist them with both the content of the reports as well as process issues of collaboration. Often the idea is that the students should learn collaboration skills and project management while doing it in the groups. Staff rarely perceive a rather unsuccessful project-report during the first semester as a catastrophe, especially when the students are able to prove that they learnt from their failures – and naturally when having learnt sufficiently to pass. However, in business life, the setting is different.

5.3 Main challenges

The main issues and challenges reported in Section 4 -- Findings -- constitute a rather long list. However, the fundamental challenge for groups is to embrace the struggle of the process. Handling the challenges is often a matter of practicality: dividing problems into manageable tasks. A couple of higher order issues, such as performance and exam anxiety, coupled with the uncertainty of doing something for the very first time, must

therefore be made adequately transparent on a continuous basis. The observed effect of the "wake up call" resulting from the status-seminar is a fulfilment of the essential need for transparency at a point where a critical mass of technical knowledge is accumulated, coupled with sufficient certainty of what-not-to-do. This spurs agency within the group, enabling appropriate handling of prioritised challenges.

A yet unanswered question in this analysis concerns the individual students' personal values, preferences, and behaviours and how these influence the path towards embracing each challenge. The Process Analyses do not provide evidence for any conclusions in this respect. Our experience tells us, nevertheless, that personal issues are important and that such issues do have impact during all undergraduate semesters, although not for all students and not in all semesters.

5.4 Validity of the Process Analyses

The analysis is based on the Process Analyses that the groups were obliged to produce as supplement to the technical semester reports in the first year of study. This naturally gives rise to questions about validity of the claims made by the students. One might argue that they tried to show themselves as better than they really were in an effort to impress the examiners. Nevertheless, the students were informed that it was a requirement to report on what went well and what did not go so well, as well as show their ability to argue for choices made and for possible improvements. We argue that we can ascribe a sufficient level of trust into the statements the students make. It is also reflected in the observation that very few groups in fact turned out to be high performing teams. Had the groups anticipated that they would be rewarded grade wise for being characterised this way, we would have seen many more groups displaying ample evidence of such characteristics.

Another source of error that might be more problematic is the issue of groups not elaborating much on some items. For instance, if a group did not write anything about whether they found their mutual differences to be a benefit, can we then conclude that they did not consider their mutual differences to be beneficial? In other words, is absence of evidence the same as evidence of absence? In professions such as archaeology, this would be a false conclusion to draw. However, since the students were asked to formulate things that went well, we argue that if they were clearly aware it was an advantage to be different, and they wanted a high grade, they then would have explicitly formulated something about this in their Process Analysis. We argue that if they do not mention a certain issue, or only mention it in a brief comment, it is evidence that they did not findthis issue particularly important or they have not yet fully realised its importance.

Another issue for validity could be that we do not know to what extent all group members have taken active part in producing the Process Analysis. Writing the Process Analysis might for some groups be something that had been delegated to some of the group members who had extra time. Likewise, some (or all) of the other group members might not have assigned high priority into producing a Process Analysis adhering to the learning objectives, as they anticipated (rightly) that the report would carry the most weight at the exam. We cannot know this from reading the Process Analyses; however, the Process Analysis was due two days after the report was due, which meant that each group member ought to be able to participate at least in the final stages of the analysis and writing, and they all should expect to be asked questions about the Process Analysis during the project exam. One might also argue that when students write about their process looking back, things might look different in hindsight compared to how the groups perceived the situation when it happened. A more accurate description and analysis of their process could have been based on weekly process analyses or assessment, observations, and interviews with the students. However, even though this

in theory would have given us data of higher validity, it is unrealistic to imagine that students would have time to provide us with detailed data of such frequency and depth.

We therefore argue that even though the Process Analysis might not be equally representative of each single group member, it is still an adequate representation of what the group members – as a group – had agreed upon. However, as evidenced by the deselection of a group due to a very weak Process Analysis, some groups chose not to put sufficient effort into writing the document. Hence analysing the Process Analyses is one way of getting information. Here we get insight into how they perceive themselves and how they reason. To get a fuller picture of how the group performed as a group, one would also need to, for instance, observe groups, interview groups and individual members, interview supervisors, and compare individual grades, but such activities are beyond the scope of this paper.

A final note concerns the objectivity of the analyses performed by the authors. Each author has been responsible for analysing the Process Analyses from the programme taught. To calibrate our assessment to the four stages within the framework set by Katzenbach and Smith (1993), we have sampled two Process Analyses from each of the other two programmes. The calibrating discussion proved valuable for refining the detailed descriptions in Section 4 -- Findings -- as well as for broadening the scope of this discussion.

6 Conclusion

Overall, we were able to apply the theory of Katzenbach and Smith (1993) to categorise different types of groups. However, the theory is not based on nor developed with university students in mind, so some specifications were necessary. One example is that the concept of working group did not apply to this particular university. We had to discuss very precise concepts in relation to determining what category a group belonged to in a university setting. We also found that our initial expectations of which types of challenges students experienced were to some extent seen in the Process Analyses, but they became clearer in our analyses.

We have seen students not only struggle with certain types of problems in the groups, they also become good at a great number of things. Regardless of the level of the groups, it was clear that the groups had learnt considerably about working in a team during their first semester. In different ways, they are able to work on projects and able to handle a wide number of problems such as lateness, different learning styles, personalities, and time management. When groups embrace the struggle with these issues, they are able to minimise consequences or solve problems – some groups do better than others, as reflected in the stage of the group.

Aalborg University has a long tradition of PBL, but PBL will not work properly unless the students learn to perform efficiently and effectively in teams. We therefore argue that educational institutions cannot expect students to learn to work in groups without assistance. What we saw in the Process Analyses were frequent references to tools learnt in the PBL course during the first semester. Such tools can be presented to students in manifold ways, but one may, as a last comment, put forward the argument that some kind of course is needed to assist students; otherwise, it will be an excessively time-consuming struggle for them to find their way through the challenges they encounter as a group during project work.

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An industry news magazine as course project to enhance learning about contemporary manufacturing

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Abstract

This work reports on a case study about a magazine news project carried out by 78 undergraduate students at the course "Manufacturing Processes II" of the majors in Mechanical & Mechatronics Engineering at National University of Colombia (Bogotá). The central idea was inspired by the "writing-to-Learn" concept, which consists of using writing as an integrative activity that require the students to apply the acquired knowledge. The course project was also grounded on implementing the learning activities within the framework of PBL (project-based learning) and CDIO (Conceive-Design-Implement-Operate) methodologies. The issues concerning to this case study are described: the particular educational framework that was designed; the conceived class project, its characteristics and specific logistic issues, the evaluation instruments that were considered and enforced to assess the impact of the class project and the general results attained. The project conceived consisted on the development of a news magazine about the manufacturing industry, with articles developed entirely by the students on the application of the methods, techniques and processes taught in the subject within the real context of the manufacturing industry in Colombia. The impact of this project on student's learning was evaluated using the quasi-experimental method named single-subject design, taking into account that only was possible to have full control of one group of students and that the treatment (in this case, the class project activity) was performed only with that group. It was concluded that the project had a positive influence in the exercise of the competences of: (1) to communicate, in a clear and effective way, the result of applying the learned content in a context of engineering knowledge dissemination; (2) to be able to effectively interact into a professional work team; (3) to be able to generate a management structure to handle complex projects.

Keywords: Manufacturing Engineering, Engineering Education, Project-based learning, CDIO, Writing-to-learn

Type of contribution: best practice paper.

1 Introduction

In Colombia, engineering education has been mainly based on traditional lecture patterns linked to memorize considerable amounts of technical information. But it could reasonably be assumed that this approach is not effective enough to respond to the characteristics of the labour market in which the students will work. In that sense, Felder & Brent (2009) have indicated that between the most important learning strategies to educate future engineers are those that involve actively the learner in solving problems coming from real situations.

On the other hand, learning-teaching methodologies like project-based learning (PBL) had been carried out in some engineering faculties around the world aimed to overcome the gap between undergraduate education and real-world working experience. Also, researchers in engineering education from USA (MIT) and Sweden (KTH and Chalmers University of Technology) had developed an specifically engineering-

oriented educational framework called CDIO (Conceive-Design-Implement-Operate) that looks promising to reach the desired abilities in the engineering graduates (Crawley *et al.*, 2010).

Due to the above, it was decided to explore and describe the effect of implementing learning activities within the framework of PBL and CDIO in an undergraduate manufacturing engineering course. This idea led to the design and implementation of a class project as a case study. This article intends to describe all the issues concerning to that case study: the particular educational framework that was designed; the conceived class project, its characteristics and specific logistic issues, the evaluation instruments that were considered and enforced to assess the impact of the class project and the general results attained.

2 Application of PBL- and CDIO- based, Quasi-Experimental Mixed-Methods Educational Research in the case study

As mentioned, the main referents for the conception and implementation of the class project activity, from a conceptual and theoretical point of view, were the Project-based Learning (PBL) approach and the Conceive-Design-Implement-Operate (CDIO) initiative.

According to Thomas (2000), in PBL, a project can be defined as any kind of complex task based on challenging questions or problems, which involves the student in design, problem-solving, decision-taking and research activities. This gives the student the opportunity to work autonomously through long periods, resulting in realistic products. These characteristics were considered as highly desirable in the context of the proposed research. Besides, PBL was selected because of the motivation and improvement in thinking and problem-solving skills that potentially generates in students (Mettas & Constantinou, 2008), the degree of active involvement that requires from the students (Mioduser & Betzer, 2008), and also because it is considered effective in an engineering education environment (Prince & Felder, 2006).

Elsewhere, CDIO was taken into account mainly due to the idea that is an educational initiative 'designed by engineers for engineers', and also due to their rationale: it started by tracking, from the real world, the desired attributes and skills that an engineering graduate should possess, and resulted in a structured way of making questions about the learning process ('what to teach?') as well as the best practices to answer them ('how to teach it?'). The proposed method is condensed in the CDIO Standards and CDIO Syllabus (Berggren *et al.*, 2003; Crawley *et al.*, 2010). CDIO was considered a good framework to define the general learning outcomes related with the manufacturing processes and the particular skills intended to be developed through the class project.

Regarding the methodology, this case study was carried out under the framework of quasi-experimental design, because of the particular circumstances in terms of logistics, number of students, schedule, and resources availability. This research design was chosen considering that it was not possible to randomly assign students that belonged to an experimental or control group (Cohen *et al.*, 2007) neither to control the assignations of study subjects to precise conditions (McBurney & White, 2009); in such cases it is recommended to address the quasi-experimental approach, with no full resignation of the required control, but applying it depending on the situation.

Between the quasi-experimental types of research, to this study was applied the so-called single-subject design (Fraenkel & Wallen, 2008; Schreiber & Asner-Self, 2010), taking into account that only was possible to have full control of one group of students and that the treatment (in this case, the class project activity) was performed only with that group; namely, it could be considered as a design applied to a single group, and this group was designated as an experimental group. The whole case study research scheme can be

viewed as a quasi-experimental mixed-methods design (Borrego *et al.*, 2009; Hesse-Biber, 2010) with these main stages:

- Pre-test and post-test in the experimental group
- Single-case design with the whole experimental group taken as study subject.

3 Implementing an Industry News Magazine about contemporary manufacturing as an undergraduate course project

Following the previous analysis and research design, it was thought that the proposed class project activity should reflect the practical application of the manufacturing processes course content in the real Colombian manufacturing context. Next sections will describe the way in which this project was devised.

3.1 Origin and references

Firstly, it was necessary to make some changes at the course curriculum level, based on the CDIO Syllabus and Standards, in order to be competencies-oriented and to allow identifying the specific skills that could confer added value to the learning process and make a difference with respect to the traditional contents. Next, with the aim to confer a reasonable level of curriculum application, three initial main lines of action were considered: modelling and simulation of machining processes, making of some tutorials for computer-aided manufacturing (CAM) implementation, and writing of a paper or monograph-type document about modern trends in machining. To make a suitable choice from these alternatives, previous experiences with students in simulation and tutorial realization who had had some degree of success were taken into account and also the fact that writing activities had not been fully implemented before. Besides, it was identified that one of the most profound lacks in engineering education, the proper professional writing, could be improved through the writing-to-Learn proposal (Daniell *et al.*, 2003; Reynolds *et al.*, 2012). This last finding guided the course project finally conceived: the implementation of a news magazine. The idea of a news magazine came from the exploration of some manufacturing news websites like Modern Machine Shop (MMS, 2017), Usinagem Brazil (Usinagem, 2017), Revista Metalmecánica (Metalmecanica, 2017) and CIMM Brazil (CIMM, 2017).

3.2 Purposes and scope

The magazine, named 'Magazín Fabricar', was conceived with the following aims:

Overall objective: collective elaboration of a divulgation internet site about the manufacturing industry in Colombia that includes a diffusion news magazine via e-mail.

The learning outcomes, structured as competencies to be promoted in the students were:

- To communicate, in a clear and effective way, the result of applying the learned content in a context of engineering knowledge dissemination.
- To be able to effectively interact into a professional work team.
- To be able to generate a management structure to handle complex projects.

The magazine was intended as a media with news and technical information focused on a potential audience of manufacturing professionals (engineers, researchers, managers, machinery importers), and engineering students. The content was also focused on conventional and non-conventional material-removal manufacturing processes.

3.3 Student roles, work structure and project deliveries and scheduling

At the beginning of the project, in agreement with the students, it was decided the formation of a journalistic committee, an editorial committee and a publishing committee. The most of the students voluntarily assigned themselves the so-called journalistic committee. Inside this committee were formed teams of three members, and each team had to write an article on a negotiated topic that them either could propose or could be assigned by the course professor. In this way were defined the topics of the 24 articles that were finally written for the magazine. The sequence of deliveries of the journalistic committee was defined as follows:

- Delivery 1: Definition of the topic and sections proposed for the article. General description of the contents of the course related to the chosen topic.
- Delivery 2: State of the art about the topic of the article. Evidence of visits to companies and interviews with professionals in the area.
- Delivery 3: Sending of the first version of the article to the editorial committee.
- Delivery 4: Sending of the final version of the article to the editorial committee.

Another group of six students voluntarily formed the so-called editorial committee; they (with supervision from the course professor) were in charge of reviewing the articles for final publication. The sequence of deliveries of the editorial committee was defined as follows:

- Delivery 1: Presentation of the criteria for receipt of the articles: format, drafting rules, form of submission, deadlines for receipt and review of the articles.
- Delivery 2: Presentation of rubrics to review the articles based on information from publication rules of scientific and non-scientific journals. Specific technical criteria should be included according to the course topics.
- Delivery 3: Reporting of the review results of the first version of the articles and forwarding of the articles with suggestions to the authors for improvement. Sending of the articles in first version to the committee of publication, to make proofs of publication in the website of the magazine.
- Delivery 4: Evaluation report of the definitive version of the articles. It should include review comments and justification of the proposed grade for each article. Submission of the articles to the publication committee for publication in the first magazine number.

Another group of six students voluntarily formed the so-called publication committee, which was in charge of structuring, designing and publishing the website and of sending the mass e-mail with the content of the magazine. The sequence of deliveries by the publishing committee was defined as follows:

- Delivery 1: Definition of the information management in the website and the e-mail format of new issues of the magazine.
- Delivery 2: Design of the graphic structure of the website and the magazine.
- Delivery 3: Beta version of the website and magazine, sending to all participants the mass e-mail with the number one-beta of the magazine and linking with the draft articles received by the editorial committee.
- Delivery 4: Final version of the website and magazine, sending to all the participants the mass e-mail with the number one-final of the magazine and linking the accepted versions of the articles.

3.4 Assessment of students work

Deliveries were made in a portfolio that each team implemented on Google Drive®. There, the teams uploaded the documents and evidence of the process of drafting the articles, or of structuring the criteria and review rubrics or of the website development process. For assessment, rubrics were specially designed (an example is depicted in Figure 1, of a team from the journalistic committee) and two evaluation modalities were used: (1) Hetero-evaluation, made by course professor for each scheduled delivery. (2) Peer-assessment, based on beta product deliveries of manuscripts, article formats, and website.

ENTREGA 2					
Grupo: Sebastián - David - Samuel	**Contenidos del curso asociados: Nuevas tecnologías**				
Fecha evaluación: Semana 6 – 7					
Competencias a evaluar: Comunicación -					
	Valor				
Indicador a evaluar	**1 (No lo cumple)**	**2 (Cumple deficiente)**	**3 (Cumple Aceptable)**	**4 (Cumple Adecuado)**	**5 (Cumple Destacado)**
El estado del arte se refiere adecuadamente a los contenidos y trabajos en el área del artículo.			X		
Las referencias bibliográficas son suficientes y pertinentes.					X
Hay evidencia de información recolectada con empresas e instituciones.			X		
Avance		X			
NOTA	**3,7**				

Figure 1: Assessment rubric example of a team from the journalistic committee.

4 Measurement of Students' overall performance as case study dependent variable

The aim of the case study was to measure the influence that the class project had on the students' performance. Usually, this performance is measured through the partial or final course grades. For this whole project, besides of this convention, performances related to the previously defined competencies were measured, in order to see if there were changes between the initial and the final state, and quantify to what extent these changes (if were) could be attributable to the proposed course activity. All those performances were integrated to obtain a dimension of the project impact over the group being studied.

The process of evaluating overall performance through the specifically structured competencies for the course included the implementation of two concrete instruments: a 20-question closed-ended test for knowledge measurement (partially illustrated by Figure 2) and a Likert scale self-assessment survey to measure self-perceived skills (partially illustrated by Figure 3). The instruments were designed to classify both in a heteronomous (that is, observed by the teacher) and autonomous way (that is, observed by the student himself) the level of each participant. Both instruments were qualitatively and statistically analyzed in order to test its validity, reliability and consistence, using both normality tests as well as difficulty and discrimination analysis (Crocker & Algina, 2006) for the closed-ended instrument, and exploratory factor analysis (Child, 2006) in SPSS® for the self-perceived skills instrument.

CONOCIMIENTOS GENERALES EN COMPETENCIAS PARA PROCESOS DE MAQUINADO.

NOMBRE: CÓDIGO:

Por favor, rellene completamente la respuesta correcta en la tabla de respuestas final según sea el caso y de acuerdo con el tipo de pregunta. Al final, relacione las preguntas que le parecieron más fáciles y más difíciles. Tiempo para completar la prueba: 30 minutos.

Comprensión de procesos de maquinado

1. Se define avance como:

a. El movimiento de penetración que determina la velocidad de corte.
b. El movimiento de la herramienta que determina el volumen removido de material.
c. El desplazamiento fundamental de la pieza de trabajo respecto a la herramienta.
d. El desplazamiento relativo de la herramienta respecto a la pieza.

2. Una operación de desbaste involucra una de estas combinaciones de parámetros:

e. Baja velocidad de corte, avance y profundidad de corte.
f. Alta velocidad de corte, bajos avance y profundidad de corte.
g. Baja velocidad de corte, altos avance y profundidad de corte.
h. Alta velocidad de corte, avance y profundidad de corte.

3. El trabajo con altas velocidades de corte en torneado se utiliza para:

a. Operaciones de desbaste.
b. Operaciones de acabado.
c. Operaciones con grandes avances.
d. Operaciones con grandes profundidades de corte.

4. En un torno, una herramienta *izquierda* generalmente:

a. Efectúa el corte hacia la copa.
b. Efectúa el corte hacia el eje de la pieza.
c. Efectúa el corte alejándose de la copa.
d. Efectúa el corte alejándose del eje de la pieza.

5. En una operación de fresado frontal, el eje de la herramienta de corte:

a. Se desplaza de forma perpendicular a la pieza.
b. Se desplaza de forma paralela a la pieza.
c. Se desplaza de forma concéntrica a la pieza.
d. Se desplaza de forma tangencial a la pieza.

Selección de insumos bajo condiciones específicas.

6. ¿Qué pasa si el radio de punta de una herramienta de corte es demasiado grande?

a. El acabado de la pieza tiende a parecerse al de un laminado.
b. Aumenta la vibración en la pieza de trabajo.
c. Se gana más masa en la pieza de trabajo.
d. Se desprende viruta más gruesa.

7. ¿Qué condición de las siguientes podría evidenciar que la herramienta de corte está sin filo?

Figure 2: Extract from the closed-ended test for specific knowledge measurement.

Autoevaluación en competencias - Procesos de fabricación por maquinado

Por favor, conteste esta evaluación con sinceridad. Este instrumento se ha diseñado para permitirle tomar conciencia propia sobre su estado actual de formación y competencia; una vez finalizado el curso, tendrá con esto criterios para medir su grado de avance, la pertinencia y la utilidad de lo que verá y trabajará durante el semestre.
Por cada indicador, marque la casilla que corresponda a su propia valoración sobre el mismo.
Como guía, la escala de valoración es la siguiente:
1 Definitivamente no sé o no puedo hacerlo.
2 Quizá sé hacerlo, pero no estoy seguro y requiero ayuda.
3 Sé hacerlo de manera simple y sin ayuda.
4 Sé hacerlo con cierto dominio y sin ayuda.
5 Sé hacerlo de manera experta.
Tu nombre de usuario (**jdorjuelam@unal.edu.co**) quedará registrado al enviar este formulario.
¿No eres **jdorjuelam**? Salir
*Obligatorio

Competencia 1: Comprende los distintos tipos de procesos de maquinado que se ejecutan en la actualidad, para aplicarlos en los contextos adecuados.

1.1 Sé en su mayoría cuáles son los procesos de fabricación que implican arranque de viruta. *

1 2 3 4 5

1.2 Puedo calcular y relacionar los parámetros de corte de cualquier operación de maquinado. *

1 2 3 4 5

Figure 3: Extract from the Likert scale self-assessment survey to measure self-perceived skills.

Also, in a final survey, students were asked about the effect that the class project activity had on the development of skills associated with communication and teamwork. This survey consisted essentially of questions with a Likert-type rating scale, as well as Yes/No questions, multiple-choice selection questions and open-ended questions for additional observations.

These instruments were implemented in the following stages:

(1) Application of the closed-ended instrument to measure the level of knowledge, at the beginning and at the end, for the group that is part of the quasi-experiment (that is, the experimental group).

(2) Application of Likert-type survey for the self-assessment of attitudes and skills, again at the beginning and at the end, for the experimental group.

(3) Implementation of the evaluation by rubric-performance matrix to the groups of students who were participating in the project class activity.

(4) Application of the Likert-type survey to measure the project impact, at the end, for the experimental group.

5 Results and discussion

5.1 Products made by students (web magazine and articles)

At the end of the semester, it was obtained a set of 24 technical papers, disseminated through a web platform (made by the journalistic committee) that also included a system which allowed an e-mail alert of each new magazine number. Figure 4 shows the final aspect of the main page of the web magazine, and Figure 5 shows how one of the articles published in the platform looks like.

Figure 4: Main page of the manufacturing news website developed in the magazine project.

Figure 5: Header of one of the final articles published in the magazine.

A peer assessment mechanism was implemented in the website of the magazine through the comments that registered users made. From the third delivery, also through this mechanism, the members of the editorial committee and the assessors emitted a concept on the articles, highlighted the strengths and pointed out the aspects to be improved. In addition, it was implemented a system of valuation of each article from all the users, whose average appeared in the heading of the article in a graphical scale of one to five stars.

5.2 Internal evaluation of the project and impact of self-assessment

To internally assess the project students´ performance through hetero-evaluation, based on the products delivered and in the portfolio content, two main criteria were considered: product quality, referred to the degree of matching respect to specifications, and industry knowledge, referred to the degree of collected information about the respective real industry context, the level of interaction with manufacturing professionals, with people in charge of business, and the specific application of course contents in function of the context. These criteria were transferred to the rubric indicators, and each indicator was assessed in a 5-scale through the rubric.

Figure 6 shows the evolution of the hetero-evaluation (on a 5-scale basis) of the portfolio in each delivery. It represents the typical evolution of scores observed in all the working groups, especially in those belonging to journalistic committee. The results evolved markedly between the first and second deliveries, at which point the students had acquired a greater awareness of the expected quality of the products. In the third instalment, there was a reduction in performance, associated with the modest quality of the first drafts of the articles. In the last instalment, the quality of the products improved remarkably. Several of the

teams that began with modest performance applied the suggestions received in the assessment scenarios and this was reflected in the good evolution of the products.

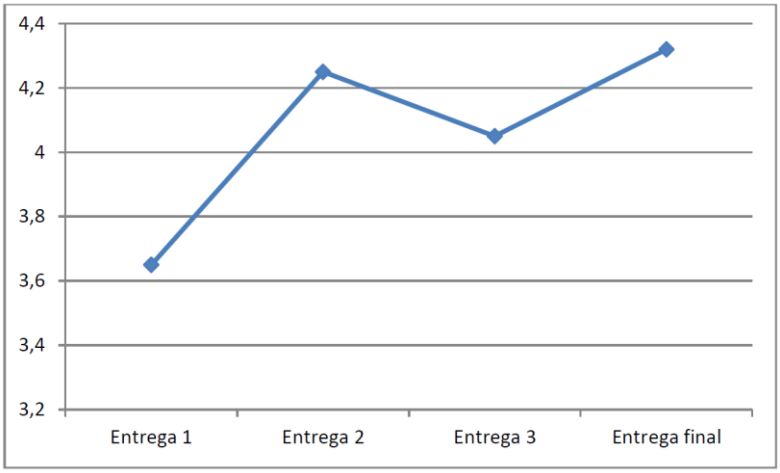


Figure 6: Evolution of portfolio hetero-evaluation in each delivery (5-scale).

Also, in the form of trend measures, the results of the surveys applied at the end of the project to the participating students were collected; here are the main results:

- 75% of the participants expressed their agreement with the statement that through the project they learned to create products to communicate the results of their research.
- 70% of the participants expressed their agreement with the statement that participation in this type of project required skills they normally do not employ.
- 60% of the students indicated their agreement with the statement that participating in the magazine helped them to understand how a project must being carried out.
- 75% of the students expressed their agreement with the statement that through the magazine they learned to create better quality products to respond to the guidelines of a project.
- 65% of the students expressed their agreement with the statement that the project was a relevant alternative of learning about manufacturing processes real context.
- Most students considered that the use of a rubric as an assessment tool positively influenced their learning motivations.
- Most of the students described the project as interesting, novel and formative, although a certain percentage considered it as too demanding.

5.3 Overall performances comparison

Figure 7 shows, via box diagrams, the differences between the pre-test (that is, the test applied at the beginning of the semester) and the post-test (that is, at the end of the semester) distribution results in the total score obtained by the students (viewed as the experimental group) in the closed-ended knowledge test associated to the competences. There is evidently a marked global difference in the mean post-intervention performance with respect to the result they obtained upon entering the course: the mean in the pre-test was 10.6 points, while in the post-test it reached 14,8 points (bearing in mind that the maximum possible score is 20 points).

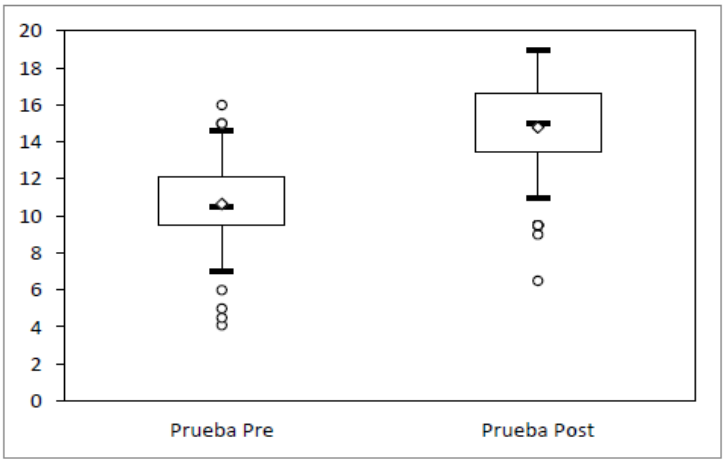


Figure 7: Distribution of total scores in pre- and post-tests of knowledge associated with competences.

In order to determine if this difference was statistically significant, a Wilcoxon rank-signs media difference proof was applied using SPSS® (Leech *et al.*, 2008). This proof was selected because just one of the above distributions is normal, and also because the samples are non-independent. The Wilcoxon results (Figure 8) showed that the difference found was significant, and it gave some insight about the influence of the project.

6 Conclusions

According to Stefanou (Stefanou *et al.*, 2013), the emphasis of project-based learning is to apply or integrate knowledge. Based on this definition the reported work can be classified as a case in the universe of concrete project-based learning implementations. The learning project was launched to enhance the learning opportunities of the students in areas no traditionally covered in the course. For this reason, we did not divide the class to apply different learning approaches and then proceed to compare two different groups to draw conclusions.

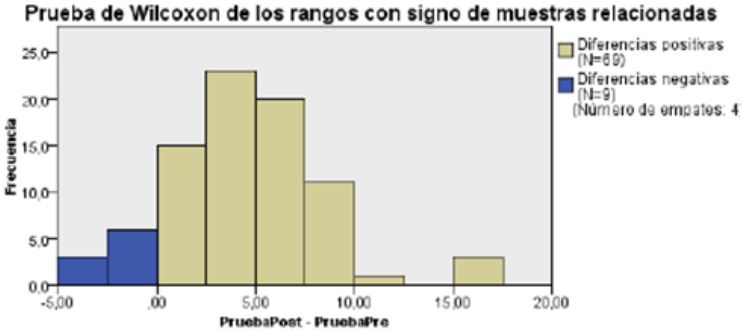
The activity level of the teaching team, formed by the professor and the course assistants, at the beginning of the project was quite high, because the students did not have much experience in a project with the characteristics of the magazine or with such a large number of participants. In the first weeks of the semester, the students were interested in working only in their individual "assignment", but without major contributions to the overall success of the project. The teaching team reversed this situation, little by little, by implementing a greater specific weight in the individual assessment to the contributions of each student as a reviewer of the work of his colleagues. On this respect, the tool implemented to comment the work of each team on the magazine website was an excellent resource.

Once the teams took the initiative on their assignments and even made modifications to the initial guidelines, the workload diminished considerably, and the teaching team essentially engaged in assessment and feedback in each one of the defined sessions for deliverables examination. This project served the team to experiment with the skills of contemporary young students with social networks and with information technologies.

Within the experimental group, it was observed that in general there is a significant variation of the average results in the performance with respect to practically all the competences projected, a result especially remarkable in the students belonging to the Journalistic Committee. This indicates - in principle -

that the interventions carried out in the course (that is, the project class activity) resulted in improvements in expected performance.

The development of this type of activity based on PBL and CDIO generated in the students a learning environment that, in the concept of the majority, is interesting and formative. Likewise, the students recommended continue implementing this type of activities in the course, because of the acquired experience. This indicates that the activity generated a positive impact on the students, when measured qualitatively.



N total	82
Probar estadística	2.927,500
Error típico	200,700
Estadística de prueba estandarizada	6,911
Sig. asintótica (prueba de dos caras)	,000

Resumen de prueba de hipótesis

	Hipótesis nula	Test	Sig.	Decisión
1	La mediana de las diferencias entre PruebaPre y PruebaPost es igual a 0.	Prueba de Wilcoxon de los rangos con signo de muestras relacionadas	,000	Rechazar la hipótesis nula.

Se muestran las significancias asintóticas. El nivel de significancia es ,05.

Figure 8: Validation of statistical significance when applying the Wilcoxon test for pre- and post-test scores for knowledge test.

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Enhancing Student Learning through Problem Based Learning

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Abstract

In this paper the authors report the course design elements aimed to enhance student learning in a PBL course delivered at McMaster University. The course "Conceptual Design of Electric and Hybrid Electric Vehicles" that includes automotive design is offered in the last semester of the Automotive Engineering Technology program offered by the Faculty of Engineering. This paper presents the motivation to employ the PBL approach for this specific course, and describes the course structure, the PBL delivery approach, the associated learning objectives, and describes the activities that the students undertake in the course as well as the skills they will acquire in the process of learning.

The main focus of the paper is to describe elements that enhance student learning. These elements are concentrated around five major themes: request for innovative ideas, structured group work, peer teaching, active engagement, and assessment methodology. The paper shows that a proper design of these elements can lead to activities that lead to enhanced student learning.

Keywords: Problem Based Learning, automotive engineering, student learning, McMaster University, PBL

Type of contribution: Best practice paper.

1 Introduction

In 1969, the medical school at McMaster University in Canada introduced a new approach to learn medicine called Problem Based Learning (PBL). The approach allows students to identify their own learning needs as they attempt to understand the problem, synthesize and apply information to the problem, and begin to work effectively to learn from group members through a structured problem solving strategy. Effectiveness of the problem based learning approach is disputed in the published literature. While some authors advocate for the superiority of the traditional teacher-centred approach based on direct guided instruction (Mayer, 2004; Kirschner *et al*, 2006) other suggest that student-centred inquiry based approaches like problem based learning (Barrows & Tamblyn, 1980; Barrows, 1986; Woods 1994; Biggs, 2003; de Graaff and Kolmos, 2003; Wood, 2004;) and teaching approaches with a strong experiential learning content (Kolb *et al*, 2011; Kolb, 2015) encourage deep learning and provide superior learning outcomes. Nevertheless, with a successful application of this strategy to undergraduate and graduate life-long learners at McMaster University's medical school, PBL has now been adopted in various fields in several universities (Bridges & Hallinger, 1996; Burch, 2000; de Graaff and Kolmos, 2003 and 2007; Savery, 2006; Papinczak *et al*, 2007; Reynolds & Hancock, 2010; Stentoft, 2011; Pan & Allison, 2011; Krishnan *et al*, 2011; Raine & Symons, 2012; Savin-Baden, 2014; Galvao *et al*, 2014) and has led to the development of various levels of PBL implementation models, i.e., from course-level in many universities to program level

at universities like Maastricht University in the Netherlands, and Aalborg University in Denmark (Guerra & Kolmos, 2011).

In PBL, students work in groups. After understanding the problem and identifying the current concepts that are applicable to solve the problem, they collectively work to evolve their knowledge and understanding, to solve each problem. Unlike the traditional forms of pedagogy where the material is delivered in a lecture-format, the role of the instructor is to mentor and advice the students, playing the role of a facilitator. Although group work for students and the lack of formal delivery from the instructor provides the intended enhanced learning outcomes of the course described in this paper, these approaches are not suited for all students. This paper will describe some of the concerns raised by students.

To employ PBL in a classroom, an instructor must design good problems whose solution will adequately demonstrate that the learning objectives are met (Cohen, 1997). Such open-ended problems, referred to as ill-structured problems in PBL literature, tend to have multiple solutions. As a result, the students are expected to consider several possible solutions, evaluate the merits and demerits of each, and propose an optimal solution. Thus, these ill-structured problems serve as a stimulus for the students to identify the topics of interests to them and draw an outline of the way they want to study the topics. In doing so, the students take control of their education by defining their learning needs, planning classroom activity/discussions, and assessing their progress as well as that of their peers. While this is true for many students, the differences in specific knowledge and interest in the course presented in this paper create a small number of mixed feelings between students with respect to the effectiveness of the PBL approach.

With these advantages and challenges in mind, the paper presents the approaches that enhance student learning in a fourth year undergraduate engineering technology course. The motivation for implementing a PBL approach is presented in Section 2. The model of the PBL implementation and details related to curriculum, course structure, delivery approach, course learning objectives, and assessment methodology are presented in Section 3. The components of the PBL model that enhance student learning and the associated challenges are discussed in Section 4. A summary of the PBL implementation and conclusions are presented in Section 5.

2 Motivation for the PBL Implementation

The modern designing and manufacturing approaches currently implemented in the automotive industry have significantly reduced the lead time to introduce new vehicles into the market. Most car manufacturers adopted the strategy of offering at least one electric or hybrid electric vehicle, and they implement every year new solutions to improve their existing designs. Preparing graduates for such a fast evolving industry cannot be accomplished in a single course using a traditional lecture-intensive approach. Pedagogical approaches that have been documented to improve the student experience include complementing the lectures with laboratory experiments, using active learning strategies both in lectures and in labs, and delivering courses using project-based and problem-based approaches. Due to the amount of information needed to develop a conceptual design of a vehicle, the problem based learning approach has been selected to be the most appropriate model for delivering a course related to the conceptual design of electric and hybrid electric vehicles.

A conclusion that can be drawn after surveying the PBL literature is that there is no single set of strategies that is suitable for all types of courses. The choice of the best PBL approach is a combination of reading PBL literature, analysing the expected advantages and challenges, and identifying an implementation model

that fits a specific topic and level of education. A detailed analysis of a successful PBL implementation, combined with face-to-face discussions with faculty and students directly involved, is a valuable asset for any new PBL implementation. With a strong tradition of PBL already developed in the medical school at the same university, McMaster University's Department of Chemical Engineering decided to implement PBL in 1982 using a model developed and implemented by Don Woods (Woods, 1997; Woods *et al*, 1997). Woods' model, currently used in several chemical engineering courses, was adopted in 2012 for a capstone design course in the McMaster University's W Booth School of Engineering Practice and Technology. This capstone design course is presented in this paper.

3 PBL Model

The course Conceptual Design of Electric and Hybris Electric Vehicles described in this paper is delivered to students enrolled in the last semester of the Automotive Engineering Technology program offered by the Faculty of Engineering at McMaster University. Different departments in the Faculty of Engineering offer different PBL approaches. For the students enrolled in Automotive Engineering Technology the course described in this paper is their first course offered using the PBL approach. At this stage of their undergraduate university education, students have acquired considerable automotive engineering and management knowledge and gained relevant industrial experience through 12 months of full-time co-op employment. By employing the principles of PBL in conducting this course, the students use previously taught knowledge, investigate various forms of published information, use problem solving activities, identify relevant design approaches and distinguish between acceptable and non-acceptable solutions, and assess the applicability of innovative ideas. Thus, at the end of this course, the students have a good understanding of the state-of-the art in the field of automotive engineering. Further, the PBL approach also allows all students to carry out managerial and project management activities, and to evaluate the information prepared by peers in formulating design solutions. The section below describes the course delivery approach, the learning outcomes, and the assessment strategy. The course elements that enhance students learning are presented in Section 4.

3.1 Delivery Approach

The typical approach in PBL is to divide the course topics into weekly problems and to split the class into groups, an approach used in several PBL classes offered at McMaster University. In the course described in this paper, students are expected to cover eight problems (Centea & Srinivasan, 2015). Each problem is divided into four major sections, each section containing multiple topics. The problems, the relevant sections, and the suggested topics are presented by the instructor at the beginning of each week. Although the problems are ill defined with open ended solutions, the suggested topic have been refined several times in the last five years to ensure that the major topics involved in automotive design are included in students' brainstorming meetings, design options, selection of the best solution, and reports.

The class enrolment is between 40 and 60 students, split alphabetically into groups of four. Every week one of the group members acts as group manager. All four members of the group are expected to be involved in brainstorming activities in order to identify the knowledge already known, perform online inquiries using various forms of published information, recognize and study the latest level of knowledge in the subject area, use problem solving activities, and decide on the novel and innovative design approaches that will be employed in their design solutions.

In the PBL approach implemented in this course students learn in multiple ways. The weekly group brainstorming sessions address their general knowledge and encourage them to learn the topics and ideas presented by the group members. Students tackle each problem by performing inquiries, reading the concepts taught in several previous courses, and making connections between the tasks at hand and the knowledge concepts taught in these courses. The amount of information required to address each problem being significant, the group members need to split the work into components and teach each other at the end of the week. The way in which peer teaching enhances student learning is presented in Section 4.

An important course design aspect that leads to enhanced student learning is a design of the assessments that addresses the intended learning outcomes. The course presented in this paper includes three major types of evaluations on the student work: individual assessments; group assessments; and peer evaluations. Each assessment method has its own merits for a certain type of course deliverable. While a combination of these types of assessments can be employed for a particular set of deliverables, the choice of the proper assessment methodology is important to ensure that students' mastery of the learning objectives is appropriately measured. Section 4 of this paper describes the connection between assessment approaches and student learning.

3.2 Learning Objectives

The main objectives of the open-ended design course described in this paper include (i) recalling automotive engineering concepts learnt in previous courses; (ii) investigating modern comprehensive topics related to vehicle design; (iii) analysing design options and selecting appropriate solutions; (iv) delivering presentations, defending decisions, and debating; (v) developing group collaboration and managerial skills; (vi) preparing comprehensive reports that include technical, business and sustainability topics.

The achievement of the learning objectives have been analysed through course deliverables. The course presented in this paper includes weekly group reports, weekly presentations, a final design presentation, and a final report. These deliverables, the weekly work done by the group members and the peer evaluations are assessed by different individuals. Appropriate assessment methods have been employed so that they are compatible with these learning objectives, as proposed by de Graaff and Kolmos (2003).

4 Discussion

The PBL implementation presented in this paper includes a series of course design elements that are aimed at enhancing student learning. These elements include a request for innovative ideas; a structured group work in which each student acts either as group member or as group manager; peer teaching; active engagement; and a choice of the proper assessment methodology that ensure students' mastery of the learning objectives. These elements are discussed below.

4.1 Request for innovative ideas

Although students are expected to cover the topics suggested in every problem, each group is allowed to address a problem in its own way. Modern and innovative approaches are encouraged as long as they are realistic and the groups can justify their solutions. The students taking this course are enrolled in an automotive program, and many of them are hungry for new information about cars. Therefore, they perform a lot of research to end up with their dream car, and this excitement leads to excellent learning

exercises. However, the amount of information that a group uses when preparing the report for any given problem is restricted to the information collected by the group members in that week. Furthermore, the interest in each topic varies between the group members. As a consequence, it is possible for a student to propose a design solution that is either too futuristic and impossible to be technically obtained within the suggested 3 to 5 years, or have a depth and breadth of knowledge below expectations. These issues can be kept in a check via: (i) the feedback provided by the course facilitator for the weekly reports, and (ii) the class questions and feedback provided at the end of each presentation.

4.2 Structured group work

Right at the beginning of the term, the students are divided into groups of four. The approach used in selecting the groups plays an important role in both the weekly activities and the overall level of the designs. Allowing students to select the groups can provide some excellent projects. However, a potential pitfall is that weaker students could be working together in groups that provide much weaker/substandard designs. Besides, allowing students to work in groups based on friendship does not mimic the realities of the workplace. With these in mind, in this course, the students are grouped in an alphabetic order. This reduces the requests for group change to zero. Furthermore, students accept working with peers that might be academically stronger or weaker fully understanding that this approach mimics real workplace groups. The advantage of the approach is that the academically weaker students are pushed forward by the academically stronger students who want to produce excellent group work. This will enhance the learning process of the academically weaker student due to peer pressure. However, on the other hand, the academically stronger students will work more every week. This issue of work imbalance is addressed by the confidential assessment of the work done by the group members that group managers submit every week.

A group manager is responsible for a variety of activities such as: moderating the brainstorming activities, dividing the work between group members, leading the face-to-face and online discussions, playing a lead role in the decision process, and setting deadlines for receiving the work from the other group members. Finally, the manager is required to prepare a written report and a presentation based on the materials submitted by the group members. Furthermore, as mentioned before, a group manager is also required to submit a confidential assessment of the work done by each member of the group. We observed that, by simulating such real life group environments, many students accept being led by peers who are academically stronger or weaker than themselves. Although this is a good learning skill, accepting to be managed by a student assumed to be academically weaker presents serious challenges that cannot be easily mitigated. Although letting the student to choose their group members at the beginning of the course is a possible solution, it defies the intention of the course to simulate a real live environment where the team members are selected by the management and not by friendship.

4.3 Peer teaching

With eight problems and four-members per group, each student occupies the position of group manager twice and is a group member on six other occasions. The manager's deliverables depend on the work done by the other group members, and therefore a manager has to use his/her project management skills to ensure that the level of the received materials is of high standards. Meanwhile, the other three members are aware that their work is important for the weekly group deliverables. They tend to produce a good level of work as they will also expect to receive the same level of work when acting as group manager. This rotation of roles between manager and group member has two advantages. On one hand, it creates a

sense of responsibility of the manager that increases both course attendance and student engagement. On the other hand, each group member knows that his/her part of the work is important for the success of the projects, and is often eager to teach the other group members the knowledge that they have discovered. This peer teaching process is a powerful tool recognized to enhance student learning. The approach is also known in the published literature as cooperative learning, in which a class is divided into small groups, with each person in the group being responsible for teaching others and contributing a unique piece to the group performance. This approach provides enhanced learning benefits because "students receive more time for individualized learning; direct interaction between students promotes active learning; peer teachers reinforce their own learning by instructing others; and students feel more comfortable and open when interacting with a peer" (Briggs, 2013).

4.4 Active engagement

In the PBL implementation presented in this paper, students start by understanding the details of each problem, recognizing what they know, and identifying what they need to find out. They carry out extensive research, conduct brainstorming activities, identify possible solutions, adopt a design, and prepare an engineering report. Participation of each group member is expected in all these active learning activities. The design solutions are disseminated through weekly class presentations given by the group managers. The design solutions are scrutinized by the course instructor and by peers. The discussions that follow the presentations promote self-reflection and active engagements via question-answer sessions among the students, and have often been an opportunity to provide constructive feedback.

4.5 Assessment methodology

The students enrolled in this course take responsibility for assessing other projects and for assessing one's contribution to the team efforts. De Graaff & Bogaard (2011) describe the distinction between peer assessments of *products* and *process performance*. In the *product peer assessment* students evaluate each other's product. In the *process performance peer assessment* students evaluate each other's performance as a member of the group. Both these types of assessments are included in this course. These types of assessments empower students and in the same time require them to take responsibility of their actions. Students are not allowed to assess their product, as they do not assess the presentation of their manager. Meanwhile, students can assess the process performance through the group manager's assessment of the group members is confidential and cannot be tracked down from the grades. These approaches allow many students learn how to make a distinction between friendly and fair assessment of their peers. As expected, these are also challenges that are difficult to overcome, one of them being grade fixing – an agreement between all the group members to provide an equal 33% contribution to all three group members. Although such an assessment of absolutely equal contribution for each group member can be discouraged, a fair assessment still depends on each individual student.

Individual- and group-assessment are evaluation methodologies the most used by the course instructors. Group assessments reduce the amount of work done by the course instructor when compared with the individual assessment. However, individual assessments provide a better estimate of the knowledge of individual students. Academically weaker students have an opportunity to hide their level of knowledge through group assessments, and therefore they prefer group assessment. On the other hand, students with high academic performances prefer individual assessments; they claim that group assessments downgrade their performance. A study carried out at Alborg University by Kolmos & Holgaard (2007) indicates that, overall, the majority of students prefer group assessments instead of individual assessments.

The question that arises is simple: which of these two types of assessments enhance student learning. Although for this course we believe that the individual assessments provide the foundation for better learning, group assessments are also important as students learn how to work in groups (Centea & Srinivasan, 2015).

At the end of this Section we should ask ourselves: is a pure PBL approach with no direct instruction appropriate for this course? Students' evaluations of the course provide both positive and negative answers. Although encouraging critical thinking for all students is definitely a way to enhance student learning, it comes with challenges to students related to cultural background, personality, education background, expertise in the field, willingness for self-development, communication and negotiation skills – challenges that are discussed in the literature (Guerra & Holgaard, 2016) and these challenges can be identified in the student evaluations of the course. Every cohort will have a different combination of possible challenges, and the instructors will need to find the course delivery approach that fits the majority of the students.

4.6 Lessons learned

Student evaluations have been collected every year. The comments provided by the students have been used after every delivery of the course to improve the subsequent course delivery. Meanwhile, the comments provided by the final project evaluators – all of whom are engineering managers from the automotive and manufacturing engineering in automotive-related large companies – have also been used to improve the content of the course with each passing year. This section describes these improvements.

The initial delivery of the course included eight ill-defined problems, each one including a brief description of the suggested topics that the students were supposed to include in their projects. The descriptions of the topics were brief to ensure open ended designs. The result of these very brief descriptions was a combination of excellent and poor final designs. Students interested in automotive engineering design covered much more topics than the students interested to pass the course. To account for these differences, the topics of each problem have been provided in each subsequent delivery in greater detail, but general enough to ensure open ended final designs.

Each group includes 4 students – with one exception due to the number of students enrolled in the course. One of the requirements of the course is to specify the name of the student who wrote each section of the report. It has been observed that that amount of work done by students varied in some groups – mainly due to students with low interest in the course. To reduce the differences in the work done by each student, the topics included in each problem have been divided in four section of approximately equal weight, each student being required to cover one topic. This approach led to a better distribution of the work done by the members of each group, and increased the overall engineering level of the design.

The grades reported in many university courses indicate a bimodal distribution of the grades. There are students interested in learning and obtaining high grades, and there are students interested just in passing the course. On top of this difference between the interests of the students in a course, another challenge has been observed in the PBL delivery of the course described in this paper. Being the first course delivered with the PBL approach, the students are not prepared to plunge themselves into the ill-defined problems. Although some students like the idea that they can provide innovative ideas and design solutions, some students prefer the traditional lecturing followed by assessment approach. These differences produce mixed feelings about the PBL delivery approach. There are students who absolutely love the approach and ask why this approach was not used in previous courses, and students who definitely prefer the lecturing

approach and don't understand the reason of using PBL in a course. The ratio between the percentages of students in each category varies every year. For this reason, the student satisfaction with the PBL approach is not constant or increasing every year as the instructors hopes. A more detailed analysis of the student satisfaction with the course will be conducted at the end of the next delivery of the course.

5 Summary and Conclusion

The fast evolving automotive industry constantly requires graduates with knowledge and skills that cannot be taught using a traditional lecture-intensive approach. The PBL approach used in this course allows for the development of a learning environment that encourages students to identify and read relevant published research related to the design of modern vehicles, makes students aware of the current trends in the automotive industry, encourages students to use engineering design and analysis methods that have been taught in previous courses, asks students to perform a variety of problem-solving activities, and refines their technical, business-related, engineering collaborative and managerial skills.

This paper describes the PBL model implemented in an undergraduate automotive program offered at McMaster University, and concentrates on the course elements designed to enhance student learning. These elements include a request for innovative ideas, structured group work, peer teaching, active engagement, and assessment methodology. Each of these elements is discussed in details. The challenges to students for each of these elements are presented, and possible mitigation strategies are presented. Overall, it has been found that the course provides many ways in which the PBL approach enhances student learning.

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Empowering students to co-construct the PBL environment

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Abstract

In this study we have analyzed students' reflections on institutionally defined Problem Based Learning (PBL) principles and discussed students' ability to actively conceptualise PBL principles. The study was carried out at the Faculty of Engineering and Science, Aalborg University in 2016, in the first year of the international Bachelor program of Media-technology. The purpose of the study was to facilitate students' identity formulation as self-directed learners in a PBL environment through enhancing their awareness of the principles that constitute this environment. In connection with the study newly enrolled students actively reflected on the PBL principles, made their own definition of PBL and, last but not least, used this PBL definition to analyze their learning process during the first project. The findings show that the principles of self-directed learning, business collaboration and the work with real life authentic problems were stressed by students as new aspects of PBL. When asked to point out the most positive characteristics about studying in a PBL environment, the students pointed to team work, meta-learning and self-directed learning, whereas less attention was given to the direct support provided by staff. When asked to point out the most challenging characteristics, approximately half of the students pointed to self-directed learning; even though this characteristic was seen as one of the most positive aspects of problem based learning, it was also one of the most challenging. In the process analysis, reflecting on the first PBL project, students document their ability to not only define PBL from their own perspective, but to also use the defined understanding of PBL to analyse their learning process and as a result refine their understanding of PBL.

Keywords: PBL principles, conceptual understanding, self-directed learning, meta-learning.

Type of contribution: Research paper.

1 Introduction

Problem Based Learning (PBL) is not a fixed concept; the conceptualisation of what we call PBL is very dependent on the different contextual settings as well as on the actors who attach meaning to the concept, at the conceptual as well as at the practical level. Not only staff but also students will give different meanings to the concept and will have different practices. These inner meanings and conceptual understandings will influence the learner's practice.

However, meanings and understandings of PBL often remain implicit in the move from the theoretical to the practical level. At the institutional level, some institutions explicitly formulate their PBL principles across faculties, but less attention has been given to how students interpret and shape their understandings of PBL based on these institutional formalised PBL principles. In this study we have focused on how students interpret the explicitly formulated PBL principles and whether they are capable of relating these principles

to their own study practice. We do this by letting students with limited experience with PBL move beyond being informed to actively and critically reflect on and discuss the PBL principles.

1.1 PBL principles

Some basic principles have to be in place under the headline of PBL. In Table 1 is shown the comparison made by Kolmos & de Graaff (2014) of the original learning principles at four of the universities that first applied PBL. The table shows similarities regarding the emphasis on problems and small groups. But placing the students in a group with a predefined problem does not seem to be enough, as there is also a strong emphasis on self-directed learning. With reference to Rogers' (1969: 162) perception of learning with relevance for students' own purpose, De Graaff et al (2016) have described self-directed learning as a transformative process which is characterized by active participatory processes involving "the whole person" and a significant amount of "doing".

Table 1: Original Learning Principles at four of the PBL Universities (Kolmos & de Graaff, 2014, p. 145)

McMaster and Maastricht Universities *Problem-based learning*	*Aalborg and Roskilde Universities* *Problem-based and project organised learning*
• Problems form the focus and stimulus for learning • Problems are the vehicle for development of problem-solving skills. • New information is acquired through self-directed learning. • Students-centred • Small students groups • Teachers are facilitators/guides	• Problem orientation • Interdisciplinary • Exemplary learning • Participant-directed learning • Teams or group work
Barrows, 1996	Illeris, 1976

As seen in the second column of Table 1, the PBL approach described by Illeris (1976) moves beyond the way to learn to focus on contents of learning, as it calls for interdisciplinary and exemplary learning contents. Whereas the interdisciplinary aspect of PBL points to more complex problems, exemplary learning stresses a more contextual perspective and the learning of transferable knowledge. Oscar Negt (1968) has been one of the most influential sources of inspiration to the Danish use of the principle of exemplarity, due to his work on 'Soziologische Phantasie and exemplarisches Lernen". As explained by Zeuner (2013: 149), the ambition for societal changes in such a conceptualisation of exemplarity is related to wider political, economic and global contexts.

Holgaard et al (2016) related contextualisation of problems and potential solutions to the problem design process pictured as the identification, the analysis and the formulation of a problem, as the problem analysis includes considerations to such wider contexts. Andersen and Heilesen (2015: 32) has furthermore explained the relation between the exemplary principle and project work in the following way:

"The exemplary principle may be implemented by different pedagogical strategies, for example, by requiring project reports to reflect on social, theoretical, or methodological issues, by requiring group members to

discuss the projects among themselves taking into consideration a broader scientific and social framework, or by committing the students to reflect on the relation between course content and their own project work."

Thereby PBL is not only a transformative process at the individual level; it is also a process, which is set out to have a broader social and even societal impact.

Aalborg University (AAU), Denmark is working from Problem Based Learning principles embracing exemplarity and contextual view on learning. Therefore, Aalborg University is seen as a suitable case to explore the way students co-construct the meaning of PBL and relate PBL principles to their educational practice. The next sub-section gives a more detailed description of the principles underlying the AAU PBL model.

1.2 The Aalborg University PBL principles

Aalborg University was founded in 1974 and has from the beginning been based on principles of problem orientation, project organisation and teamwork (see table 1). At the faculties, these principles were formulated in greater depth by domain specific researchers, e.g. engineering education researchers (see for example de Graaf and Kolmos, 2007).

In 2010 the university management started a development process to not only explicitly state the PBL principles but also explicate the responsibilities and activities of different actors in implementing these PBL principles. The process was initiated by hiring an external consultant with an "outside" view on the commonalities in the way PBL was practiced at institutional level (see Barge, 2010). During the following five years, the management explicitly formulated their commitment to embed PBL principles in all programmes and in the educational practice of all actors in all faculties, This process was supported by other institutionalisations, such as a cross-faculty PBL academy. In 2015 the folder "PBL Problem-Based Learning" describing the AAU PBL principles was published from the Rector's office stating that "*All educational activities at Aalborg University involve problem-based project work, which takes as its point of departure a set of principles that constitute the Aalborg model of Problem-Based Learning (PBL)*" (AAU, 2015:3). As a first basic principle it is stated that:

"The problem is the starting point directing the student's learning process. A problem can be both theoretical and practical. It must also be authentic and scientifically based. "Authenticity" implies that the problem is of relevance outside of academia. "Scientifically based" implies that the problem is comprehensible and may be analysed and solved, taking an interdisciplinary approach. " (AAU, 2015:4)

This first principle is followed by another five principles describing the problem based learning environment at AAU:

- Project organisation creates the framework of problem based learning
- Courses support the project work
- Cooperation is a driving force in problem-based project work
- The problem-based project work of the groups must be exemplary
- The students are responsible for their own learning achievements.

The description of the six principles is accompanied by descriptions of the educational *framework,* including an educational vision, curriculum and assessment, the educational *practice,* including students, academic

staff and external relations and the *support functions,* including resources, student organisation and programme administration and research in PBL.

In the PBL folder the formulated AAU PBL principles have been made explicit and they are to be anchored in written curricula as well as in the educational practice. The latter implies that not only staff but also students are important stakeholders in appropriating the PBL principles and translating them into study practice. This leads us on to the two research questions explored in this study:

- *How do newly enrolled students construct meanings and understandings of the PBL-principles?*
- *How do these meanings and understandings influence their study practice and learning processes?*

In the next sub-section the methodology applied in the study is described.

1.3 Methodology

This study is based on the experiment of getting newly enrolled students to actively reflect on the AAU PBL principles in relation to their study. The students in the experiment are first year Media-technology students doing the first project, the so-called P0 project, which has a duration of 5 ECTS. It runs from the first day, in parallel with courses, and students work in project groups of up to 7 students. The groups have about 25 days to do the project and document their findings in a report and their reflections regarding project management, collaboration and learning in a process analysis report.

The students come from different cultural backgrounds. Furthermore, the group of students are very diverse in terms of their prior experiences with PBL – whereas some have had no experience, others have worked on light scale problem based learning projects in small groups in high school.

The experiment took place as a five steps process.

First, students had a short lecture introducing the PBL principles. This happened at the first day of study and both PBL and Media-technology researchers was present at the lecture, to combine PBL principles with examples from the disciplinary field.

Second, during the first week, the 99 students were encouraged to read the folder about the AAU PBL principles individually at home, and to fill out a note-sheet reflecting (in writing) on the following 5 open questions:

- Insights from reading the folder that add to your prior understanding of PBL
- Examples of how the PBL principles relate to your prior studies
- Any principle you find hard to grasp – or lack concrete examples
- Three points you consider to be the most positive about working in a PBL environment
- Three points you consider to be the most challenging when you are about to work in a PBL environment.

Apart from being a part of the experiment on PBL principles, this activity also aimed at enhancing students' skills in note taking in connection with reading of scientific literature. They were encouraged to share their note-sheets on the learning management system Moodle. A total of 59 students out of the 99 shared their note-sheets on Moodle.

Third, at the end of the first week, students were attending a two hour workshop facilitated by a PBL researcher. Students were asked to bring their note-sheets on PBL principles and they entered into dialog in their project groups to make a joint conceptual map of PBL and a shared definition of PBL.

Fourth, students applied their PBL understanding in practice during their project work. They were encouraged to align their study activities with their understanding of PBL and note down study activities in a logbook.

Fifth, towards the end of the P0 project, students had a lecture and consultation from PBL staff to support them in reflection on their learning process and in writing their process analysis report. In this connection students were asked to reflect on the alignment between their original definition of PBL and their study practices by using this definition to reflect on the way the project group had worked and learned during their first project.

The data analysis has included content analysis of:

1) Note-sheets (59 sheets) handed in by individual students in step 2, describing students' reflection on the conceptualisation of PBL in the beginning of the study.
2) Written process analysis reports handed in by 14 groups in step 5, containing students' reflection on PBL practice during the P0 project period.

The note-sheets have been coded in relation to the type of PBL principles they relate to; and specific quotes are added to explain students' elaborations on their choices. The process analysis has been analysed with focus on the way students relate their understanding of PBL to their study practice.

2 Students' initial reflections on PBL principles

In the following, the findings based on students' individual reflections on the PBL principles in the beginning of the study will be presented. The findings are based on content analysis of the 59 note-sheets handed in by students.

2.1 Insights adding to prior understanding of PBL

The findings show that the emphasis on self-directed learning, the business collaboration and the work with real life authentic problems were stressed as main new insights on PBL at Aalborg University.

The emphasis on self-directed learning surprised many students, as 12 out of the 59 students explicitly referred to this as adding to their prior understanding of PBL. In relation to self-directed learning one of the students explains:

"After reading that folder I've realised that PBL is not only about group work and projects but also acquisition of knowledge in theoretical and more important, practical way. Little did I know that PBL will give me so much freedom of learning on my own or in project group. Now I'm aware that I'm the only responsible for my studies and University staff is here not to set out the only possible path which I will have to follow but support me and my studies." (Student nr. 1)

Several students also touch upon the emphasis on real life problems and what Holgaard et al (2016) have termed problem design – to identify, analyse and formulate a problem based on a real life context. One of the students explains:

"It's all about improving the students' skills regarding identifying problems, analyzing them and then solving them. It is especially important that the students reflect about their work, and analyze it critically so that adjustments can be made to the project." (Student nr. 3).

Furthermore, some students were surprised that the problem is the starting point directing the student's learning process" (e.g. student nr. 19, 40, 53) and furthermore one student (nr. 34) explicitly noted the multiple definitions of a problem in PBL, referring to the folder stressing that a problem can be both theoretical and/or practical. One of the students furthermore relates the problem design to the self-directed learning aspect of PBL (Student nr. 48):

"The foundation of this project is a problem framed in the contemporary time and space. Therefore, the students are supposed to formulate the problem, find the steps to solve it and present the final results as a solution to it that could be implemented in real life."

In total, 14 out of the 59 students in some way referred to the problem design process as a new insight on the Aalborg PBL model.

Furthermore, 20 out of 59 students stated that the outlined extent of interaction with external partners during project work was a new insight, adding to their prior understanding of PBL. This seems to confirm a traditional belief of an existing divide between academia and business, held by students even when entering a PBL environment. As an example, here is a typical response to the question of new insights on PBL concerning external collaboration (Student 11):

"The influence and possibilities of external relations. ("supports the contact between university staff, students and external organisations ") It makes PBL seem more real and relevant. I did not have this kind of understanding before I read this."

Overall, students expressed that the opportunity to cooperate with companies about the solution of an actual problem in their projects was motivating.

2.2 Examples of PBL in prior studies

When students were asked to note examples of how the PBL principles related to their prior studies, it was notable that students had very different levels of experience with a PBL environment. From no PBL experience, due to what student nr. 44 characterised as having been through "a fixed educational line to follow" to having experienced a "combination of different courses into a bigger project" (Student no. 5). In this case, the connotation typically refers to assignments, subjects or topics and a theoretical approach to problem solving. Student 1 explains:

"In my high school, I had a lot of group work activities such as small projects or workshops. I had possibility to work with some kind of problems but usually we were focused on the theoretical way of solving them and hardly ever they were "real".

There are also examples of smaller but rather similar types of projects in groups with a real-life problem as starting point. Especially students, which explicitly refer to high school experiences at the Danish technical high schools, present similar experiences to a PBL environment. Some students also stress that the folder express somewhat more (Student nr. 18):

"For my prior studies PBL has not been a huge part of that. We have experienced to work with real life problems and working in groups to find a solution. However, the model of our studying was nothing like PBL"

This underlines the variation of PBL – a relatively mature observation by a 1. semester student.

2.3 Principles which were hard to grasp

Most students found that the PBL principles as such were relatively easy to grasp after having had the introduction and reading session and as expressed by one student "pretty straight forward and/or self-explanatory" (Student nr. 24). Some of the students noted however that the whole perception of how PBL would be in general and in practice was hard to grasp:

"Not really. Just the general use. I do however think that this understand will be something that you get slowly, as you are using the PBL learning system" (Student nr. 5).

Furthermore, the following three principles were noted as hard to grasp by more than one student: i) The principle of exemplarity, ii) the way to approach the problem and iii) how exactly the interaction with external parties will be.

2.4 Three points being the most positive about PBL

Students had been asked to read the fourth paragraph on Students in the PBL folder (AAU, 2015:15) focusing on students' engagement in project work in AAU. This paragraph describes the 11 types of student engagement listed in table 2, together with the number of students stressing the corresponding type of engagement as most positive in regard to PBL. Students could mark up to three points in the list.

As seen in table 2, point number 7 "support one another in their academic work and contribute to a strong culture of cooperation" is the item, which most students found positive about studying in the PBL environment. Thereby, the most positive aspect of PBL is related to team work and the possibility to be a part of a team and offer mutual support. As some of the students explain:

"You are never alone and people help you. There are people with different mind-sets, so it provides wide knowledge. It makes it possible to see the problem from different angles." (Student nr. 16).

"It is great because you can get to meet and work with a lot of new people, and at the same time get new friends" (Student nr. 42).

Students also find it positive that they are to develop strategies for project cooperation, project organisation and management of learning (point no. 4). This can be interpreted as a clear motivation towards developing process-competences, including meta-learning competences to improve their own capability to learn. Only few students elaborate on their choice of this item, and for the few who do, the considerations are that it can be helpful in future projects or in future workplaces.

Last but not least, 26 out of 59 students have pointed towards item nr. 8 as one of the most positive aspects of PBL. The point of being free to manage one's own project work within the framework of the project module relates closely to the principle of self-directed learning. Some of the students who elaborate on their choice share the following argumentations:

"It's nice also having to decide in which time frames you work, as it gives you more responsibility as well as discipline when it comes to working in a professional manner." (Student nr. 12)

"Success from when you are finally on the right track" (Student nr. 21)

"It gives the student freedom to work with something they find interesting, since it's not fixed what should be done" (Student nr. 27).

"You have to take care of yourself and your group, solve problems together, and deliver." (Student nr. 39)

Table 2: Most positive points about working in a PBL environment (N=59). Student engagement refers to the list in Paragraph 4 (AAU, 2015). Top three marked with bold.

Number	Type of student engagement:	Number of students referring to this point out of the three most positive aspects of PBL (N=59)
1	receive an early introduction to the Aalborg PBL model and the reasons for its application	8
2	are supported in their efforts to integrate the problem-based, project-oriented approach in their academic work	13
3	are supported in successfully addressing any conflicts that arise in their work	9
4	**develop, throughout their studies, strategies for project cooperation as well as project organisation and the management of learning processes**	**26**
5	are motivated and take responsibility for implementing the problem-based approach in their studies	9
6	are motivated to create synergies between different cooperation cultures by collaborating with external partners and engage in interdisciplinary learning environments	12
7	**support one another in their academic work and contribute to a strong culture of cooperation in their studies**	**31**
8	**are free to manage their own project work within the framework of the project module**	**26**
9	will have the opportunity to participate actively in the evaluation of the study programmes	6
10	demonstrate commitment as regards improvements, critical analysis and constructive feedback	7
11	take part in curricular development through systematic evaluations and study board participation	3

In sum, when asked to mention the items that students found most positive about working in a PBL environment, the following three types of engagement were mentioned: team spirit (item nr. 7, 31 students), meta-learning (item nr. 4, 26 students and self-directed learning (item nr. 8, 26 students). An interesting observation is that students paid less attention to the support provided by staff. Thus, the

students practice self-directed learning in the PBL environment, and they express agency in knowledge creation and application, rather than act as passive receivers of knowledge transmission.

2.5 Three points being the most challenging about PBL

Based on the same list of 11 types of student engagement, students were asked to consider the most challenging points of being in a PBL environment. Table 3 outlines the number of students stressing specific points about PBL as challenging (up to 3 points could be selected).

Table 3: Most challenging points about working in a PBL environment (N=59). Student engagement refers to the list in Paragraph 4 (AAU, 2015). Top three marked with bold.

Number	Type of student engagement:	Number of students referring to this point out of the three most important (N=59)
1	receive an early introduction to the Aalborg PBL model and the reasons for its application	7
2	are supported in their efforts to integrate the problem-based, project-oriented approach in their academic work	2
3	are supported in successfully addressing any conflicts that arise in their work	6
4	develop, throughout their studies, strategies for project cooperation as well as project organisation and the management of learning processes	9
5	**are motivated and take responsibility for implementing the problem-based approach in their studies**	**11**
6	**are motivated to create synergies between different cooperation cultures by collaborating with external partners and engage in interdisciplinary learning environments**	**15**
7	support one another in their academic work and contribute to a strong culture of cooperation in their studies	3
8	**are free to manage their own project work within the framework of the project module**	**30**
9	will have the opportunity to participate actively in the evaluation of the study programmes	4
10	demonstrate commitment as regards improvements, critical analysis and constructive feedback	8
11	take part in curricular development through systematic evaluations and study board participation	7

As can be seen in table 3, 30 out of 59 students pointed to item 8, self-directed learning, as one of the most challenging aspects of working in a PBL environment. Thus, while students appreciate the freedom presented by self-directed learning they are also aware that this freedom comes with the responsibility for

own learning which constitutes a challenge. The below quotes from some of the students, who have elaborated on their choice of item 8, express their concerns:

"We have been given a great freedom of work on our projects, what can cause the risk of making wrong steps and mistakes during the whole process of making a project and also it can effect on our problem understanding and exam results." (Student nr. 1)

"To decide our own workflow can be a gift as much as it can be a curse." (Student nr. 23)

"Manage your own project. It's challenging because it can be easy to get side-tracked and distracted" (Student nr. 25).

"No direct indication of what to do and when to do the assignments, projects etc." (Student nr. 28).

"To learn how important it is to hand in or deliver work at the time, and manage your time right on the projects." (Student nr. 42).

"Free to manage our project work within the framework of the project module. This is a point that I think will be a bit hard for me to get used to, because it's a completely new concept to me and I'm still getting the hang of it." (Student nr. 53)

Other challenges pointed out by students are to create synergy in intercultural collaboration (item 6, 15 students) and to be motivated and take responsibility for implementing PBL in their study (item 5, 11 students). However, the main challenge is - beyond comparison - the challenge of self-directed learning.

3 PBL reflections at the end of the first project

The above reflections delivered by students during the first week of their study in an extensive PBL environment like the one at Aalborg University shows that students in fact are capable of reflecting on the learning model in a rather sophisticated way. However, in the constructivist spirit of PBL, student was asked to present their own definition of PBL based on their individual reflection and a facilitated concept mapping session. By the end of this first P0 project, carried out in groups of 6 - 7 students, students are obliged to hand in for assessment a group process analysis report, where PBL is used as the framework for analysis.

One group (A411, 2016) presented their initial definition of PBL, constructed in the concept mapping workshop (step 3), as:

"Our definition of "Problem Based Learning" is: Creatively solving real-life problems in collaboration with others, as a group"

However after working in a PBL environment during their first project, they found it necessary to revise this definition:

"*Fundamentally, PBL is a way to approach a problem. However, in our first description, we thought that PBL was just a way to find a solution. Having completed P0 we have learned that PBL is also learning how to communicate as a group, how to work together, research together, hypothesize a problem etc. The meaning of PBL is not to find a solution, but to figure out how to find it, and learn while doing it*".

It can be questioned, whether this kind of learning experience would have taken place, if the initial PBL definition had been corrected instead of being accepted by staff during the first week of study. On the

other hand, the students also recognise the scaffolding they have received to reach to this conclusion (A411, 2016):

"It is possible to discuss whether we, as students at AAU, are responsible for our own learning, because of the guidance P0 contains. As we get more comfortable with PBL, we will most likely start taking more responsibility for our own learning."

More groups discussed the principle of self-directed learning. Here is a statement from group A409 (A409, 2016)*:*

"In reflecting on the PBL principles, our group strongly emphasizes the freedom related with working project oriented. As it is with university, we are responsible for our own education, and this principle of learning comes even more to mind in PBL as we will not only be responsible for our own education, but others too".

This quote adds a social dimension to the concept of self-directed learning, and together with students attention to the mutual support from peers as expressed above, it also raises attention to the social formation of the "team-worker".

Another important point about learning that stands out in reading about the students' experiences in a self-directed learning environment, is that making mistakes is considered to be a learning condition more than an obstacle, as one of the groups wrote: *"We learned that making mistakes early is better than making them late"* (A412, 2016).

The reflections in the process analyses reports also showed evidence of the challenges already predicted when entering the PBL environment in relation to self-directed learning (A402, 2016):

"*Making sure that we were on the right track was a hassle throughout the whole project, we had a lot of doubts whether what we did was right or wrong. This is going to be a real challenge in all our projects, but our main focus should be to remain true to our original idea/concept that our supervisor has verified, instead of loosing our focus a lot. Staying true to PBL through managing the project, is staying true to our definition."*

So even though most of the students found that the principles of PBL were easy to grasp, they also had to acknowledge that these principles seemed harder to manage in practice. However, as noted by group A402 (2016): *"Analysing our work with PBL can be very difficult, using our own definition as we understand it made it easier"*

4 Conclusion

In this study we have analyzed students' reflections on institutionally defined PBL principles and discussed students' ability to be active players in the way PBL is conceptualized in the educational practice. As the case, Aalborg University, Denmark was chosen due to the explicitly formulated PBL principles and the profound PBL environment. The study was carried out in 2016 at the Faculty of Engineering and Science in the first year of the international bachelor program of Media-technology. The experiment has been to make newly enrolled students actively reflect on the PBL principles, to make their own definition of PBL and last but not least to use this PBL definition as a framework of analysis of the learning process after the first project, which is a pilot project with a duration of 3 weeks.

The findings show that the emphasis on self-directed learning, business collaboration and the work with real life authentic problems were stressed as main new aspects of PBL when entering the PBL environment at Aalborg University. When asked to point out up to three points that students found most positive about working in a PBL environment, the most appealing for students in the PBL environment were team work, development of process competences, including meta-learning and self-directed learning, whereas less attention was paid to the support provided by staff. Thus, the students practice self-directed learning in the PBL environment, and they express agency in knowledge creation and application, rather than act as passive receivers of knowledge transmission.

When asked to point out up to three points that students found most challenging about working in a PBL environment more than half of the students pointed to the self-directed learning aspect, a fact that demonstrates that even though students appreciate the opportunity for self-directed learning, it was also seen as one of the most challenging aspects. Other challenges attracting high attention was the challenge of creating synergy in intercultural collaboration and to maintain the motivation to take responsibility to implement PBL in the line of study.

Besides being of research interest, the results of this study about students' reflections on the PBL principles were valuable as a guide for the teachers to enhance students' PBL competences. The lecturer could use the identified challenges, addressed by the students themselves, as a motivator and a guide for the course material presented and emphasised.

In the process analysis report from student groups, reflecting on their first PBL project, students document their ability to not only define PBL from their own perspective, but also to use the PBL framework to analyze their working and learning processes and as a result re-fine their understanding of PBL. Making the students reflect on PBL principles and make their own definition of PBL is one way to let students co-construct the PBL environment, not only in practice but also at the conceptual level.

Such co-construction processes can be facilitated in many ways, but this study shows that the students are indeed capable of participating in conceptual co-construction of PBL principles, moving from individual prior understandings of PBL to added new insights to a shared and explicitly formulated understanding in the project groups. In this process the understanding of PBL becomes more concrete and something that the students feel that they need to be true to. In this way, the PBL principles are transformed from being an institutional, top-down obligation to becoming a platform for students' learning, helping them create awareness about and actively reflect on the learning environment they are entering.

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Tres cursos de primer año (Introducción a la Ingeniería). Cuando el contexto es importante.

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Abstract

El plan de estudios de cada programa de ingeniería en la Universidad Nacional de Colombia incluye un curso de primer semestre que usualmente se denomina "Introducción a la Ingeniería". En este paper se muestran tres implementaciones de ese curso en tres contextos diferentes: 1) un contexto urbano en Bogotá 2) un contexto rural cerca de la capital, en Sumapaz y 3) un contexto mixto enla ciudad de Leticia, enclavada en la selva amazónica. Los tres cursos son ofrecidos por la misma Facultad de Ingeniería. Se hace énfasis en cómo las diferencias de contexto han orientado algunas decisiones en el diseño del curso. El contexto se describe a partir de un análisis PESTAL: se consideran las dimensiones Politica, Económica, Social, Tecnológica, Ambiental y Legal. La comparación de los tres cursos también es multidimensional: se comparan los objetivos de aprendizaje, aspectos logísticos, la implementación del enfoque PBL y el posible efecto en la adaptación de los estudiantes a la vida universitaria. El mensaje central del paper es que un único diseño del curso no es una buena idea, aún para cursos ofrecidos en los mismos planes de estudio, por la misma facultad, en la misma universidad y en el mismo país.

1. Introducción

La Universidad Nacional de Colombia ofrece 37 programas de pregrado en ingeniería en 4 sedes distintas. Cada uno de esos programas tiene un curso de primer semestre que suele denominarse 'Introducción a la Ingeniería X', con 'X' el nombre del programa específico (e.g. Introducción a la Ingeniería Civil). La Universidad cuenta con programas especiales de admisión dirigidos a poblaciones vulnerables; uno de ellos se denomina Programa Especial de Admisión y Movilidad Académica. En este paper se argumenta que los cursos de Introducción a la Ingeniería usuales no son adecuados para los estudianes que ingresan a ese programa y se explican las diferencias en el diseño de cursos alternativos en dos programas PEAMA diferentes, en comparación con uno de los cursos usuales. Se comparan en total tres cursos introductorios.

En la primera parte de este paper (Secciones 1 a 3) se presenta el contexto general de la Universidad Nacional, sus programas de ingeniería y el programa PEAMA. La sección 4 muestra el resultado de un estudio comparativo entre los cursos introductorios de ingeniería de toda la universidad. En la sección 5 se reseñan las principales diferencias que existen en los contextos en los que suceden los tres cursos comparados, mientras que en la sección 6 se explican las implicaciones de esas diferencias en el diseño de los cursos. En la sección 7 se incluyen unas reflexiones finales a manera de conclusión.

2. Ingeniería en la Universidad Nacional de Colombia

La Universidad Nacional de Colombia es una institución pública creada en 1867. Es una institución pública de orden nacional. Como tal, ha definido su misión en la contribución "a la elaboración y resignificación del

proyecto de nación" mediante el estudio y enriquecimiento de "el patrimonio cultural, natural y ambiental del país" (Universidad Nacional de Colombia, 2015a).

La Universidad tiene tres tipos de sede:

- Sedes andinas: son campus relativamente grandes en los que se ofertan programas curriculares completos y en los que se desarrollan las demás actividades universitarias usuales. Existen 4 sedes andinas ubicadas en las ciudades de Bogotá, Medellín, Manizales y Palmira.
- Sedes de presencia nacional: son campus pequeños ubicados estratégicamente en puntos de las fronteras nacionales. En ellos se desarrollan actividades de investigación relacionados con el contexto regional en el que están inmersos. La oferta de programas de pregrado se limita a un programa especial denominado PEAMA (ver sección 3). Existe una oferta limitada de programas de posgrado en algunas de estas sedes. Existen 4 sedes de presencia nacional, Amazonía, Oronoquía, Caribe y Tumaco, ubicadas en las ciudades de Leticia, Arauca, San Andrés y Tumaco.
- Sedes en colaboración: no son propiamente sedes de la Universidad, sino espacios disponibles temporalmente mediante convenios o acuerdos con otras instituciones para desarrollar recientes ampliaciones del programa PEAMA en pequeñas poblaciones. Este tipo de sede existe hoy en día en los municipios de Villa Garzón (departamento de Putumayo), San José de Guaviare (departamento de Guaviare), la vereda Nazareth de la localidad de Sumapaz (en Bogotá) y en la región occidental del Departamento de Caldas.

La Universidad Nacional ofrece 37 programas de pregrado de Ingeniería en las 4 sedes andinas (y a través del programa PEAMA en las otras sedes). La tabla 1 muestra cuáles son esos programas, y el número de sedes andinas en los que se ofertan.

Tabla 1: Programas de ingeniería en la Universidad Nacional, y número de sedes andinas en los que se ofrece. Elaboración propia a partir de información oficial (Universidad Nacional de Colombia, 2017)

Programa	**Numero de sedes**
Ingeniería industrial, eléctrica, civil, agrícola, agronómica y química	3
Ingeniería mecánica, electrónica, física y ambiental	2
Ingeniería de control, de minas y metalurgia, mecatrónica, agroindustrial, de petróleos, de sistemas y computación, geológica, biológica, de sistemas e informática	1

La actividad académica que desarrolla la Universidad alrededor de sus programas de ingeniería es diversa y de alta calidad académica. A título de ilustración, el Rankinkg QS ubica a la Universidad Nacional en el puesto 269 a nivel mundial, en el puesto 8 en América Latina, y como la mejor en Colombia. Las áreas de ingeniería que destacan (y sus puestos en dicho ranking mundial) son: Ingeniería Química (151-200), Ingeniería Eléctrica (201-250), Ingeniería Mecánica, aeronáutica y manufacturera (251-300).

3. El programa PEAMA

El proceso de admisión de estudiantes en la Universidad Nacional de Colombia se basa en un examen en el que compiten los aspirantes por los limitados cupos de acceso. En forma paralela a este proceso se realizan unos programas especiales de admisión enfocados en poblaciones vulnerables. Uno de ellos es el Programa Especial de Admisión y Movilidad Académica – PEAMA.

¿Cuál es la motivación del programa PEAMA? Colombia es un país con marcadas desigualdades regionales (Cortes & Vargas, 2012). No solo hay diferencias geográficas y culturales, sino que existe una situación de inequidad en términos de distribución de riqueza, desarrollo humano, participación política, penetración del Estado, etc. En términos prácticos, hay una brecha muy grande entre una parte privilegiada del país que podemos llamar 'central' y la periferia con más dificultades, a la que suele designarse como 'las regiones'. La Colombia central abarca sus principales ciudades capitales y ciertas zonas rurales aledañas. Las regiones son territorios aislados, diversos en sí mismos y con gran cantidad de necesidades básicas insatisfechas.

Uno de los sectores en los que se manifiestan notoriamente las desigualdades regionales es en el acceso a la educación, y en la calidad de la misma. Por ejemplo, de las 500 instituciones de educación superior, o sedes de ellas, registradas en Sistema Nacional de Información de la Educación Superior de Colombia, 162 están ubicadas en Bogotá, mientras que hay departamentos como Guaviare y Vichada en los que no hay ninguna (Ministerio de Educación Nacional, 2017).

En el papel, el sistema universitario colombiano ofrece sus programas de estudio a aspirantes de todo el país. No obstante, las diferencias regionales hacen que las probabilidades de acceso sean muy bajas para los aspirantes de las regiones por causas tales como: a) La muy baja oferta de programas locales, b) Los costos adicionales que implicaría para un aspirante el traslado a ciudades en las que sí existe la oferta y c) Las diferencias en la calidad de la educación básica y media, que hacen que el aspirante de las regiones sea menos competitivo en los procesos de selección.

El programa PEAMA tiene por objetivo brindar una opción real de acceso a la educación universitaria a aspirantes de algunas de las regiones del país en las que la cobertura universitaria es baja. El programa busca acercar la Universidad a las regiones en un escenario de restricciones económicas que impide crear un campus equiparable a los de las sedes andinas en todas y cada una de las regiones del país.

El programa opera en las sedes de presencia nacional y en las sedes en colaboración. Su funcionamiento se explica a continuación (Universidad Nacional de Colombia, 2007):

1. La Universidad decide para cada proceso de admisión cuál es la oferta de programas para cada una de las sedes en las que opera el programa. Esta oferta es un subconjunto de la oferta de las sedes andinas. A manera de ejemplo, puede ofertarse para la sede Tumaco el conjunto de todas las ingenierías ofertadas en las sedes de Bogotá, Medellín, Manizales y Palmira.

2. La Universidad decide para cada proceso de admisión cuál es el área de influencia de cada una de las sedes en las que opera el programa. El área de influencia es una región geográfica alrededor de la sede. Sus tamaños son muy variados.

3. Los aspirantes de cada sede compiten entre ellos por un número de cupos preestablecido.

4. Los aspirantes que son admitidos ingresan a uno de los programas ofertados en las sedes andinas (por ejemplo al programa de Ingeniería Mecánica en la sede Medellín)

5. Los estudiantes cursan varias asignaturas en la sede de presencia nacional o de colaboración. Estas asignaturas forman parte de su plan de estudios.

6. Cuando la Universidad 'autoriza la movilidad' el estudiante se desplaza a la sede andina en la que se ofrece su carrera, para completar sus estudios.

7. En la etapa final de su carrera, el estudiante regresa a la región para desarrollar su proyecto de grado; si esto no es posible, al menos lo desarrolla sobre un tema de la región.

El programa PEAMA tuvo una prueba piloto que inició en el 2000. Se consolidó en el 2008 en tres de las sedes de presencia nacional (Amazonía, Orinoquía y Caribe); en la sede Tumaco el programa dio inicio en el año 2015. En el 2016 se autorizó su extensión a las sedes en colaboración. En el periodo comprendido entre el 2008 y el 2015, se presentaron 15.000 aspirantes a ingresar al programa, de los cuales fueron admitidos 2.672, lo que significa una tasa de admisión menor al 18%. Esta cifra por sí sola refleja la pertinencia del programa. En el mismo periodo, más de 1.300 estudiantes realizaron su movilidad a la sede andina. La Tabla 2 muestra las cifras de este flujo.

Table 2: Flujo de estudiantes en la etapa de movilidad académica (2008 a 2015).

			SEDE DESTINO		
SEDE ORIGEN	**Bogotá**	**Medellín**	**Manizales**	**Palmira**	**TOTAL**
Amazonía	287	120	72	21	500
Orinoquía	368	166	72	30	636
Caribe	112	40	12	12	176
Tumaco	0	0	0	0	0
TOTAL	767	326	156	63	1312

4. Los cursos de Introducción a la Ingeniería en la Universidad Nacional de Colombia

En el mismo periodo del 2008 al 2015 el 61% de los admitidos (1.635 de 2.672) ingresó a alguno de los 37 programas de Ingeniería listados en la Tabla 1. En otras palabras, los programas de Ingeniería han resultado ser muy atractivos en las regiones. Los estudiantes de ingeniería del programa PEAMA son bastantes, pero de muchas carreras diferentes. Por restricciones de recursos, los cursos ofertados en las sedes de ingreso deben ser útiles para la mayor cantidad de estudiantes. No es posible ofertar cursos específicos para una carrera, debido al bajo número de estudiantes de cada carrera.

En general, los planes de estudio de ingeniería en la Universidad Nacional de Colombia incluyen un curso de primer semestre, que suele denominarse 'Introducción a la Ingeniería X', con 'X' el nombre del programa específico. Estos cursos sueles ser obligatorios y prerrequisito para avanzar en el plan de estudios. Son los cursos con el que la Universidad recibe a sus estudiantes en el mundo de la Ingeniería, y por tanto son de alta prioridad. Pese a su importancia, no pueden ofertarse a los estudiantes PEAMA en la etapa inicial, por ser cursos específicamente diseñados para cada carrera. Los estudiantes deben cursarlos en las sedes andinas una vez realizan su movilidad. En otras palabras, pueden transcurrir 3 o 4 semestres desde el ingreso a la carrera, sin que el estudiante haya tenido contacto alguno con el mundo de la ingeniería.

¿Qué tan parecidos o diferentes son los cursos introductorios usuales? Para responder esta pregunta se recopiló información cuantitativa y cualitativa. La información cuantitativa se refiere a aspectos logísticos tales como número de créditos por asignatura y número de horas presenciales a la semana (Ver Tabla 3). La información cualitativa se refiere a los aspectos pedagógicos de los cursos, y fue recopilada a partir de talleres y encuestas dirigidas a los profesores encargados de los cursos. La información recopilada abarca a 28 de los 37 programas.

Tabla 3: Comparación cuantitativa de los cursos introductorios usuales en los programas de ingeniería de la Universidad Nacional de Colombia

Número de créditos	**1**	**2**	**3**	**4**	**5**	**6**
Número de cursos	2	11	11	0	4	0

Horas Semanales	**1**	**2**	**3**	**4**	**5**	**6**
Número de cursos	0	9	1	15	1	2

Las Tablas 4 y 5 reseñan las habilidades y conocimientos que se declaran como objetivos de aprendizaje para los cursos introductorios usuales. En ambos casos es notorio que se pueden construir dos grupos claramente diferenciados: las habilidades y conocimientos generales (presentes en la mayoría de los cursos) y las habilidades y conocimientos específicas (presentes en muy pocos cursos)

Tabla 4: Objetivos de formación en los cursos introductorios usuales en los programas de ingeniería de la Universidad Nacional de Colombia. Habilidades y número de cursos en los que aplica

Habilidad	**Número de cursos**	**Porcentaje**
Trabajo en equipo	27	96%
Adaptación a la vida universitaria	25	89%
Comunicación oral	25	89%
Comunicación escrita	23	82%
Comunicación gráfica	10	36%
Segundo idioma	9	32%
Trabajo de campo/invernadero	2	7%
Manejo de tiempo	2	7%
ética y responsabilidad	1	4%
Trabajo interdisciplinario	1	4%
Trabajo en proyectos	1	4%
Manejo de bases de datos	1	4%
Manejo de equipos y herramientas del área de electrónica	1	4%

Tabla 5: Objetivos de formación en los cursos introductorios usuales en los programas de ingeniería de la Universidad Nacional de Colombia. Conocimientos y número de cursos en los que aplica.

Conocimiento	**Número de cursos**	**Porcentaje**
Ámbito del ejercicio profesional	27	96%
¿qué es la ingeniería?	25	89%
Conocimientos específicos de la carrera	22	79%
Entorno académico (profesores/grupos/laboratorios etc.)	19	68%
El contexto colombiano	19	68%
Normas académicas de la Universidad	14	50%
Estructura académico-administrativa de la Universidad	13	46%
Historia de la carrera	12	43%
Conocimiento de la carrera	3	11%
Innovación	2	7%
Relación suelo-clima-planta-hombre	1	4%
Conocer ejemplos del ejercicio de la profesión de ingeniero de control	1	4%
Semilleros de investigación	1	4%
Ciencia, tecnología y sociedad	1	4%
Concepto de egresados	1	4%
Laboratorios	1	4%
Asignaturas del currículo con énfasis en el componente profesional	1	4%
Investigación académica e industrial	1	4%

A la luz de los resultados anteriores, no resulta descabellado formular un curso introductorio válido para todos los programas de ingeniería. Un curso tal debería, no obstante, encontrar un balance entre los aspectos generales de la ingeniería, y las especifidades propias de los múltiples programas. Este balance, además, estará condicionado por los elementos de contexto en los que se desarrolle el curso.

5. Elementos diferenciadores del Contexto

Para explorar los aspectos de contexto que pueden incidir en el diseño del curso, se han tomado tres cursos introductorios de comparación:

- Un curso de Introducción a la Ingeniería Eléctrica, que forma parte obligatoria del plan de estudios en Ingeniería Electrónica de la sede Bogotá. En su formato actual este curso se ha ofertado más de 20 veces en los últimos 5 años.
- El curso de Introducción general ofertado para los estudiantes PEAMA de la sede Sumapaz de cinco carreras: Enfermería, Ingeniería Agrícola, Ingeniería Agronómica, Medicina Veterinaria y Zootecnia. El curso se ofertó por primera vez el segundo semestre de 2016. Al momento de redactar este paper no se ha concluido la segunda versión del curso (Cortes et al. 2017). Este curso (al igual que los demás cursos del PEAMA Sumapaz) se encuentra inmerso en las actividades cotidianas de los estudiantes, es decir, no tiene un horario definido sino que sus contenidos son cubiertos durante la realización de los proyectos seleccionados para el periodo académico.
- El curso de Introducción a la Ingeniería ofertado para los estudiantes PEAMA de la sede Amazonía. El curso se ofertó por primera vez el primer semestre de 2017. Al momento de redactar este paper no se ha concluido esta primera versión del curso.

En términos generales, los tres cursos se apoyan en el enfoque de Aprendizaje Basado en Problemas y ejecutado por Proyectos (Kolmos & de Graaff, 2014), aunque cada uno de ellos lo desarrolla de forma y con alcance diferente.

La exploración del contexto se ha llevado a cabo mediante un análisis PESTAL. Se trata de una descripción del entorno utilizando 6 dimensiones complementarias: **P**olítica, **E**conómica, **S**ocial, **T**ecnológica, **A**mbiental y **L**egal. En la descripción se hace énfasis en aquellos aspectos que pueden tener incidencia directa o indirecta con el diseño del curso. La comparación se consigna en las tablas 6 a 11.

Tabla 6: Comparación de aspectos Políticos del contexto.

Bogotá	La Facultad de Ingeniería de la sede Bogotá ha concebido su misión con un alcance prioritario de orden nacional. Está alineada con la tarea de construcción del proyecto de nación definida en la Misión de la Universidad
Sumapaz	El proyecto PEAMA en Sumapaz tiene una fuerte vocación de promoción social en relación con su entorno específico. El proyecto no tiene una Sede propia que permita desarrollar otras actividades distintas a docencia. No obstante, a través del enfoque PBL se busca impactar favorablemente en el contexto local.
Amazonía	La Sede Amazonía nace alrededor del Instituto Amazónico de Investigaciones, IMANI. La Misión de la Sede tiene un alcance regional (La región amazónica) que trasciende las fronteras departamentales y nacionales. Hay una actividad de investigación fuerte, cuyo objeto de estudio es el contexto amazónico en su conjunto, con énfasis en recursos hídricos. La docencia impartida tiene un componente importante de posgrado.

Tabla 7: Comparación de aspectos Económicos del contexto.

Bogotá	Los recursos de funcionamiento de la facultad de ingeniería provienen del presupuesto de la Universidad, que son fundamentalmente recursos públicos. Los ingresos adicionales de la Facultad se emplean en proyectos de inversión, mediante los cuales se invierte en mantenimiento y mejoras de las instalaciones y los laboratorios.
Sumapaz	El programa tienenimos anuales por estudiante matriculado cada semestre. La Sede Bogotá aporta el trabajo de los docentes del programa. La financiación cubre los aspectos logísticos y operativos.

Amazonía	Los recursos de funcionamiento de la sede provienen del presupuesto de la Universidad, que son fundamentalmente recursos públicos.

Tabla 8: Comparación de aspectos Sociales del contexto.

Bogotá	Los estudiantes de la Facultad de Ingeniería provienen en su mayoría de los estratos socioeconómicos 2 y 3. Aunque hay estudiantes de todo el país, la gran mayoría son de la región cundiboyacense, con prelación de la ciudad de Bogotá.
Sumapaz	Los estudiantes del programa Peama de Sumapaz provienen de lan zonan rurales de las localidades de Sumapaz, Ciudad Bolivar y Usme. Se trata de estudiantes de muy bajos recursos económicos. La mayoría de los estudiantes viven en habitaciones arrendadas en inmediaciones de la sede. Unos pocos viven en sus hogares, también muy cerca. Los estudiantes reciben alimentación por parte del programa, y algunos una ayuda económica que les permite pagar el arriendo. La Universidad presta un servicio de transporte que los lleva el lunes en la mañana a la vereda y los regresa el viernes en la tarde.
Amazonía	Los estudiantes del programa PEAMA en la sede Amazonía provienen de los departamentos de Amazonas, Putumayo y Caquetá. Aproximadamente el 50% son de la ciudad de Leticia mientras que cerca del 40% provienen del Valle de Sibundoy; un 10% provienen de comunidades indígenas. Las comunidades indígenas están organizadas por cabildos regidos por un gobernador. Existen asociaciones de cabildos indígenas que les dan mayor fuerza de negociación política.

Tabla 9: Comparación de aspectos Tecnológicos del contexto.

Bogotá	La Facultad de Ingeniería de la sede Bogotá cuenta con muy buenos recursos tecnológicos en materia de laboratorios, talleres, salas de computador, conexión a internet, etc. Además, está en un entorno que facilita conocer instalaciones industriales modernas, así como obras de infraestructura.
Sumapaz	El programa se desarrolla en un espacio de formación de tres salones (2 aulas de clase y una sala de computadores). Cada estudiante tiene acceso a un computador portátil. La señal de conexión a internet es buena, aunque su confiabilidad está afectada fuertemente por el tiempo meteorológico. No hay laboratorios.
Amazonía	La sede Amazonía cuenta con tres laboratorios de vocación de docencia e investigación. La dotación de salas de cómputo es limitada y sus equipos ya requieren una actualización o remplazo. La conexión a internet es la mejor con la que cuenta la ciudad, pero aun así dista de ser la ideal. En el entorno sólo existe una industria (una fábrica de gaseosas). Dentro de las instalaciones de servicios públicos importantes está una central de generación de energía, el acueducto, y el nuevo aeropuerto que está en construcción. El suministro de servicios básicos no logra cubrir toda la ciudad de Leticia; en corregimientos y comunidades alejadas de la región el cubrimiento es muy limitado. En la ciudad de Leticia hay barrios que han crecido sin planificación ni urbanización previa.

Tabla 10: Comparación de aspectos Ambientales del contexto.

Bogotá	Bogotá es una urbe de 8 millones de habitantes. Sus conflictos ambientales son los típicos de

	una gran ciudad: contaminación del aire, hacinamiento, manejo de residuos, principalmente.
Sumapaz	La vereda Nazareth en la que se desarrolla el programa es fundamentalmente rural. Se desarrolla en la parte baja del páramo de Sumapaz. El principal conflicto ambiental consiste en la presión que la agricultura y la ganadería ejercen sobre el páramo mismo.
Amazonía	Leticia es una ciudad de 40.000 habitantes contigua a la ciudad brasilera de Tabatinga, que aporta otros 50.000 habitantes. Está enclavada en la selva amazónica, a la ribera del río Amazonas. La ciudad tiene problemas por el manejo de residuos y de aguas negras y luvias. La región sufre el impacto de diversas actividades extractivas (forestales, mineras y petroleras principalmente). La sedimentación del río ha convertido el antiguo puerto en un estrecho canal de baja capacidad, y ha construido una isla. Esta isla se ha poblado paulatinamente, pero sin planificación previa.

Tabla 11: Comparación de aspectos Legales del contexto.

Bogotá	El Programa de estudios de Ingeniería Eléctrica se rige por el Acuerdo 248 de 2008 del Consejo Académico y el Acuerdo 34 de 2016 del Consejo de Facultad. El programa cuenta con Acreditación de Alta Calidad otorgada por el Ministerio de Educación Nacional según Resolución 444 de 2012
Sumapaz	El programa Peama de Sumapaz se creó mediante la resolución 405 de 2016 de la Rectoría de la Universidad Nacional. Es un programa asociado a la sede Bogotá, enmarcado en el Acuerdo 201 de 2015 del Consejo Superior Universitario. El programa aplica a 5 colegios específicos, y la oferta se restringe a las carreras de Enfermería, Ingeniería Agrícola, Ingeniería Agronómica, Medicina Veterinaria y Zootecnia
Amazonía	La sede Amazonía se creó mediante el Acuerdo 012 del 15 de marzo de 1995 del Consejo Superior. El programa PEAMA fue creado mediante el Acuerdo 25 de 2007 del CSU, en parte como desarrollo de la ley 84 de 2006. El programa se aplica a los bachilleres de los departamentos de Amazonas, Caquetá, Guainía, Guaviare, Putumayo, Vaupés, el municipio de Piamonte en el Departamento del Cauca, los municipios de la Macarena, Mapiripan y Puerto Concordia en el Departamento del Meta y el municipio de Cumaribo en el Departamento del Vichada. La oferta incluye programas de Artes, Ciencias, Ciencias Agropecuarias, Ciencias Sociales, Ciencias de la Salud (excepto Medicina) e Ingeniería.

6. Implicaciones del contexto en el diseño del curso

Implicaciones de orden logístico:

El curso en Bogotá cuenta con todos los recursos necesarios al alcance de la mano. En particular, sus profesores son profesores de planta que están a disposición de los estudiantes permanentemente. En contraste, los profesores del curso de Sumapaz y Amazonía deben desplazarse hasta las sedes; en el caso de Sumapaz, esto implica un desplazamiento por carretera desde Bogotá, de aproximadamente tres horas y media. En el caso de Amazonia, el desplazamiento es por vía aérea desde las ciudades de Bogotá, Medellín, Manizales y Palmira. Los vuelos disponibles tienen horarios limitados, lo que implica la necesidad de pernoctar en Leticia.

Las diferencias anteriores tienen una incidencia directa en la programación del curso. La componente presencial del curso en Bogotá consta de dos sesiones semanales de 2 horas cada una, durante 16 semanas.

El curso lo imparten dos profesores, pero solo uno de ellos acompaña a los estudiantes en las actividades enfocadas en PBL.

La componente presencial del curso en Amazonía tiene 4 sesiones de dos horas que se ofrecen cada 15 días en bloques contiguos (la tarde del viernes y la mañana del sábado). Cada 15 días viaja un profesor diferente, experto en alguna de las temáticas seleccionadas para el curso. El equipo de profesores (aproximadamente 10) se distribuye el acompañamiento de los equipos de trabajo en las actividades enfocadas en PBL.

La componente presencial del curso en Sumapaz se realiza con viajes semanales de dos o tres días por parte de profesores de la Sede Bogotá. Los profesores trabajan de forma intensiva con los estudiantes. El trabajo se complementa con estudiantes de la Sede Bogotá trabajan competencias de lenguaje y comunicación y con 3 profesores auxiliares que han trasladado su sitio de vivienda a la vereda Nazareth para brindar un apoyo permanente a los estudiantes. Estos profesores auxiliares son, a su vez, estudiantes de posgrado cuyo tema de investigación está en el área de la Educación en Ingeniería.

Implicaciones en objetivos de formación:

El curso de Bogotá es para estudiantes de Ingeniería Eléctrica; dentro de los conocimientos específicos que se trabajan, destacan: 1) el concepto de energía y 2) el significado de las principales variables físicas asociadas a la electricidad 3) la cadena de valor de la electricidad y 4) la organización del sector eléctrico.

Por su parte, el curso de Amazonía es para estudiantes de todas las ingenierías; se han seleccionado unos temas generales tales como : 1) La energía 2) El Agua 3) El sector agrario 4) El sector Industrial 5) Aspectos éticos 6) Sostenibilidad ambiental y 7) Modelos de desarrollo; estos temas se complementan con tareas individuales en las que cada estudiante explora aspectos específicos de su carrera.

El curso en Sumapaz es para estudiantes de 5 carreras diferentes: Enfermería, Ingeniería agrícola, Ingeniería Agronómica, Medicina veterinaria y Zootecnia. La formulación de los objetivos de formación se ha llevado alrededor de identificar el aporte de cada una de las carreras en la solución de problemas concretos que se evidencian en la región.

Implicaciones en actividades e implementación de PBL:

El curso en Bogotá mezcla actividades puntuales como charlas, debates, lecturas, etc. con una actividad de largo plazo enfocada en PBL. Durante el periodo académico, los estudiantes deben formular una propuesta de proyecto relacionada con la Gestión de la Energía. A lo largo del curso se van presentando los elementos básicos de la propuesta tales como identificación del problema, análisis de actores, definición de objetivos y alcance, diseño de la metodología de solución y estimación de recursos. En otras palabras, el proyecto que deben realizar consiste en preparar una propuesta de proyecto.

El curso en Leticia tiene una implementación de PBL semejante a la de Bogotá, pero con dos diferencias importantes: 1) La propuesta de proyecto no se restringe a la gestión de energía, sino que debe buscar solucionar un problema a través del uso de la ingeniería y 2) El problema de la propuesta debe estar localizado en la comunidad en la que viven los estudiantes. Este último aspecto es consecuencia directa de la misión de la Sede Amazonía y del objetivo del programa PEAMA, en cuanto buscan ser motor de desarrollo regional. El curso se complementa con charlas, talleres y tareas de temas generales. Las tareas se reportan haciendo uso de un sistema LMS web (*moodle*).

El curso en Sumapaz está completamente implementado bajo el enfoque PBL. Durante un periodo académico los estudiantes se dedican a identificar los problemas que aquejan a la región, y su relación con la carrera propia. En el siguiente periodo desarrollan un proyecto relacionado con alguno de los problemas. En el proceso se identifican las necesidades directas de aprendizajes, y estas se realizan con apoyo docente. El equipo docente también identifica los conocimientos básicos esperados que no han surgido del proceso anterior, y se desarrollan en forma paralela. Esta implementación de PBL permite trabajar simultáneamente con los estudiantes de las carreras involucradas, pese a que su corpus de conocimiento tiene diferencias notables. Al centrar la atención en el problema, y no en las técnicas de solución, es posible crear un ambiente verdaderamente interdisciplinario, que por otra parte, era la única posibilidad en la sede Sumapaz. Al igual que en el caso de la sede Amazonía, los problemas abordados son problemas reales de la región, con lo que se espera un aporte concreto a su desarrollo.

Implicaciones en adaptación a la vida universitaria y a la convivencia:

Tradicionalmente, los cursos de Introductorios de primer semestre tienen un objetivo oculto, o pocas veces explicitado, que va más allá de los objetivos de formación oficializados en el syllabus. A través de estos cursos se busca facilitar en la medida de lo posible la adaptación del estudiante neófito a la vida universitaria, sus ritmos, sus costumbres y su lógica. Para el curso de Bogotá este es un objetivo muy importante, debido a que la sede recibe un número importante de estudiantes provenientes de otras poblaciones. En particular, es frecuente encontrar estudiantes que por primera vez en sus vidas se enfrentan al reto de vivir autónomamente en una gran urbe; algunos de ellos han ingresado a la Universidad a través de programas especiales de admisión. Por esta razón, en el curso se incluyen actividades que buscan ayudar a construir las redes de apoyo académico entre los estudiantes.

En la sede Sumapaz los estudiantes conviven, literalmente, en tiempo completo con sus compañeros. El entorno de la sede es un pequeño asentamiento de menos de 50 casas. Además, por las condiciones académicas, todos los estudiantes de una misma promoción realizarán la movilidad académica a la misma Sede (Bogotá) y al mismo tiempo. Esto facilita la construcción de sus propias redes de apoyo, que más tarde deberán conectarse con las de sus nuevos compañeros. Además, se aprovecha la cercanía con la sede andina para realizar unos pocos viajes con el objetivo de que conozcan las instalaciones de la Universidad y su entorno antes de tener que desplazarse a vivir allí.

En la Sede Amazonía hay una situación intermedia entre el duro entorno urbano Bogotano y el más apacible entorno rural de la vereda Nazareth. La ciudad de Leticia tiene un tamaño intermedio que permite a los estudiantes tener un contacto cercano, aunque no permanente. Sin embargo, el reto de construcción de redes de apoyo académico es muy grande, debido a que existen notorias diferencias culturales entre, por ejemplo, el estudiante proveniente de la misma ciudad de Leticia, el estudiante que proviene de un entorno rural en Putumayo y el estudiante que proviene de una comunidad indígena. El reto es aún mayor debido a la distancia (física) entre estudiantes y docentes, lo que dificulta que estos últimos promuevan la integración del grupo.

7. Reflexiones finales a manera de conclusiones

En este paper hemos presentado tres cursos introductorios que en una primera mirada podrían parecer semejantes: se trata de cursos para ingeniería, en una misma universidad, en un mismo país y apoyados en el mismo enfoque pedagógico (PBL). No obstante, los tres cursos están inmersos en contextos muy

diferentes desde cualquier perspectiva que se le mire: geográfica, ambiental, social, cultural, económica, etc. Al considerar las diferencias de contexto se hace evidente que el diseño de cada curso debe adecuarse a su propio entorno. Es necesario adaptar los objetivos de formación, las actividades a desarrollar, la evaluación y toda la logística que ello implica. Esta adaptación, o al menos una parte importante, es posible y casi inmediata con el uso del enfoque PBL: un problema bien identificado y un proyecto bien diseñado, necesariamente reconocen los aspectos del contexto que inciden tanto en el problema como en sus posibles soluciones. En otras palabras: en la esencia misma del PBL está la semilla para adaptar los cursos a su contexto. De esta forma, el diseño mismo del curso se convierte en una experiencia PBL.

Los tres cursos que se han presentado en este paper pueden ser comparados en cuanto a su efectividad. Esta evaluación, no obstante, está aún en desarrollo, debido a que dos de ellos han sido implementados muy recientemente. La evaluación es parte de un proyecto de investigación que se adelanta con recursos de la Dirección Académica de Sede de la Universidad Nacional de Colombia.

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Using teamwork games to enhance the success of problem-based learning course

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Abstract

Teachers always think of ways to enhance students' motivation in learning with motivational learning materials and efficient teaching strategies. Problem-based learning (PBL) is one of the strategies, which encourages students to find solution(s) to a given and usually open-ended problem themselves. Many universities have implemented PBL method to enhance the academic performance of students. With PBL approach, it is important to have empirical examples to illustrate or simulate its theoretical concept. The purpose of this study is to investigate whether teamwork games such as *SAVE THE EGG, ZOOM, MINEFIELD, 4-Way Tug Of War, and KEEP IT REAL* can be integrated into Business Administration classes with positive results for both the teacher and students. Through considerable literature review, an integrated framework of teamwork games and PBL model was found, which provides a solid theoretical foundation for this study. Data was collected from observation of business students in PBL-based courses and a series of interviews with instructors of those courses. The results have shown that teamwork games leverage students' skills, such as creative thinking, critical thinking, effective collaboration, and versatile communication. Consequently, their acknowledge relating to course is also improved considerably, which is illustrated by their learning outcome (scores on final exam). This study affirms the effectiveness of PBL as well as provides an empirical insight into the integration of teamwork games in a PBL-based class.

Keywords: Teamwork games, creative thinking, critical thinking, effective collaboration, versatile communication, problem-based learning

Type of contribution: Best Practices Papers.

1 Introduction

The Problem-based learning (PBL) has been adopted in various disciplines including math, law, education, economics, business, engineering, and physical sciences and etc. (Barge, 2010). It focuses on learners, using real-life problems and situations to stimulate students' learning which is usually carried out in small group discussions (Shreeve, 2008). Therefore, PBL can be seen as a small group teaching method that combines the acquisition of knowledge with the development of generic skills and attitudes. As teachers and researchers, we have followed the evolution of the education of students in this field at DUY TAN UNIVERSITY. It has come to our attention that the way PBL is applied. The purpose of this study is to investigate whether teamwork games such as *SAVE THE EGG*, *ZOOM*, *MINEFIELD*, *4-WAY TUG OF WAR*, and *KEEP IT REAL* can be integrated into the Business Administration classes, as the "problems" in the PBL approach, with positive results for both the teachers and students.

The use of games to promote student's learning has been done in the past to capture student's interest as we learn better when we are motivated (Mahmoud & Tanni, 2014). Through considerable literature review,

an integrated framework of teamwork games and PBL model was found, which provides a solid theoretical foundation for this study. Data were collected from observation of business students in PBL-based courses and a series of interviews with instructors of those courses. The results have shown that the teamwork games leverage students' skills, such as creative thinking, critical thinking, effective collaboration, and versatile communication. This study affirms the effectiveness of PBL as well as provides an empirical insight into the integration of teamwork games in a PBL-based class.

2 Theoretical background

2.1 Problem-based learning (PBL)

PBL is not a new phenomenon. It is a methodology that has been used before the classroom concepts were introduced which was first applied in business schools (Zabit, 2010). The PBL process consists of intensive small group tutorials with a teacher as the PBL tutor whose role is to facilitate the learning process of the group. Typically five to eight students work together in a group (Lehmann, ChristensenDu & Thrane, 2008). Active discussion and analysis of problems enable students to:

- learn from each other;
- apply content knowledge to a practical real-world problem;
- learn and practice both individual and group communication skills;
- and evaluate the learning and discovery process they used to achieve their goals and solve the problem.

The PBL process requires students to be actively involved in their own learning so that students in their respective small groups will need to construct their own meaning and understanding of materials or the subject matter to be learned. Students in a PBL group are also required to provide feedback about them as well as to obtain feedback from peers and the tutor.

2.2 Critical thinking, creative thinking, effective collaboration, and versatile communication

Critical thinking is a key component of 21st-century learning. When a student learns how to think critically, he/she goes beyond memorization and seeks to understand the how and why. Students need to question data, consider various perspectives of issues, determine patterns of information, form judgments, and present individual points of view with evidence and logical reasoning. These are merely a few of the critical thinking skills essential for students to acquire in order to become citizens and productive members of a future workplace (Lai, 2011). Therefore PBL is one of methods that foster critical thinking.

Creativity is as much about the student's experience because it is about the end result. Students demonstrate creativity in many forms and through multiple learning style preferences. They are encouraged to dream, elaborate and embellish, to be open and responsive to new and diverse ideas, to generate multiple responses and to respond with originality and innovation. When students examine and evaluate ideas from different perspectives, think in new directions, and synthesize information in useful ways, they demonstrate their creative thinking abilities (Sendag, S. & Odabasi, H.F., 2009). Then PBL is also one of the ways that champion creativity.

The concept of collaboration is based on the belief that "the whole is greater than the sum of its parts." Nowadays, individuals from diverse backgrounds and people with different abilities work together to study and bring resolution to on-going issues or problems. Thus, students must learn how to collaborate with others, respecting each other's knowledge, cultures, differences, and viewpoints. Multiple and varied

learning opportunities should be designed those lead students to value individual contributions. Students can work with partners or in small groups to investigate and collaborate about current learning, or other relevant topics (Bell, 2010). Based on PBL teaching method, collaboration skills could be encouraged.

Whether representing themselves as a group or as individuals, future-ready students must be able to communicate with clarity, focus, energy and passion. Students should learn to move easily from print to non-print, and from communicating face-to-face with peers to communicating through other technological means such as online learning environments. They demonstrate effective communication skills by clearly expressing their thoughts to various audiences and for a range of purposes. The purposes include entertaining, persuading, or informing (Wood, 2003). Thus, PBL oriented class will promote effective communication skills.

3 Research framework

PBL helps to promote deep approaches to learn instead of surface approach. According to Wood (2003), after being exposure to PBL methods, students demonstrated that they were able to take a more pro-active role in their learning, they more readily develop self-management skills in term of their own learning and more self-directed in their learning activities (Salleh *et al*., 2007). Since the PBL method dictates that the students' projects must aim at solving a problem, this approach challenges and engages the students by inspiring them to set up an objective, which they must accomplish through analysis, design, implementation, test and reflection. Based on above discussion, we suggest that PBL activities through teamwork games are able to enhance students' skills and bring benefits to them (Figure 1)

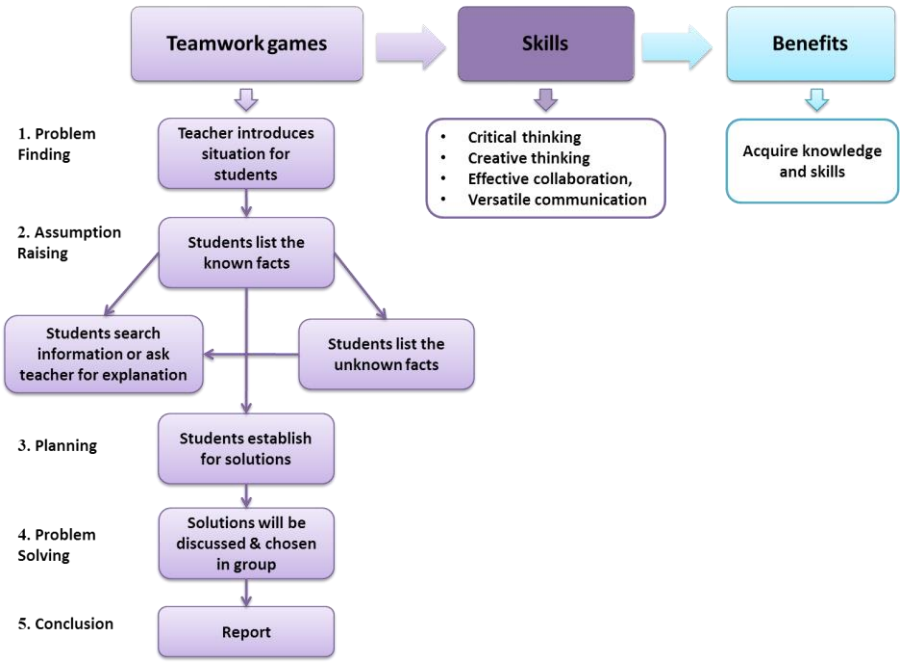

Figure 1. Research framework

The PBL approach begins with a problem that is contextualized. In this phase, teacher introduces either the game or the rules of games. Students need to solve the problem raised by a teacher in the game. The problem becomes more defined as students separate the known facts from the unknown issues. In PBL, the problem becomes the focal point for knowledge acquisition and application. The students' research, investigate and evaluate to arrive at the solution. There is no correct answer. The students are not judged on how well their answers match the teacher's but on the validity of the solution. After several cycles of

data collection and analysis, possible solutions to the problem are formulated. The potential solutions are examined in the light of all the evidence collected and the most viable solution is then selected.

Throughout the game, one of the important skills for the students to practice is to constantly apply critical thinking. Since it is the intended goal of any PBL project to force the students to attempt to solve a problem that has either never been solved before, or never been solved by that specific approach before, it can be suggested that this in itself will increase the chance of something truly innovative to emerge. Therefore, creative thinking is essential. In addition, collaborative and communication are also needed to figure out the best solution for each case.

4 Teamwork games description

Located in Danang, Duy Tan University (DTU) is the biggest private university in the Central Vietnam. A majority of the students are from the local province and 80% of those choose a workplace in cities in the Central provinces. By leverage the PBL method, DTU can provide students with mentioned skills to meet the needs of economic and social development. Most of the business courses in DTU have been conducted in a collaborative way to enhance the interaction between teacher and students as well as students and students. Every course that adapted the PBL method, the teacher would let students play a teamwork game. Students needed to work hard to find the way to fulfill the requirements of the game. The teacher required groups to have between 6 to 8 members. Members in each group had complete control over their game tasks as well as managing their own progress in the limited time set. These games were designed with the purpose of that students could develop or enhance four main skills: critical thinking, creative thinking, effective collaboration, and versatile communication. In this study, we analyzed fives types of games which teacher implemented based on PBL method in business courses in the first academic semester in 2016.

In order to observe if there is any effect from implementing the PBL method, students were put into two classes (A and B) without prior information about how the content would be delivered (i.e. how they would be taught). Students in Class A (n=35) received the content via traditional teaching method, while the ones in Class B (n=35) learned the content via the PBL method. The experimental period took place during eight weeks. For the first week, the students in two classes received the same teaching method. After that, we gave students in both classes a regularly test. The result of the test suggested that there was no difference between the groups.

Next seven weeks, the two classes received the same lessons, yet different teaching/learning methods. Only the students in Class B would play a PBL game before the each session start (the purposes of playing the PBL games were as the discussed in above paragraph). After the game, the main teaching/learning session began. Students in both classes would have the chances to discuss the session content with their group mates, then share their answers with the whole class. Yet, when they shared their answers with the class, the teacher would give direct comments to the students' answers in Class A; but would ask further questions (e.g. the *why*'s) to the students in Class B. On the ninth week (the final week of the semester), both groups of students had to take the same final exam designed by facilitators. This way, we could evaluate the difference in their learning outcomes.

The games used in class were adopted from the Website: http://wilderdom.com/games. This site illustrates classic and novel group games, activities, exercises and initiative tasks. Currently, the games pages receive

about 3000 visitors a day. During teaching time, the teacher selected five types of games which were deemed suitable for students, and in line with the purpose of courses.

4.1 Game 1: Four way tug a war

Purpose: Building effective collaboration, communication skills, and creative thinking
Description: For a unique variation, set up a multi-directional game by tying ropes in such a way that three or four teams tug at once. Several teams pull against each other. The teams will then engage in a tug-of-war game where one team will win if it passes behind a certain point. In traditional 1 on 1 tug-of-war it is mostly strength that wins, with a few tactics. In multi-way tug-of-war it is mostly tactics that wins, with some strength.
Materials Required: 4-pieces of rope tied to a central metal ring, or 2 pieces of rope tied so as making them 4-ways. Cones will be needed to mark play areas. Gloves will be optional to protect student's hands.
Participants: 12 - 25 students in a game, 3-5 students in a group
Time Required: 30 - 60 minutes
How to conduct:

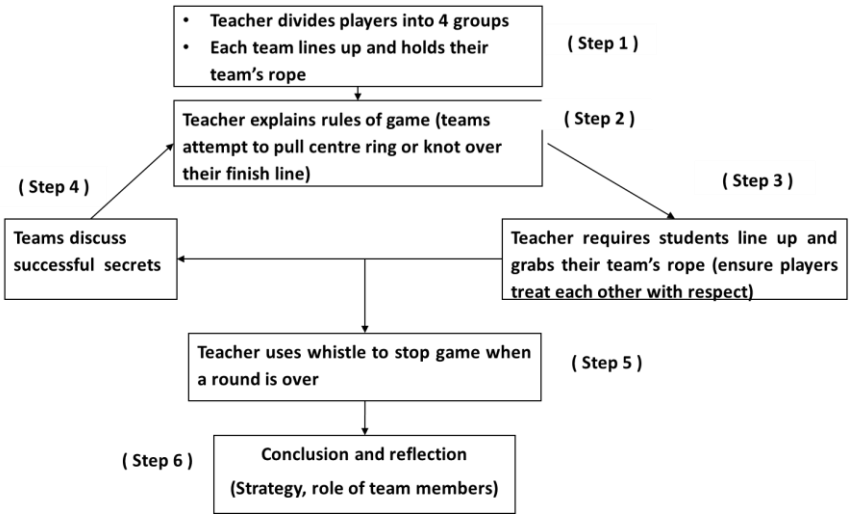

Figure 2. Four way tug a war game

The Four way tug a war master makes sure the center ring is stable and centred. This needs strong leadership because teams are always keen to add extra strain. Teams attempt to pull the center ring or knot over their finish line. This can rarely be achieved by strength alone and instead will require guile. Teams can swivel to cooperate or compete with other teams, then switch directions, etc. Team building groups may wish to discuss what the secrets to success were in this activity - and whether these lessons apply elsewhere.

4.2 Game 2: Minefield

Purpose: Increasing effective collaboration and versatile communication.
Description: Set up a "minefield" by using chairs, balls, cones, boxes, or any other object that could potentially be an obstacle and trap to trip someone over. Leave enough space between the objects for one to walk through. Students take turns navigating the "mine field" while blindfolded, with the guidance from their teammates. A popular and engaging game involves the communication skill and trust. The task is very flexible, works for groups of various types and sizes, and can be adapted to youth, adults, corporate, etc.
Materials Required: A very large outdoor or indoor space; light and soft objects to serve as obstacles (such as large paper cups, empty plastic bottles, cones, soft foam balls, etc.); a blindfold.

Participants: 6 students in a group
Time Required: 30 - 60 minutes
How to conduct:

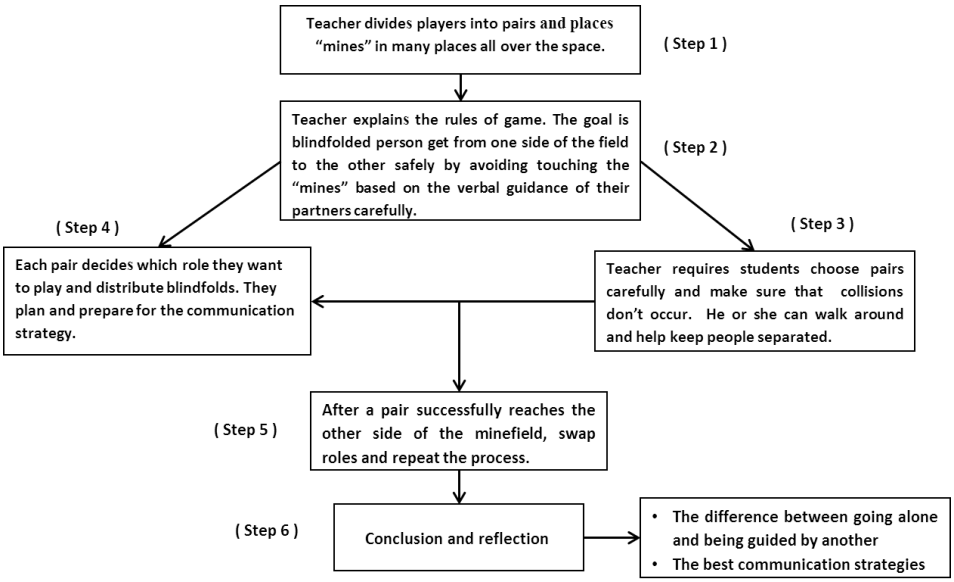

Figure 3. Minefield game

This game helps students develop a genuine sense of trust and safety. One person is blind-folded (or keeps eyes closed) and cannot talk (optional). The other person can see and talk, but cannot enter the field or touch the person. The challenge is for each blind-folded person to walk from one side of the field to the other, avoiding the "mines", by listening to the verbal instructions of their partners. It can help participants develop a unique communication system.

4.3 Game 3: Zoom

Purpose: Building critical thinking skill, and promoting effective collaboration and communication skills
Description: Each group tries to create a unified story from a set of sequential pictures. The pictures are randomly ordered and handed out. This activity is based on the picture books "Zoom" and "Re-Zoom" by Istvan Banyai which consists of 30 sequential "pictures within pictures". Every member in each team is given an image but is not permitted to show it to anyone else. Together, the team has to figure out the correct sequence.
Materials Required: A copy of "Zoom" by Istvan Banyai
Participants: 15 - 20 students in a group
Time Required: 30 minutes
How to conduct:

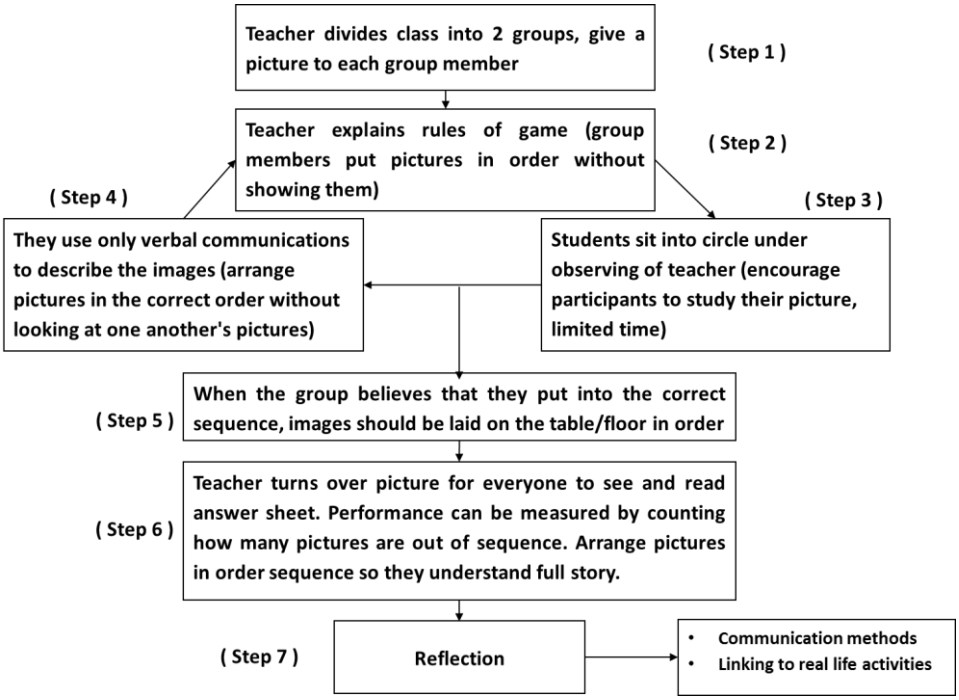

Figure 4. Zoom game

The challenge is for the group to sequence the pictures in the correct order without looking at one another's pictures. Participants will generally mill around talking to others to see whether their pictures have anything in common. Once the challenge is finished, allow everyone to see the pictures and encourage participants to sort out any mistakes in the order (can be done on a table or the floor), then let everyone walk around view the pictures in sequence so they understand the full story.

Figure 4. "Zoom" by Istvan Banyai

4.4 Game 4: Save the egg

Purpose: Promoting critical thinking, creative thinking, and developing effective collaboration and versatile communication skills.

Description: Teams must work together to find a way to "save" the egg. In this game, an egg will be dropped from a specific height. So teams create a device that protects the raw egg safely to the ground with given materials in limited time.
Materials Required: Raw eggs (one for each group plus extras in case of accidents), cardboard, tape, several thin straws (at least 4-12 straws per group), paper towels for clean-up.
Participants: 4 - 6 students in a group
Time Required: 15 – 30 minutes
How to conduct:

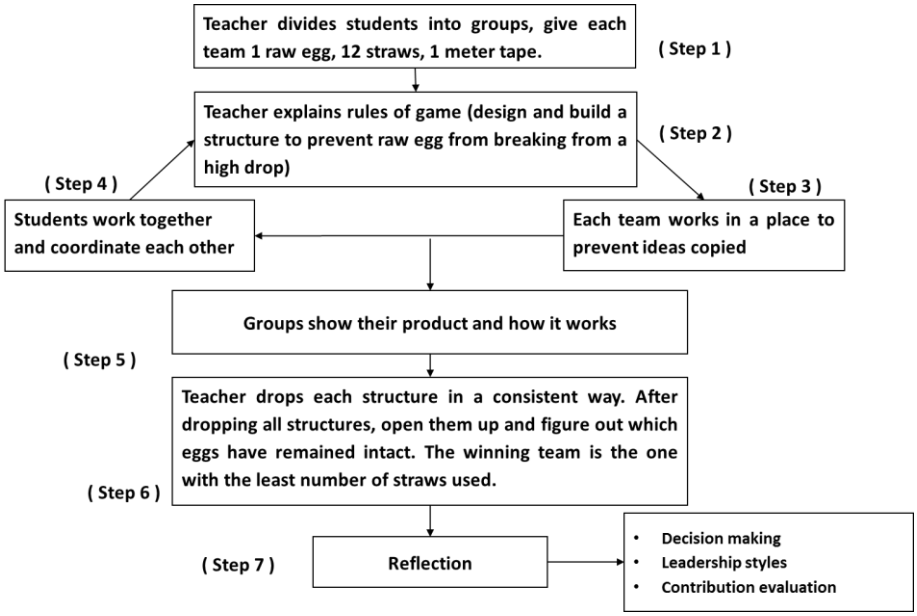

Figure 5. Save the egg game

The game focuses on teambuilding activities that involve creativity and problem solving. It is useful to ask debrief or reflection questions afterwards. This activity is useful to illustrate the importance of team and to highlight aspects of project management.

4.5 Game 5: Keep it real

Purpose: Developing critical thinking, creative thinking, collaboration and communication skills
Description: This open-ended concept is simple and serves as an excellent segue into problem-based learning. Challenge students to identify and cooperatively solve a real problem in their schools or communities.
Materials Required: Depend on each group
Participants: 5 - 9 students in a group
Time Required: 60 minutes
How to conduct:

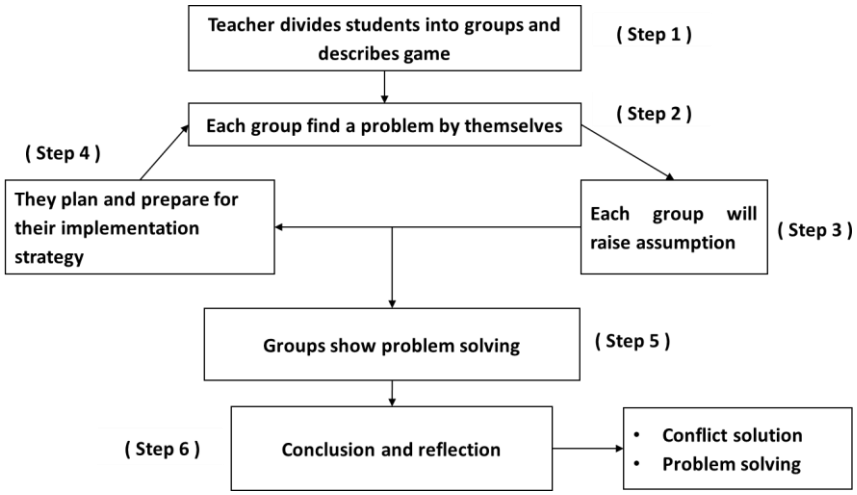

Figure 6. Keep it real game

The Keep it real game engages and allows even the most resistant people to open up and speak their truth to one another within moments. It provides a safe space in which people experience one another in deep, meaningful, real and transformative ways. Therefore this game facilitates understanding, compassion and empathy towards others.

5 Findings and discussion

5.1 Skills development during processes

Basing observation, we found that the roles of teacher and students in each game and in different stages of implementing, as illustrated in Table 1:

Table 1. Reflections of cases

Game	Problem Finding	Assumption Raising	Planning	Problem Solving	Conclusion	Skill			
						Critical	Creative	Collaboration	Communication
4 way tug a war	T*	T	T	S**	T			X	X
Minefield	T	T	T	S	T			X	X
Zoom	T	T	S	S	T	X		X	X
Save the egg	T	S	S	S	T	X	X	X	X
Keep it real	S	S	S	S	T+S	X	X	X	X

T: Teacher. **S: Students

After the games, we found that the students would conduct an autonomous study (i.e. they would look for information in order to solve the given problems themselves), rather than relying solely on the teachers to provide them the information, of which the latter is common to many students in DUY TAN UNIVERSITY. The skills the students developed through the games were critical thinking, creative thinking, effective collaboration, and versatile communication (as indicated in Tables 1 and 2). These developed skills assisted these students perform better in the related business courses, in terms of initiating actions (e.g. research, communication, and collaboration) for solving problems proactively, when compared to the students who were not in the class which adapted the PBL method.

Table 2. Skills development during processes

Activities	Skill
1. Students list known and unknown facts	Critical thinking
2. Searching information about unknown in the Internet or ask teacher for explanation	
3. Students establish solutions	Creative thinking.
4. Solutions will be discussed in group and choose the best	Effective collaboration
5. Report	Versatile communication

5.2 Evaluation of the implementation of the PBL method

Two business classes (A and B) were selected to test. The 35 students in class A were taught by traditional method. The 35 students in class B were given PBL based lessons. The results from the final exam suggested that the differences between the students in class A and in class B were significant. The number of students in class A obtaining high scores was less than the number of class B. Such results from the final exam implied the benefits of applying the PBL method, in which had not only reinforced students' skills but also their academic performance.

By leverage these games, teachers can apply in business courses in different parts of teaching content, as illustrated in Table 3:

Table 3. Implication of games in Business Courses

Game	Teaching content	Description
4 way tug a war	Overview	All of members in group will introduce themselves. Each group is different from others
Minefield	Environmental Management	Each pair will list factors which affect operation of company
Zoom	Making Decisions	Teacher gives 3 pictures. Each group will tell a story from 3 pictures.
Save the egg	Planning	Each group will choose a product or service and make business plan for that product or service
Keep it real	Assignment	Each group will choose a company and make a presentation how business operates

The challenge for many teachers in adopting a PBL approach is to make the transition from knowledge provider to facilitator of learning as smoothly as possible. The reality is that learners who are new to PBL require significant support from teachers. Teaching institutions that have adopted a PBL approach to curriculum and instruction have developed extensive tutor training programs in recognition of the importance of this role in facilitating the PBL learning experience. Games and other forms of interactive entertainment are today accepted as a serious element in teaching in all levels of education. Yet, this learning and teaching approach is still new to most educational institutes in Vietnam. We believe that PBL is not only a source to engage students through innovation, but also result in an increasable amount of stable successful innovative creations. To the best of our knowledge, this research is one of the few studies investigated the implementations in business field in the Central Vietnam. We hope the findings presented in this paper will not only inspire educational leaders and fellow educators to learn more about PBL but also aspire discussions and future research.

Here are a few strategies we can use to integrate PBL into our teaching method:

- Clearly define the purpose(s) for doing PBL: Know the procedures you will use, along with your expectations, well before your first PBL session.

- Develop ill-structured problems: Based on student input about course topics, the instructor develops ill-structured problems, or open-ended problems that have multiple solutions and require students "to look at many methods before deciding on a particular solution."
- Refrain from providing information: Regardless of how topics were selected, the instructor presents the problems to student groups before providing any formal instruction on the topic.
- Allow time for collaboration: Students then work on the problems in groups of three to eight students, depending on the number of students in the course and the number of available instructors or tutors.
- Conduct regular assessment: Assess progress at regular intervals. If necessary, interrupt group work to correct misconceptions, or to bring groups up to par with one another.
- Hold class discussions: Allow time for class discussion of the problem at the end of the PBL session, or at the beginning of the next class period.
- Facilitate peer feedback: A critical part of assessment in PBL is the feedback students receive from their peers.

6 Conclusion

The focus of this paper is leverage teamwork games for enhancing skills of students through implementing PBL method. Through the implementation of the games in the business courses, the students demonstrated better performance than the students in previous years, as well as the students who were not exposed to the PBL method. Furthermore, these students who have been exposed to the PBL approach have more confidence in expressing their ideas and contributing themselves in teamwork. Unlike traditional teaching method (i.e. lecturing only), the PBL approach would demand more efforts from the course instructors, especially for observing students' learning progress and provide minimum but tailored instructions that allows the students to solve the problems themselves without being too frustrated. PBL approach is new to Vietnam tertiary education system, especially in the institutes in the Central Vietnam. The results from this study illustrate a promising teaching and learning approach for the students and the educators in the business field in this region. Further research and studies would be needed to the PBL implementations in other fields in the region.

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Tactics for handling large teams in PBL project classes

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Abstract

PBL teaching method has been adopted at Duy Tan University (DTU) for the last three years. While there have been a great number of successful stories, there are also shortcomings in the implementation of PBL at DTU. Most notably, according to students' feedback on the perception of PBL courses, many classes, especially those at the sophomore level, still have very large class size with more than 60 students in each class. This, in effect, hinders many advantages of Active Learning and teamwork collaboration under the PBL model because (1) it is hard to carry out interactive learning activities in large classes, (2) large teams of 8 to 12 members always take much time and effort for communication, (3) contributions of members in large teams are usually uneven and hard to be measured, and (4) it is usually difficult to find enough different real-world projects for many teams at the same time. From the collective experiences of staff members at various schools and faculties of DTU, a number of evolved tactics have been gathered and recommended to better serve the dynamics of large classes. Specifically, those include newly-designed individual and team games, general guidelines for team formation and collaboration, strict monitoring tools for team planning efforts, peer reviews and inter-team evaluations, social venture plan projects, etc. The relevance and validity of these tactics has been proved empirically and statistically by our students' recent performance results as well as through their evolved perceptions. This paper is expected to be very helpful to universities and colleges in countries which have limited economic capability and where large classes are more prevalent.
Keywords: Active learning, creative thinking, social venture plan, teamwork games, team planning work
Type of contribution: Best practice paper

1. Introduction

As the student-centered teaching method which promotes the creativity, autonomy and flexibility in the study of student, PBL method has been widely applied on a large scale for all training programs at Duy Tan University (DTU) over recent years. DTU is the first and largest private, multidisciplinary and multi-sectoral educational institution in Central Vietnam. Currently it has approximately 20,000 students and the classes are typically held on a large scale of approximately 80 – 100 students each. Accordingly, in the PBL courses, each class has about 10 groups with 8 to 12 students for each group. The advantage of large size class can be seen in financial aspect, but on the other hand, the large size class can create difficulty in achieving teaching objectives and hardly promote all the benefits of PBL teaching method if instructors do not have suitable teaching tactics. In reality, in the first year of PBL application for large size classes (academic year 2013 – 2014), it seemed that the students from the large size classes did not appreciate the benefits of PBL method to their study. Therefore, university and faculty leaders required an official evaluation of the effectiveness of PBL teaching in these classes and demanded further measures if necessary to remedy the situation.
As the university leaders' request, the researcher group which consists of Ms. Nguyen Thi Kim Huong, Ms. Hoang Anh Thu and Ms. Luu Thi Thu Huong conducted surveys to evaluate the effectiveness of PBL teaching method in these classes. The goal of the survey was to review

students' perception on PBL after two years' study which involves attitude toward group work, attitude towards working with facilitators, learning objectives, self- directed learning (Ryan, 1995). From students' feedback, the researchers coud determine the results achieved as well as the drawbacks in students' viewpoints. And if necessary, the researchers would carry out survey on instructors of these classes in order to identify if the instructors did a good job in adopting PBL teaching method in large classes from project launch process, project creation process and project completion process. Based on the findings, the researchers could suggest further action plans with the instructors including discussing to identify what techniques should be applied to overcome the failures (if any) in implementing PBL in class with large teams.

2. PBL application at Duy Tan University

The application of PBL teaching method at DTU followed the general approach as in other universities over the world. In the process of implementing PBL, the first thing that the instructors do is team formation. Each team has 8 to 12 students. After that, instructors assign projects (games) to teams or teams can choose projects (games) to work on. Based on the projects, all teams do the planning, task assignment, cost estimation, and anticipate the challenges that they will encounter during the implementation process under the guidance of instructors.

Once the preparation process has been done, teams carry out the project according to initial planning and, if necessary, they may have some adjustments to create the desired products. During the project implementation, instructors supervise and require periodically progress reports so that they could have guidelines for adjustment.

At the end of the course, teams make presentation of their products to the class, announce and assess the contribution of each team members and receive contribution comments from instructors and other teams. Based on the opinions of instructors and other teams, each team will perfect their product and complete the course.

Currently PBL teaching method is implemented for sophomore, junior and senior students in different courses, and each course has different target, methods, and projects.

O PBL 296: This course is at the sophomore level, and it provides an introduction about PBL and active learning. The major approach of the course is "learning through playing", in which students will play teamwork games so as to build their problem-defining and problem-solving skills as well as basic teamwork skills. Products of this course are the items that teams create in every game and will be judged by instructors and other teams. The objective of this course is to learn about task assignment, how to set a target product and coordinate among team members.

O PBL 396: This course is at the junior level. In this course, students will have the chance to work on a project related to their major, which simulates real-world activities of their future career. Each student would play a different role in the project. The problems presented in the project are usually well-defined with a readily-available set of solutions for accurate assessment of the students' performance. Products of this course are the products made in the project which, to some extent, are feasible and related to their specialized major. The objectives of this course include determining project, planning, assigning tasks to members, implementing project, making periodic evaluation, adjusting and reporting products.

O PBL 496: This course is designed for the senior students with the expectation of preparing them for their internships. It very much resembles the settings and structures of PBL 396 except for one major difference that the big problems presented in the project are open-ended with no right or wrong solutions. The problems sometimes come directly from the industry; but many times, because of the shortage of requests from local businesses, they are simply created by our instructors to simulate problems in the real world. Students in teams will need to formulate their own integrated solution(s), using not only skills and knowledge in their

major but also in other related fields. Usually in this class, students will work under the guidance of two instructors.

3. Achievements and drawbacks of teaching large team in PBL project classes

Ever since the adoption of the PBL teaching method, the most visible benefits and improvements that can be seen at DTU: (1) Students participate in active learning activities which help them promote personal and interpersonal skills. (2) Students learn professional skills through real-life situations. (3) The introduction of three PBL-project courses of PBL 296, PBL 396 and PBL 496 definitely has raised the bar for the required level of skills in critical thinking, problem-solving, project management and teamwork. (4) Students feel proud of what they have done in the projects and become confident during the internship.
However, there are still some issues need to be concerned during the adoption of PBL:
(1) No new projects (games) are designed since the first date of PBL adoption. The same projects (games) are used repeatedly from semester to semester and from class to class. This make the project launch process less exciting and interesting to both instructors and students. Students know exactly what projects (games) will be launched to them, so they can look at the products previously done by other class and try to imitate or even worse they reuse these products and hand them to the instructors. This does not promote the creativity, initiative and collaboration among team members;
(2) There are no team formation and collaboration guidance during the implementation process;
(3) There are no strict monitoring tools to motivate team planning efforts;
(4) Students expect peer reviews and inter-team peer evaluations should be made on a regular basis throughout the learning process rather than the end of the project.
(5) The projects (games) are not very practical and social – related and there is no involvement of businesses and professional organizations in project development and evaluation;

4. Studies and results

With the motto "All for the benefit of learners", DTU strives to create the best learning conditions for students. Therefore, at the end of the courses, DTU always takes the feedback from students to learn about students' opinions on the courses... So, for the new courses like PBL project courses, the survey for student opinion has extremely important implications. Stemming from the requirements of university leaders, the research team conducted the survey to evaluate the effectiveness of PBL teaching method in these classes.
The studies were conducted at the end of 2 academic years: 2013 – 2014 and 2014 – 2015. Originally at the end of the first academic year of PBL adoption, in June 2014, the researchers intended to conduct the survey only on the students to get their feedback concerning the typical features of PBL project courses including work group, facilitator role, self-directed learning, learning objectives, and projects after one year of PBL application. However, from the survey results, the researchers decided to conduct another survey on the instructors for a more comprehensive view of the issues to be addressed in this course. From the survey results, the team discussed with the instructors to devise new tactics suitable for the teaching of these courses. After one year of application of the new tactics, at the end of academic year 2014 – 2015, the researchers conducted the second survey to students and instructors to assess the effectiveness of new tactics to handle large PBL project courses
Therefore, in this section, the authors present three main contents (1) survey result on the effectiveness of PBL project classes with large teams after one year of PBL application in academic year 2013 – 2014, (2) a number of evolved tactics gathered and recommended from the collective experiences of staff members to better serve the dynamics of large classes, (3) re-evaluating results after applying the new tactics for handling large team in PBL project classes in 2014 – 2015.

4.1. Survey result on the effectiveness of PBL teaching method in large size classes after 2 years of PBL application.

After one year of application of PBL teaching method, at the end of academic year 2013 – 2014, the research team conducted a survey to assess the effectiveness of teaching and learning under PBL method for large size classes.

The survey was first conducted on all of 324 sophomore level students of Business Administration Faculty. The reason for choosing Business Administration students stem from the fact Business Administration Faculty is the largest faculty at DTU, the courses in the curriculum often require students participate in teamwork activities, learn theory, combine and contrast with social – economic reality. In addition, Business Administration students are usually highly evaluated for their studiousness and enthusiasm. The researchers hoped that the survey result would reflect the general ideas of students on large PBL project courses. For the survey with students, the researchers adopted a 3-point Likert scale of Disagree, Neutral, and Agree because the main purpose here was not to carry out a quantitative study, but rather, the researchers continue to inquire for students' qualitative response and explanation given that their answer to any one question is either Agree or Disagree.

Table 1: Survey about the effectiveness of PBL to students (Academic year 2013 – 2014)

Variables	Statement	Disagree	Neutral	Agree
1. Student response to attitude toward group work	1.1. My team mates and I can proactively organize and implement group project in large team	126/ 38.9%	95/ 29.2%	103/ 31.9%
	1.2. All team members can efficiently help one another in the large team	120/ 37.2%	94/ 29.1%	109/ 33.8%
	1.3. I felt respected by and listened to by my peers in the large team	126/ 38.9%	77/ 23.8%	121/ 37.3%
	1.4. All team members can evaluate one another efficiently in large team	128/ 39.6%	111/ 34.3%	84/ 26.0%
2. Student response to facilitator role	2.1. Facilitators can regularly assist and guide our large team in developing our process	109/ 33.5%	92/ 28.3%	124/ 38.2%
	2.2. Facilitators can promote the integration and synthesis of information in our team	123/ 38.1%	121/ 37.3%	80/ 24.7%
	2.3. Facilitators can listen and respond well to our team's concerns and problems	121/ 37.4%	83/ 25.7%	119/ 36.9%
	2.4. Facilitators conduct fair and objective summative assessment for the overall team and individuals	114/ 35.3%	116/ 35.8%	94/ 28.9%
3. Student response to learning objectives	3.1. We have good understanding of the courses' learning objectives	114/ 35.3%	114/ 35.2%	96/ 29.5%

	3.2. We feel that we have mastered the learning objectives expected from the projects presented.	105/ 32.5%	101/ 31.1%	118/ 36.5%
4. Student response to self-directed learning	4.1. My ability to find, read and analyze information had improved from the PBL courses	112/ 34.5%	103/ 31.8%	109/ 33.7%
	4.2. The courses helped me to obtain information from a variety of resources and I benefited from the process of researching and discussing the problems with my facilitators and team mates	117/ 36.2%	120/ 37.2%	86/ 26.6%
	4.3. I become more self-directed in learning in large team	112/ 34.5%	128/ 39.6%	84/ 25.9%
5. Student response to the efficiency of PBL courses with large teams	5.1. Large members help our group easily collect, synthesize information and implement the projects	102/ 31.6%	113/ 34.8%	109/ 33.6%
	5.2. I learn more knowledge and skills from the course compared to other courses	105/ 32.3%	120/ 37.0%	99/ 30.7%
	5.3. I feel more responsible in large team than in small team	140/ 43.1%	92/ 28.3%	93/ 28.6%
6. Student response to the diversification and practical aspect of projects	6.1. We can choose a wide range of projects to work on.	106/ 32.6%	125/ 38.7%	93/28.6%
	6.2. Projects are practical since they can address pressing social issues related to our major.	128/ 39.5%	79/ 24.4%	117/ 36.1%

Survey results showed that students had negative feedback for all criteria include teamwork attitude, teacher role, self – directed learning, understanding learning objectives, efficiency of PBL for large size classes as well as the diversity and practicality of the projects. From students' explanation, the researchers found that the inefficiency of PBL adoption for large size classes attributed to the drawbacks of this kind of classes. Most notably, there was no effective interaction between instructors and students. Since there were many large groups in the classes, instructors could not have timely intervention and guidance for students to keep them on track and instructors could not distinguish the free riders from the groups so the grading, to some extent, were unfair. Besides, the interaction within a group was so weak, there were uneven contributions among members to project. Students also complained that the projects are so limited (the same project are deployed among classes and from semester to semester), students could easily anticipated what projects would be delivered to them so they were not excited at the project launch. In addition, the projects were not practical and suitable to their majors, so they do not understand learning objectives…

This led the research team decided to conduct another survey on all the 18 instructors of Business Administration Faculty involved in teaching these classes in hopes of finding out how instructors evaluate their role as well as their ability to create and organize suitable and

practical projects. The content of the survey related to the instructors' role in the processes of project launch, project implementation, project completion and the ability to create practical projects (Mergendoller, Markham, Ravitz, & Larmer, 2006).

Table 2: Survey about the role of instructors (Academic year 2013 – 2014)

Variables	Statements	Disagree	Neutral	Agree
1. Facilitator role in project launch process	1.1. In PBL course with large teams, I can stimulate student interest, enthusiasm and concern	5/ 27.8%	8/ 44.4%	5/ 27.8%
	1.2. In PBL course with large team, I can establish high expectations for the students and they have clear understanding and vision of the depth of learning and quality of academic performance	5/ 27.8%	7/ 38.9%	6/ 33.3%
	1.3. In PBL course with large teams, I can clarify rules, procedures, products, timeline and grading practice to all students in the class.	6/ 33.3%	6/ 33.3%	6/ 33.3%
2. Facilitator role in guiding inquiry and product creation process	2.1. In PBL course with large teams, I can help students define tasks and assess progress of the overall team as well as individual student	6/ 33.3%	7/ 38.9%	5/ 27.8%
	2.2. In PBL course with large teams, I can regularly guide and intervene when necessary to keep the students on track	6/33.3%	6/ 33.3%	6/ 33.3%
3. Facilitator role in summative assessment	3.1. In PBL course with large teams, I can conduct fair and objective summative assessment for the overall team	6/33.3%	7/ 38.9%	5/ 27.8%
	3.2. In PBL course with large teams, I can conduct fair and objective summative assessment for individual student	6/33.3%	7/ 38.9%	5/ 27.8%
	3.3. In PBL course with large teams, each team member can assess their own work and they should learn how to critique other members' work.	4/ 22.2%	4/ 22.2%	10/ 55.6%
4. Facilitator role in creating practical projects for large PBL class to work on	4.1. I can easily create practical projects for PBL courses with large teams.	6/ 33.3%	6/ 33.3%	6/ 33.3%
	4.2. I have a wide source of social venture plan projects to deploy in PBL courses with large teams	7/ 38.9%	6/ 33.3%	5/ 27.8%

From the survey results, the researchers found that quite a lot of instructors did not think that they had played a good role in large PBL class. This was evidenced by the fact that the negative proportion was greater than the positive rate and in many statements, instructors answered by choosing the neutral responses. Another striking issue was that most instructors agree that

students could be empowered to evaluate the performance of their friends. Concerning the ability to create practical project for large PBL class, only 27.8% of instructors were confident that they had a wide source of social venture plan projects for the students choose to work on.

4.2. Survey result on finding out new tactics for handling large teams in PBL classes

The above survey results indicated that instructors had encountered many difficulties in handling large teams in PBL classes. This was a major challenge which required urgent solutions of instructors in order to maximize the effectiveness in handling large groups. Therefore, the researcher team made depth interviews with a number of managers and instructors who had taught or were teaching PBL classes with large groups to find out some new tactics for handling large teams more effectively. After interviews to collect experiences of staff members at various faculties of DTU, a number of evolved tactics have been gathered and recommended to better serve the dynamics of large classes. Specifically, those include newly-designed individual and team games, general guidelines for team formation and collaboration, strict monitoring tools for team planning efforts, peer reviews and inter-team evaluations, social venture plan projects, etc (Fraenkel & Wallen, 1993). Based on those tactics, we designed another questionaire and conducted on 18 instructors who were teaching large PBL classes to test and confirm those tactics before applying them in next school year.

After the survey, research team synthesized many specific tactics and suggested that they should be applied in school year 2015-2016. The specific tactics include:

<u>* Newly-designed individual and team games:</u>

Each faculty discusses and resets the new game system that should be deployed for each major and each course to ensure the game system suitable to the objectives of the education programs. Game system must include both individual and team games. In addition, instructors have to update the game system continuously after each course. Besides, it is necessary to avoid repeating the same games between the different courses. (Fraenkel & Wallen, 1993)

<u>* General guidelines for team formation and collaboration</u>

The faculty rebuilds the guidelines for team formation and collaboration. In order to create the best conditions for students to set up the group members, avoid the possibility of sectarian between groups, improve collaboration with other classmates as well as enhance group working, instructors guide students to create groups by themselves based on some criteria which include disposing students' academic ability and gender in rational way for each group. Moreover, all teams are encouraged to proactively discuss, plan and implement their projects. At the beginning of each class, instructors will allow each group to talk about different kinds of self-behaviors that they consider to be important to a successful PBL experience, and at the same time, they have to discuss to develop guidelines for collaboration during the course. After that, each group will share their guidelines with other groups. Thus, students can find out the similarities and differences between the groups, so that they can create the best guidelines for their team. In addition, the class designs a list of rules to guide the group interaction (i.e., sharing a creative material in a manner which maximizes student input and interaction). Specifically, the list of "ground-rules" is part of a team contract that all members agreed to adhere to for the duration of the term. In this contract, teams documented rules of conduct and rules regarding timelines for completion of shared work. Team members also keep track of their grades on weekly assignments and quizzes, and their impressions of the team's overall efficiency, which was assessed by members' verbal and written feedback at the end of each class and each weekly case. Group rules were posted on the course website and were used after each scenario to evaluate each group. (Sawyer, 2007)

- Those guidelines need to be updated every semester by instructors.
- In the process of group discussion in class, teachers must constantly observe, evaluate the process and give questions to stimulate thinking for each group. With a large number of students, instructors should work with group leaders. The leaders summarize and send any

reflection or opinion of their group mates to instructors. That is the reason why members are asked to assign a recorder and leader for the group.

* Strict monitoring tools:

Strict monitoring tools for team planning efforts are extremely necessary to manage large teams in PBL classes. The projects are carried out throughout the whole semester, therefore, instructors must have weekly inspections on the progress of doing group projects by many methods such as: asking each group to post their reports weekly on the course website, requiring periodically report to the class about the group's projects... Specifically, each group sets up a separate group page so that all group members can discuss and share ideas, each member must be responsible for collecting and processing information according to their assigned tasks. Before each session, each member must post the contents prepared for the group's project on the group page. One member of the group (which may be the leader) will be responsible for accumulating the information and post to the course website so that other groups in the class can comment on the progress and content of the group assignments. During this time, teachers monitor the group process (i.e., frequency of postings and punctuality) and the quality of the individual to the scenario contributions.

Besides, teachers interview regularly any member of the group to evaluate their performance and collaboration capabilities with other members in the group. For various classes, instructors should develop various monitoring tools depending on the characteristics of the major.

* Peer reviews and inter-team evaluations

Peer reviews and inter-team evaluations are necessary to operate every week. Peer review helps improve self-consciousness and responsibility as well as creates interest of learning for individual student. Due to large classes, the self-assessment of each group member will be more accurately and objectively. The evaluation process must be carried out regularly throughout the learning process. Lecturers set up online survey for students to do mutual evaluation every week. Based on this online tool, instructors will find it more easily and quickly to control the results and gather feedback about the performance of each student in the class. After the periodical presentation of each group, teachers continue to assess inter-team evaluations to help them draw experience and absorb the opinions of other groups in order to do their project better.

- Every week, instructors require students to do multiple choice questions to test their knowledge related to the course objectives. In addition to weekly quizzes, midpoint and final peer evaluations were conducted based on the criteria of preparation, contribution, respect for others' ideas, and flexibility. (Conway & Kember, 1993)

* Social venture projects

To adapt the market demand, the needs and the orders of corporations in many different fields, or the direction of some national or international competitions, the instructors in each division will discuss with one another and suggest a list of projects' titles which can maximize the effectiveness and applicability of the project. Each group will choose a specific title base on the suggested list of titles. The projects must have high applicability and be suitable for students' major knowledge and academic ability.

For instance, all groups of students in Business administration are asked to do real projects. Based on the objective of restoring traditional villages in the neighbourhood of Danang city, lecturers will require each group to choose a certain traditional product, then do marketing research, and propose a business project on that product. Each group will be instructed the necessary steps in every session, from doing market research to making a detailed project. These steps include forecasting sales, cost, and determining the profit as well as making marketing strategies to advertise that product to the community extensively. There are a lot of tasks to complete this type of projects, so they are only appropriate to PBL class with large groups. In order to finish these projects, students should combine knowledge which was learnt in many previous courses, and the task assignment among group members must be reasonable.

Another example of social venture projects is DTU Estock game which is very popular to DTU students. As an emerging country, Vietnam is nurturing the development of the stock markets, thus, the role of stockbrokers is highly appreciated on Vietnam job markets nowadays. In order to equip finance and banking degree students with essential major knowledge to become talented brokers, lecturers ask the whole class to analyze the financial market to create the most reasonable portfolio to invest. The fact that DTU has a virtual stock website called DTU Estock (all data and transaction rules are imitated as the true Stock Exchange) has facilitated instructors and students in deploying the financial simulation games. Hence, each group can buy or sell stocks and determine their lost/profit as they will do in the real world in their future jobs. Lecturers will instruct all groups to analyze the rate of return and risk of the target corporations and then create an appropriate portfolio for each one. The financial analysis takes a lot of time and effort, so this type of project is only able to be applied in classes with large groups. In addition to providing students with basic and technical analysis, lecturers also invite some experts from some securities companies come to share their experience with students. Thus, students find it easier to apply their knowledge to practical investments.

4.3. Survey results after the application of new handling tactics for large PBL classes

After one year's application of new handling tactics for large PBL classes, at the end of academic year 2014 – 2015, the researchers, again, conducted surveys on both students and instructors of Business Administration Faculty to verify if the tactics improved the handling of large PBL classes.

Table 3: Survey about the effectiveness of PBL to students (Academic year 2014 – 2015)

Variables	Statement	Disagree	Neutral	Agree
1. Student response to attitude toward group work	1.1. My team mates and I can proactively organize and implement group project in large team	50/ 14.3%	89/ 25.4%	211/ 60.3%
	1.2. All team members can efficiently help one another in the large team	42/ 12.0%	81/ 23.1%	227/ 64.9%
	1.3. I felt respected by and listened to by my peers in the large team	64/ 18.3%	75/ 21.4%	211/ 60.3%
	1.4. All team members can evaluate one another efficiently in large team	54/ 15.4%	64/ 18.3%	232/ 66.3%
2. Student response to facilitator role	2.1. Facilitators can regularly assist and guide our large team in developing our process	40/ 11.4%	89/ 25.4%	221/ 63.1%
	2.2. Facilitators can promote the integration and synthesis of information in our team	58/ 16.5%	79/ 22.6%	213/ 60.9%
	2.3. Facilitators can listen and respond well to our team's concerns and problems	25/ 7.1%	81/ 23.1%	245/ 70.0%
	2.4. Facilitators conduct fair and objective summative assessment for	25/ 7.1%	79/ 22.6%	246/ 70.3%

	the overall team and individuals			
3. Student response to learning objectives	3.1. We have good understanding of the courses' learning objectives	79/ 22.6%	78/ 22.3%	193/ 55.1%
	3.2. We feel that we have mastered the learning objectives expected from the projects presented.	52/ 14.9%	87/ 24.9%	211/ 60.3%
4. Student response to self-directed learning	4.1. My ability to find, read and analyze information had improved from the PBL courses	75/ 21.4%	82/ 23.4%	193/ 55.1%
	4.2. The courses helped me to obtain information from a variety of resources and I benefited from the process of researching and discussing the problems with my facilitators and team mates	75/ 21.4%	89/ 25.4%	186/ 53.1%
	4.3. I become more self-directed in learning in large team	52/ 14.9%	86/ 24.6%	212/ 60.6%
5. Student response to the efficiency of PBL courses with large teams	5.1. Large members help our group easily collect, synthesize information and implement the projects	91/ 26.0%	92/ 26.3%	167/ 47.7%
	5.2. I learn more knowledge and skills from the course compared to other courses	94/ 26.9%	100/ 28.6%	156/ 44.6%
	5.3. I feel more responsible in large team than in small team	95/ 27.1%	100/ 28.6%	155/ 44.3%
6. Student response to the diversification and practical aspect of projects	6.1. We can choose a wide range of projects to work on.	65/ 18.6%	91/ 26.0%	194/ 55.4%
	6.2. Projects are practical since they can address pressing social issues related to our major.	52/ 14.9%	77/ 22.0%	221/ 63.1%

The survey result on 350 second year students showed that after the implementation of new tactics for large PBL classes, the positive rates of response to all the criteria including teamwork attitude, teachers' role, grading, autonomy training, learning objectives understanding and practical aspect of projects were much higher than the precedent survey. Strikingly, 63.1% of the students were pleased with the social related projects, which was a noticeable increase from the previous proportion of only 36.1% in 2013 - 2014. Also, the feedback on the role of teachers was also much more positive, 70.0% of students appreciated instructors' timely response to their concerns and problems, and 70.3% of students were completely satisfied with the assessment results.

Along with the positive survey results from students, the researchers also obtained very encouraging feedback from 18 instructors.

Table 4: Survey about the role of instructors (Academic year 2014 – 2015)

Variables	Statements	Disagree	Neutral	Agree
1. Facilitator role in project launch process	1.1. In PBL course with large teams, I can stimulate student interest, enthusiasm and concern	1/ 5.6%	4/ 22.2%	13/ 72.2%
	1.2. In PBL course with large team, I can establish high expectations for the students and they have clear understanding and vision of the depth of learning and quality of academic performance	2/ 11.1%	3/ 16.7%	13/ 72.2%
	1.3. In PBL course with large teams, I can clarify rules, procedures, products, timeline and grading practice to all students in the class.	2/ 11.1%	2/ 11.1%	14/ 77.8%
2. Facilitator role in guided inquiry and product creation process	2.1. In PBL course with large teams, I can help students define tasks and assess progress of the overall team as well as individual student	2/ 11.1%	4/ 22.2%	12/ 66.7%
	2.2. In PBL course with large teams, I can regularly guide and intervene when necessary to keep the students on track	0/ 0%	2/ 11.1%	16/ 88.9%
3. Facilitator role in summative assessment	3.1. In PBL course with large teams, I can conduct fair and objective summative assessment for overall teams	1/ 5.6%	3/ 16.7%	14/ 77.8%
	3.2. In PBL course with large teams, I can conduct fair and objective summative assessment for individual student	1/ 5.6%	2/ 11.1%	15/ 83.3%
	3.3. In PBL course with large teams, each team member can assess their own work and they should learn how to critique other members' work.	3/ 16.7%	4/22.2%	11/ 61.1%
4. Facilitator role in creating practical projects for large PBL class to work on	4.1. I can easily create practical projects for PBL courses with large teams.	3/ 16.7%	5/ 27.8%	10/ 55.6%
	4.2. I have a wide source of social venture plan projects to deploy in PBL courses with large teams	4/ 22.2%	5/ 27.8%	9/ 50.0%

Through in-depth interviews, the teachers confirmed that the diversity and practicality of the project made the project launch become more exciting and interesting to students. Up to 72.2% of instructors were confident that they could stimulate student interest, enthusiasm and concern. In addition, the instructors agreed that general guidelines for team formation and collaboration helped team members to monitor and share the work, which has promoted a sense of responsibility of each individual, and instructors can assess the work of groups and individuals and support them when necessary. In addition, the online discussion through web page allows a quicker and much more effective way for the students to share ideas and collaborate among themselves and the instructors could have a timely intervention and ensure that all groups keep going on the right tracks. Besides, peer review and inter-team evaluation did support the instructors in providing a fair and objective summative assessment in the

project completion. Approximately 66.7% of instructors agreed that students should learn how to critique other teams and members' works in a constructive manner during PBL courses.

5. Conclusion

In conclusion, applying some new tactics in teaching PBL classes with large teams in Duy Tan University did help instructors to handle classes more efficiently. Benefits from new tactics were quite visible for the last two academic years through the positive feedback from both students and instructors as mentioned above. In addition, the direct assessment for the recognized improvement could be seen from our AUN (Asean University Network) accreditation, which set forth that at least 80% of students need to achieve 70% or more for the final course grades in the courses.

Table 5: Business Administration Students achieving 70% and above the Final Grades of PBL 296, PBL 396, PBL 496

Percentiles of Students achieving ≥ 70% of Final grades	***ACADEMIC YEAR***		
COURSES	2013 - 2014	2014 – 2015	2015 – 2016
PBL 296	72.6%	80.5%	84.3%
PBL 396	76.4%	82.3%	85.0%
PBL 496	77.9%	85.1%	86.2%

As we can see from Table 5, the study result improved much from the adoption of new tactics. In academic year 2013 – 2014, percentiles of students achieving ≥ 70% of final grades were less than 80%, but in later years, more than 80% of students managed to get 70% or more for their final grades. There was also an increasing trend in the percentiles from year to year which indicates that instructors may have become more proficient in PBL teaching methodologies and/or students have managed to build up their PBL learning skills.

However, there remain several limitations of the application of PBL for large group formats. For example, some students expressed that although the new tactics did rectify the drawbacks of large group format but not as completely as they wish since there are still some *free riders* in groups, and due to large size groups, the instructors usually work directly with the group leaders since group leaders are nominated as group spoke-persons, so in some cases, instructors could not hear the voice of the timid students and encourage them to speak out their ideas and opinions. For the instructors, the large size format creates tension for students and requires instructors to repeat the process and the aims of the PBL approach throughout the courses. The issue may be more amplified with multiple PBL groups with only one instructor. Besides, the success of online Estock games places new challenge to instructors to create more interesting and practical games for students to play in order to keep their enthusiasm in PBL learning in the following school years. This requires the collaboration and involvement of the whole education system at DTU including the IT sectors, facility sector and instructors as well. In brief, we recognize that new tactics need to be updated constantly and there is always room for improvement, not only in the training of our instructors to better apply new tactics as well as better recognize their guiding role but also our students for better skills of group working and doing practical projects. (Fraenkel & Wallen, 1993). Through interval evaluation in the future, we do hope to make changes to ensure the continuous improvement for the handling of PBL in large class format.

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Serious Games as a Creative Problem Solution Method

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Abstract

Games are the first creative method which can be applied even by very small kids and which lead to astonishing problem solutions. The application of serious games within educational institutions offers astonishingly results concerning an increase of creativity and other abilities. Committed to fixed rules creativity can be considered as a productive problem solution even without comprehending creativity that way. Thereby, serious games offer an approach to generate creative problem solutions without applying and implementing classical creative methods and tools purposely. Furthermore, serious games as an interdisciplinary approach, not depending on a certain discipline, offer the possibilities to produce on the one hand comparable intellectual approaches and on the other hand comparable approaches to solution. On top this, to make use the creativity it is important to minimize restrictions while having the necessity of rules. However, the advantage of the application of serious games is not to improve the already existing knowledge, but to support new intellectual approaches which lead to new perspectives of thinking and viewing. At the same time these new alternatives have to be matched with the market requirements by not losing ideas which seem to be unattractive at a first glance. In consequence of this hypotheses, the authors apply various serious games within engineering and non-engineering classes. The common issue of these games is to support creativity towards innovation while generating problem solutions. This paper gives an overview on three games which aim on decision making, quality and communication, and intercultural collaboration. To verify their ideas the authors carried out different case studies. Within these case studies students generated problem solutions by applying serious games. In comparison to the case studies control groups including students generating problem solutions by applying traditional teaching methods took place. Furthermore, evaluations were carried out in relation to the tasks in order to compare the results of the gaming and non-gaming student groups reached. Even though, the groups were heterogeneous it turned out that the outcome of the gaming groups was higher in all areas of the evaluation. The evaluation was based on the issues of approaches and perspectives, flexibility, originality and innovativeness, realization, and results.

Keywords: serious games, innovation, creativity, problem solution

Type of contribution: best practice paper

1 Introduction

Engineers are expected to be the main moving power in industry and organisations. This leads to the requirements of an adequate engineering education to be offered by the universities. The traditional curricula of engineering includes technical engineering issues as well as business knowledge. In daily life engineers have to solve problems, to generate new ideas, they have to be innovative. Their working space is not characterised by an engineering environment, meaning working just within a group of engineers or even alone. They work in interdisciplinary teams, they lead teams and therefore, they need management skills. These management skills are expected by industry but rarely trained within higher education. There exist many theories about management skills. But how to teach leadership abilities, teamwork, decision-making processes and intercultural co-operation? Traditional theoretical lectures are the common way to teach these theories and skills (Hoeborn 2014). The authors aims at teaching management skills in a way to remember them due to applying and feeling them at the same time. Therefore, the management courses are exceptional in that offering the training of management skills by the application of serious games.
These games are applied within classes, interdisciplinary and disciplinary classes, national and international classes, which aim at innovative problem solutions. The games support the creativity and they train the management skills at the same time. The students need these skills for problem solution.

2 Serious Games

The application of games within education is defined as Serious Games (Wouters, P et al. 2011) and they are hypothesised to address as well the cognitive as the affective dimensions of learning (O'Neil et al. 2005). Even though, serious games offer many advantages, their number of applications is limited in higher education. Serious games are an innovative teaching methodology. They include entertaining goals as well as educational objectives, they use the effect of gaming and having fun and at the same time of learning.

Serious games have a long tradition in the education of military offers, nowadays they are applied for civil purposes more and more from business games up to logistics. A characteristics of all serious games is the personal activity of the participants. When applying the games they have to interact, depending on the game it is an interaction with other participants or it is just a computer based serious game. This kind of application leads to the different learning experience, because the students live and feel what they play, they often even experience the consequences directly. This quite direct and specific experience leads to a change of behaviour towards the given tasks. Thereby, the students experience the consequences of their activities and decisions directly and this leads to a new way of awareness and it increases their abilities.

Experiences and measures concerning the application of serious games in engineering education and the learning effects present an increasing of students' abilities. The gained management skills by gaming are higher than the ability out of theoretically gained knowledge. However, the creating and managing of intellectual capital requires management skills which have to be trained intensively. Additionally, the industry reflects an inability of the students to carry out management skills and, therefore, to manage intellectual capital and knowledge.

Serious games are applied within education even though not as much as desirable for the above mentioned reasons, and one additional advantage is to learn individually in a holistic context. Therefore, serious games are also used for life-long-learning (Baalsrud Hauge, J. et al., 2009). This is one more reason to apply serious games within higher education and to, thereby, enable the students to apply the serious games. Through these application the students, and all participants not depending on their ages, increase their competences; they increase individually their skills and knowledge (Pikkola, 2004).

3 Methodological Approach

3.1 Preliminary remarks

The authors apply three very different types of serious games mostly within engineering classes, but as well in interdisciplinary and international classes. The overall aims are on the one hand to enable the students to practice problem based learning and on the other hand to enable them to develop management skills. Therefore, the tasks of the serious games are divers, they have to awake the students' creativity to solve the problems, they have to teach the students to apply serious games, and they have to teach them management skills. The atmosphere within the classes when gaming is very important, the students need to feel free to learn out of mistakes, no pressure to reach fault free results, no negative statements or evaluations. During the classes, the students, especially the female engineering students, like this risk free environment for active experimentation.

Depending on the game, the students develop innovative and sustainable solutions (game 1), make decisions having downstream consequences (game 2), or find compromises to negotiate (game 3). The authors apply the three serious games using a mixed learning concept, which includes a couple of separate lectures. As mentioned above the industry complained about missing management skills of the students, these complains were gathered by a survey to define the missing skills. The missing skills are matched to success factors (Hoeborn, 2016). These success factor describe the necessary skills to manage a situation and a team. There are three overall issues to be matched: co-operation, decision-making, and handling of unknown. These issues themselves are matched by different success factors.

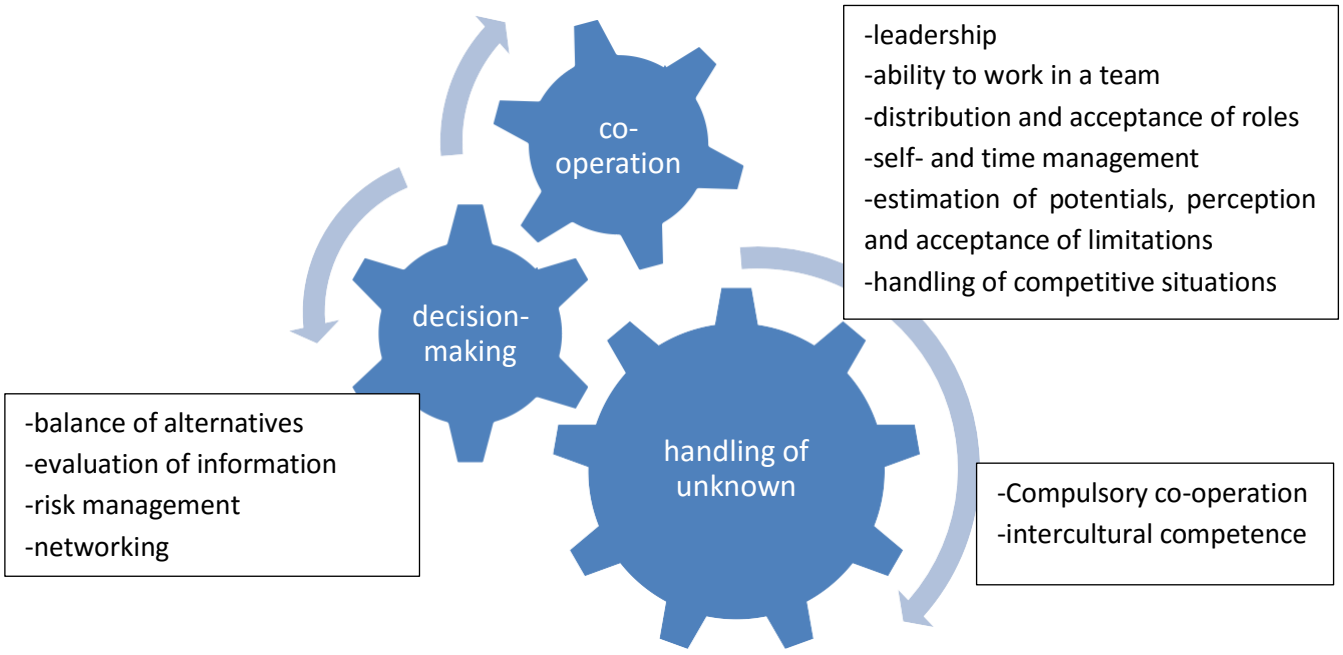

Figure 1: Main issues of management and matching success factors

The tasks and goals within the system management can only be solved and fulfilled if all three success factor fields, the main issues, are available within the abilities of the manager. These main issues themselves include many success factors, various necessary abilities and competencies being required. Figure 1 offers an overview on the main issues of management and the related success factors.

3.2 Co-operation

The main issue of co-operation includes leadership, teamwork, communication, and continuous improvement. Having a deeper look at the main issues and the matched success factors leads to the following definitions and descriptions of the success factors (Hoeborn, 2015 and 2016):

Success factor **leadership**, meaning the leading of a team with all the related tasks and responsibilities like power to steer and to decide, being in charge of results, social responsibility regarding the team, conflict management e.g.

Success factor **ability to work in a team**, teamwork is required nowadays as the typical way to co-operate, this means the team is equally entitled. Nevertheless, the team leader, the manager gets the responsibility. This requires tolerance, acceptance, openness, reliability, and confidence.

Success factor **distribution and acceptance of roles**, this is directly related to teamwork, because the team members have to be aware of the existence of different roles which have to be distributed, accepted and fulfilled, this includes leading the team as well as the manager's task.

Success factor **self- and time-management**, this is directly related to methodological skills as well as to social skills. The manager deals with giving priorities regarding the overall time schedule.

Success factor **estimation of potentials, perception and acceptance of limitations**, management processes include potentials which have to be estimated and evaluated within a short time. To do so, the manger has to be able to perceive and accept limitations.

Success factor **handling of competitive situations**, management is characterized by competition. The team leader has to consider that she/he and her/his team are within a competitive situation, he/she has to manage it without losing focus.

Getting used to and master the above mentioned success factors leads to the ability of co-operation. Additionally, all these success factors are necessary as well to deal with the second main issue of decision-making.

3.3 Decision-Making

Additionally, to the six already described success factors concerning co-operation, decision-making requires information evaluation, risk management, balance of alternatives, and networking. Having a deeper look at the main issue decision-making and the matched success factors leads to the following definitions and descriptions of the additional success factors (Hoeborn, 2015 and 2016):

Success factor **balance of alternatives**, meaning to evaluate alternatives while taking downstream consequences into consideration.

Success factor **evaluation of information**, within management processes many information are offered and required. At the same time the pressure of competition goes along with daily business. Therefore, the ability of conceiving the main information has to be trained.

Success factor **risk management**, decision-making is not only influenced by downstream consequences, furthermore, the unpredictable influences may lead to negative results, an estimation of risk concerning reliability and seriousness has to be carried out.

Success factor **networking**, networks as company affiliations, as helpful tools. There have always been networks in private and professional sphere, but today within the time of globalization and digitalization the working environment is characterized by networking.

Getting used to and master the above mentioned success factors as well as the success factors related to co-operation leads to the ability of decision-making. Additionally, all these 10 success factors are necessary as well to deal with the third main issue of handling of unknown.

3.4 Handling of unknown

Within the field of globalisation managers have to cope with different cultures. Additionally, to the 10 already described success factors concerning co-operation and decision-making, handling of unknown requires coping and compromising. Having a deeper look at the main issue handling of unknown and the matched success factors leads to the following definitions and descriptions of the additional success factors (Hoeborn, 2015 and 2016):

Success factor **compulsory co-operation**, co-operations have to go along with different partners. Even unexpected difficulties, situations, in which seemingly insuperable difficulties appear, exist. Different priorities may occur, while having a mandatory co-operation

Success factor **intercultural competence**, the working environment is a global one which requires a global networking at the global market. Different cultures having different values and priorities are meeting and they have to compromise and to cope, to tolerate and accept each other, to develop a basis of co-operation.

Getting used to and master the above mentioned success factors as well as the success factors related to co-operation and of decision-making leads to the ability of handling unknown. Furthermore, all these 12 success factors are necessary to perform well as a manager. The described success factor are additionally supported by communication, self-reflection, and continuous improvement issues.

4 Application of serious games

4.1 Situation in class and educational setting

It was already mentioned that the authors teach in different degree courses and different countries. Therefore, the application field of the serious games varies. They are applied for Bachelor students regularly as well as for Master's students within engineering degree courses.

In general in Germany at the University of Wuppertal, these games are applied with Bachelor engineering students each semester, who are studying safety and security engineering. Additionally, the games are carried out each semester within mono-educative engineering classes, at the Bachelor level as well, with female students of civil engineering and mechanical engineering. The students are first to third semester students, depending on the curricula. Within these degree courses the games are carried out for about 9 years by now. Furthermore, the games are applied within the master's degree for mechanical engineering as well as for safety and security engineering. The master's course of mechanical engineering has been an international course till 2014, since 2014 it is a national degree course.

The games are applied during one semester. The first game takes about one class, the second two classed, and the third again one class. Additionally, some more time is spent to evaluate the games and the students' performance. During the other classes the students get knowledge input by classical lectures and work on their projects within groups.

Within the international content the games were applied within a master's degree of agribusiness in Chile for the last years. Additionally they were applied in different countries within and outside of Europe.

4.2 Educational setting and general pedagogical approach

The overall pedagogical approach is split into three steps:

Firstly, the students should be enabled to apply serious games by taking them seriously and by enjoying the gaming itself. This approach requires an atmosphere of trust and feeling comfortable in class and with the lecturers. The authors try to generate this kind of spirit by carrying out special welcome ceremonies e.g.

Secondly, the students' creativity should be awakened by applying serious games. This approach requires the described atmosphere as well as the freedom of a fault free environment.

Thirdly, this creativity should be applied to solve problems. Again the approach requires the special spirit and the freedom expire consequences and faults. This offers the possibility to develop innovate solutions.

The subsequent educational situation is the solving of the given tasks/projects themselves by applying the lessons learned out of the games on the one hand, and on the other hand, by using the gained creativity.

The overall aim is to support the management skills of the students to enable them to solve the content part of the problem based learning. Therefore, three different types of serious games are carried out within the classes. The content and the application of the games differ a lot. Additionally, these games are applied consecutively to achieve the learning effect of the management skills. They start with the issue of co-operation, going through decision-making, up to handling the unknown. Each game requires the success factors of the previous game. All games are non-digital games. They are applied in different kinds of classes like engineering classes or interdisciplinary classes, national or international classes using a mixed learning concept. These classes include different lectures. It starts with introduction lectures, where different management systems, teamwork, communication, cultural influences and various decision-making theories are shortly taught and discussed. Additionally, the content problem to be solved is discussed about as well as the necessity to be skilled in management abilities. It is very important to create an atmosphere of trust and confidence to make the students feel comfortable. The following lectures are used for gaming and feedback reflections. Within the process of teaching the students' improvement is evaluated. The change of their soft skills is used as an indicator of their learning successes out of the previous games.

The following three games are applied: Lego Racers Championship developed by a consultancy of Lego (effective 2011), **E**ntscheidungsfindung **f**ür **e**ine **U**nternehmensstrategie (EfeU) developed by Jennifer Bredtmann (2008, unpublished) and further developed by Gabriele Hoeborn (2012), and TeCuVa (**Te**amwork within different **Cu**ltures and **Va**lues) which is close to the Cocktail Party Simulation by Daphne A. Jameson (2007) just modified to class purposes.

To involve all students very actively into the process of gaming the group size is up to ten students.

4.3 Lego-Racer-Championship

The Lego Racer Championship is a game which obviously aims at scoring as many points as possible by using cars built out of Lego bricks on the track. The number of groups playing the Lego Racer Championship may vary, they are in competition with each other. Pedagogical issues are not discussed in advance. The students get all the information about the game via power point and may ask questions to clarify before and during the game. All necessary stuff like Lego bricks to build a car or material to build a ramp is offered to them. The students are allowed to communicate within their groups during the whole game. About 10 students constitute one group. Being a member of one group may be random or driven by the lecturer, depending on the group and its dynamic. It is up to the lecturers to choose the team leader of each group. Originally there was a detailed description of the game by an internet link, which is not working by now.

The game originally was designed to be applied within companies on management levels. Some modification were carried out to adapt the application for the students. The general instructions are, that the students have to build non-motorised cars out of Lego bricks. These cars perform in a racing within a race track, one for each group, of about 3 m having a bull's eye at its end and a Launch Area at the starting point. The goal is to score as many points as possible by reaching the bull's eye. The game includes two phases. The first phase is the preparation phase when building and testing the cars. Additionally, they get material like scissors, card board, adhesive tape and the boxes with the Lego bricks. They are free to build any kind of a construction within the launch area which may be changed during the entire game by using the given materials, they do not have to build a construction. The second phase is the racing phase. There the cars have to be started from the launch area and should score at the bull's eye. The given time limit is depending between 12 and 20 minutes, depending on the grades of the students, and it includes both phases. Just during the racing phase points are scored. But the group may lose points as well by touching a car in motion, destroying a car, or by not reaching the bull's eye. Furthermore, advices are offered to be bought, which are cheap during the preparation phase and ten-times as expensive at the race phase. No information, concerning the kind of advice they will get, are offered in advance. After the end of the game a feedback lecture, evaluating the students' decisions and performance is carried out. These parts combines cognitive and constructive learning paradigm by including problem based and experimental learning. The active participation of students in the process of gaming is very important. At the end of this evaluation the students are told which team won.

The Lego Racer Championship aim at the issue of co-operation and it trains the six success factors being mentioned above which match with co-operation.

4.4 EfeU

Jennifer Bredtmann developed in 2008 EfeU as a business game especially for the use in higher education and it was developed further on and adapted by Gabriele Hoeborn in 2012 concerning different degree courses. EfeU focuses on the simulation of complex processes in and between companies. The field of application is a company producing bikes. Within this management game decision-making based on

information evaluation, balance of alternatives, risk management and networking is trained. The awareness and knowledge about decision-making and the handling of a group including performance within the group and towards other groups are the main issues of this game. EfeU simulates by simplifying the different company processes. Relevant decisions have to be taken and downstream consequences have to be considered. This serious game can be applied without any economic knowledge. The economic profit seems to be the obvious aim of the game. But pedagogically it aims at raising awareness and experience processes of decision-making and the related consequences. Therefore, getting the highest profit is not the overall goal of the game. Like with the Lego game before the pedagogical aims are not discussed in advance.

Concerning the evaluation of the game special decision making points can be gathered concerning the performance of the group, which means for example how they stick to their roles or how the evaluate information e.g. Another additional point of evaluation is the economic benefit. As the implicit learning goal is not explained to the students explicitly, they nevertheless know that their decisions are affecting the economic well doing of their company. The success of a gaming group is not just driven by the profit itself, but by perception of the consequences as well as by the impact of team work within a decision process.

The students play in competitive groups, each including 5 – 10 students. Each group gets a separate place for gaming to discuss undisturbedly. As leading a company producing and selling bicycles the students get the task of steering all processes and requirements regarding to the company and the product. This requires a skillful decision-making. All companies (all groups) have the same sales market, this characterizes the competitive situation. In general, the game is divided into two phases symbolizing a business year. For the first part of the game all student groups get their specific information like company key figures, sales figures, and capital. Furthermore, the students get supplies through information by letters. They offer special information and sales by suppliers, product offers, investment possibilities, and costumer information. The students need to evaluate the given data and to plan their business year within a time limit of about 30 minutes. Afterwards they may attend a so called ‘forum’ where they may invite and meet representatives of the other companies (networking). They are free in their way to use this forum as a place to network, to co-operate, to exchange information. After this forum the students have to make up their decisions for the first business year. At the next term, second phase, the students get their economic results of the first term. Furthermore, they get new information. Partly this information show up consequences of the decisions of the first phase. Again they discuss, meet the forum, and finally make up their decisions.

After the final end of the game a feedback and a discussion is carried out. Within this evaluation by the students, they identify their problems and their experiences and feelings. Decisions regarding to communication, risk management, and decision-making including evaluation of alternatives and estimation of consequences as well as evaluation of information within time and competition pressure are discussed. The economic profit results of the students’ group were offered. Furthermore, the information which had to be considered for decision-making are analyzed. The handling of the information and their downstream consequences are marked by decision points.

The EfeU business game aim at the issue of decision-making and it trains once more the six success factors being mentioned above which match with co-operation and furthermore, the four additional success factors characterising decision-making.

4.5 TeCuVa

Daphne A. Jameson developed the serious game 'cocktail party simulation' for training intercultural communication for hospitality managers. It was originally designed by her at the School of Hotel Administration of Cornell University, USA, and can be down loaded as tool no. 7, July 2007 (Jameson, 2007). Jameson offers this, to the opinion of the authors, excellent game to train intercultural communication. The authors adapted it to German and Chilean language and costumes. Hoeborn developed it further on in 2012 and adapted it to disciplinary and interdisciplinary education. Regarding to higher education it is a valuable game to train intercultural competence, because it deals with managing different cultures. Therefore, it trains the intercultural competence and thereby, lowers barriers regarding meeting different cultures. At the same the game offers a specific task to fulfill, which may not be neglected. Therefore, TeCuVa is a role-play-game, when sticking to the given cultures, and a kind of a business game, when aiming on the content goal, at the same time. It also offers the experience and training of decision-making and co-operation within a defined team, but additionally, of compromising processes within groups of quite different cultural background and values. The game supports the reduction of cultural barriers, it makes the participants feel and experience a new culture they have to adapt. According to Jameson the game is aiming at four educational goals. The situation of the cocktail party, demonstrates the principles and limits of intercultural communication realistically, firstly. And furthermore, this underlines and points out the relativity of cultural values and emotions. The students experience and feel these contradictions. They especially experience and feel the contradictory between the required professional performance and the emotional stress. According to Jameson the second educational goal is to live the obvious and visible cultural manners on the one hand and on the other hand the invisible cultural values themselves. The students experience characteristics as a part of their roles and as a characteristic part of their business partners. The decision of adapting is the third educational goal, how to compromise and when to cope. The necessity to overcome cultural differences is a big challenge for the students. They experience the complexity of cultural identity being more than nationality or religion, this is the fourth educational goal.

The authors calls this cocktail party simulation 'Teamwork within different Cultures and Values (TeCuMa)' aiming at the content of the game. The different parties, presenting the different fictive cultures as well as different businesses, are planning a joint venture. The joint venture is a compulsory decision, it has to be carried out. The cocktail party is the first meeting of the managers of the three company, all students are managers and therefore all of them participate, and it is their first working meeting. The lecturers decide about the group leaders (vice presidents), the sex of the leader is depending on the culture. The vice presidents are responsible to prepare themselves and their teams. This includes the preparation of culture attitudes and values as well as the preparation of the work content. This means to adapt the culture to perform at the cocktail party and to develop a strategy of negotiation. One company is the host. Each team (company) gets just its own description of culture and values, no information concerning the other cultures. During the party the students get an additional challenge which they know in advance: they have to interact with unknown and very different cultures and business concepts. The three groups represent different cultures and, concerning the joint venture, different business interests. This leads to a competition on the one hand, but on the other hand they have to reach the mutual goal of the joint venture at the same time. During the cocktail party the different managers (students) interact and thereby notice the different values and attitudes. The students are supposed to play their cultures, but may not talk about their cultures explicitly. The cultures lead to high barriers. Therefore, it seems to be impossible to establish any joint venture or to compromise. Thereby, the students experience very directly the contradictions. Sometimes they get angry and leave classes, but usually they come back after a while and continue gaming.

At the end of the game like for all serious games a feedback and discussion is carried out. The different cultures are discussed and the managing of different cultures as well as possibilities of interaction. The decision-making and compromising within this game is a great challenge, which need to be answered by adapting and coping. The TeCuVa cocktail party simulation game aim at the issue of decision-making within a compulsory co-operation and cultural differences, and it trains once more the 10 success factors being mentioned above which match with co-operation and decision-making and, furthermore, the two additional success factors characterising handling of unknown.

5 Conclusions

Problem based learning often is applied within student groups. Working in a group requires soft skills close to management skills as required by industry. Due to the industrial feedback these competences and skill are missing.

Serious games are a new and rarely used methodology to train knowledge and competences while combining the fun of gaming and the content of learning. Serious games may offer simulated problem situations. The students are actively involved, they have to participate, to play, to experience the process of problem solution. At the same time the students are aware of being apprehensive of individual consequences or failures within an atmosphere of feeling comfortable. The described and applied games lead to the competence of management skills by reaching the ability of success factors.

The three presented serious games in this paper are applied consecutively. Aiming at a consecutively training of the success factors as well. Starting with the six co-operation success factor trained in the first game, repeating them in a second context and adding the four decision-making success factors to be trained within the second game. All these 10 success factors are repeated in game number three and additionally two more are trained matching the issue of handling the unknown. Thereby, management skills are trained consecutively as well.

The undergoing, the experience and feeling of specific situations and their solutions as well as the reflection afterwards support the learning process. It has to be admitted, that there are limitations for the application of serious games. The application requires a lot of support and supervision, necessary time and class rooms, limited number of participants. Additionally the results are influenced by gender issues and the cultural background of the participants.

Therefore, the lessons learned for instructors include a lot of social science applications. Especially gender issues lead to different setting of the games within classes. Female students were more often instructed to take a leading position to experience this feeling and responsibility. If the lectures noticed that the female students did not perform adequate, these students are invited to participate in a special mono-educative mentoring class to improve their skills. Furthermore, the cultural background of students lead to different activities to generate a faithful working atmosphere in class. Additionally, the cultural background have to be evaluated in advance to know about their attitudes concerning faults and development processes to generate innovation. In general, applying serious games takes more supervision than traditional classes.

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Learning based on interdisciplinary projects with students from several engineering courses: Case study on energy sustainability

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Abstract

The study of environmental and energy issues are as important as the specific disciplines of engineering courses. Within this context, the Environmental Sciences course provided the students an analysis of the relationship between the specific disciplines of their courses with relevant environmental issues, using the Project-Based Learning Methodology. Students were sorted into teams of ten from different Engineering courses and encouraged to create a project with feasible solutions for economy of energy and use of more sustainable energy sources. As a result, three projects were proposed: *1*. Development of an application where the consumers can analyze their electricity consumption and the best way to save it, using mobile platforms like Android®, IOS® and Windows Phone®. *2*. "Recharge your ideas": project for the installation of an individual photovoltaic system, which is an individual and non-interconnected electrical energy generating system, in order to provide clean and sustainable energy in a safe and satisfactory way at the University campus. *3*. "Low cost solar heater": developed to serve low-income rural communities. A prototype was made to estimate all necessary costs to make it and what would be the return in economy for the residences. With the development of these projects, it is perceived that interdisciplinarity is fundamental to the understanding of the themes developed, requiring the effort of students and teachers from the most diverse areas of engineering. The solution to most of the current problems in different areas of knowledge requires a more effective dialogue between disciplines and between professionals towards more adequate and self-sustainable solutions. To the students in particular, these activities promoted a practical experience and theoretical approach of different processes of Science and Technology and the opportunity to act in the solution of problems based on the knowledge acquired in the course in the resolution of real environmental and energy problems.

Keywords: Project-Based Learning; sustainable development; interdisciplinary.

Type of contribution: Best practice paper.

1. Introduction

Faced with the challenges presented by the world society and the responsibility for training people related to innovation and technological development, it is necessary to reflect on teaching and learning methodologies and the development of more flexible and dynamic curricula for training in different engineering courses.

According to Ministry of Education (2002), that established the new National Curricular Guidelines (NCG) for Engineering Undergraduate Courses in Brazil, engineering education should be in line with the requirements imposed by globalization. According to the Article 3, engineers must be generalist, humanist, critical and reflective, which enables them to absorb and develop new technologies, stimulating their critical and creative roles in identifying and solving problems, considering their political, economic, Environmental and social aspects , with an ethical and humanistic vision, in response to the demands of society.

There are those who defend the idea of an approximation with the productive, technological and entrepreneurial sector and those that defend the approach with the postgraduate and the science. Although these ideas seem to be antagonistic, they must be reconciled in the formation of the professional in a broader and more effective way, so to make this come true there is a need for opportunities to experience different realities in the context of Engineering.

Nowadays, there are several sciences seeking the interdisciplinary approach as a viable way for the organization of their curricula, as they seek the training of professionals who can interact holistically. The health area is one of the highlights, including publications about their experiences (VARGAS et al, 2008). Interdisciplinarity can foster more meaningful learning and flexibility in organizing higher education curricula.

The problems of study in the context of professional practice are linked to action and, from this perspective, a flexible curriculum organization has to be developed, one that allows a professional experience closer to its academic formation and thus becomes more meaningful. According to Vallim et.al., (2000) the emphasis on teaching techniques rather than concepts results in a rapid forgetfulness on the part of students. Teaching theory unrelated to practical aspects does not adequately prepare students for the exercise of their profession.

The theory of meaningful learning was proposed by Ausubel and later propagated and investigated in several areas of knowledge by researchers such as Novak (1977), Moreira (2006) and others. Ausubel proposes that, in order for learning to have a modifying effect on the individual's cognitive structures, it must be meaningful. In making use of this premise, Ausubel suggests the need to define meaningful learning and its opposite, non-meaningful learning.

Another methodology that favors interdisciplinarity and complements it is the Project- Based Learning Methodology. It originated in 1900, when the American philosopher John Dewey (1859-1952) proved "learning by doing", valuing, questioning and contextualizing students' ability to think in a gradual way of acquiring a relative knowledge to solve real situations in projects related to content in the area of studies. Thus, project-based learning, which has been studied in recent years, is associated with constructivist theories, where it is verified that knowledge is not absolute, but is constructed through progressive knowledge and global perception.

The development and success of an Engineering Project is a complex process, since it involves many aspects, like: the students' ability to develop it considering all the variables involved, such as the limitation of time and resources, among others, as well as the skills and abilities acquired; the reorganization of classroom space for facilitation of interaction and shared

knowledge development; integration of new computational technologies; revaluation of the evaluation system, among others. Therefore, its management, due to its complexity, is fundamental to its success. When the curriculum allows for flexibility this can favor greater team performance. The current demands of the labor market require new skills and competences of future engineers (Dobbs et al., 2012). Thus, these new characteristics imply the development of cognitive and relationship skills.

Moraes, 1999, suggests that new guidelines in education and the new profile of the engineer that is being required in recent years require the development of a contextualized subject with multiple intelligences that builds knowledge according to its genetic, cultural and social background. A paradigm that values the learning process, the constant updating of the contents, the adoption of more flexible and adapted curricula to the conditions of the students, that respects the individual and group rhythm in the processes of assimilation and accommodation of knowledge.

2. Objectives

The systemic approach of Problem-Based Learning (PBL) or Project-Based Learning (PBL) involve students in the acquisition of knowledge and skills through a process of investigation of complex issues, authentic tasks and products, carefully planned for efficient and effective learning.

In an interdisciplinary way, promoting the development of critical thinking, teamwork, creativity and capacity to lead processes of innovation of technology and the sustainability of the environment, the aims were:

-Develop a visual product such as prototype, mock-ups, applications, according to the project developed by the team;

- Elaborate a scientific article from the project developed.

3. Theoretical basis and methods

Within the context of engineering courses, the Environmental Sciences course has as main objective the approach of Environmental concepts. It is a daily challenge for teachers who teach such discipline, since many students does not realize how important in their academic background are environmental concepts and applications.

The Active Learning Methodology based on interdisciplinary projects in engineering courses at the Federal University of Itajubá (Unifei, campus Itabira), framed in the PBL (Project Based Learning) model was a facilitator of the teaching-learning process in the Environmental Sciences course.

In order to carry out the projects, the teams were organized in such a way that they were composed of students from the following engineering courses: Computing, Mobility, Health and Safety, Production, Control and Automation, Electrical, Mechanical, Materials Engineering.

In this way, the projects should have contributions and perspectives of different visions, because the students have different academic formations, that is, with emphasis in a certain area of the different Engineering Undergraduate Courses. The projects should respect the pillars such as:

- Be based on projects with real results;
- To work in teams, respecting other opinions (even if contrary to yours), inducing them to take an active and responsible part for their learning;
- Develop carefully planned products for efficient and effective learning.
- Develop critical thinking, with teamwork, presenting creativity and the ability to drive innovation processes of technology and the sustainability of the environment in their products.

The selection of the project to be developed in the disciplines is fundamental in the application and success of the PBL, since it must be able to motivate and lead the learner to new discoveries, minimally covering the programmed content defined for the course. A project is a temporary effort undertaken to create a unique product, service or result and this temporary nature indicates a well-defined beginning and end, taking care of proper management in its development, applying knowledge, skills, tools and techniques (Campos, 2011).

The work was organized in stages over 16 weeks. In 9 weeks a specific activity of the PBL was developed and occurred the delivery of products, in the other weeks contents of the course were studied with the objective of integrating the students with subjects pertinent to the learning proposed by the discipline. As a product of the proposed project, students presented their proposals orally, implemented and planned new project ideas, developed prototypes, and wrote articles as final outcomes, as outlined in Figure 1. The evaluation of the learning process occurred in each of the stages, each product delivered to the team was evaluated if the proposed objectives were achieved.

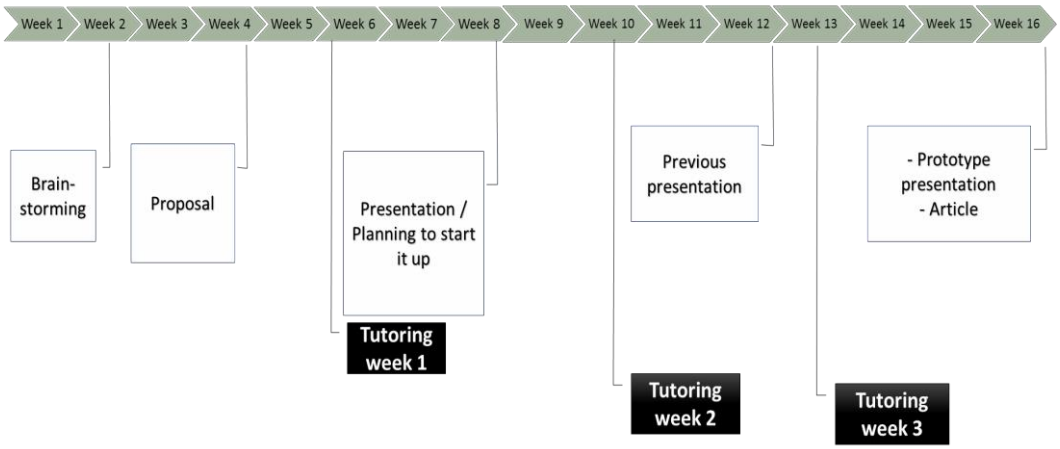

Figure 1 – Schedule of the process during the 16 weeks of the course.

The contributions of the active methodologies are diverse and allow us to predict that, instead of students leaving school with the illusion of having learned something just because they were participating in the lesson and had access to the contents in lectures, we will have students experiencing learning situations deeply significant in their lives (Blikstein, 2012).

4. Results and Discussion

As a result, this work created interdisciplinary conditions, where the solution of the problems exceeded the boundaries related to the discipline, generating works applied in the different areas of Engineering such as Mechanics, Computing, Automation and Production without losing focus in the environmental aspects.

During the evaluation process, it was noticed that the ability to solve problems and create more sustainable solutions motivated the students in the development of all the stages of the project, favoring the acquisition of new complex and changeable knowledge, parallel to the development of professional attributes that pass necessarily by the differentiated and alternative methods to facilitate this broader formation.

4.1. Projects developed

One of the teams has developed an application where consumers can analyze their electricity consumption and how best to save money using mobile platforms such as Android®, IOS® and Windows Phone®, in a project entitled "Save energy: a new way of electricity management in residences". The group concluded that new technologies are constantly associated with the high consumption of electricity, causing, therefore, enormous damages to the nature. Furthermore, this study showed that several innovations could be combined with sustainable projects, so it is necessary to have a vision focused on the environment.

This project proved to be feasible, requiring some adjustments in order to improve the proposed objectives. One of them is analyze in the residences the electricity consumption estimated according to each electric and/or electronic device. In this situation, the application will give tips to users and make suggestions to save energy.

According to the group, "studies of sustainable projects and the impacts of new technologies on the environment are very important to engineering students as they add knowledge about the preservation of nature and will be of great value when future engineers work in the job market". It could be perceived that the applied methodology can favor the perception and the capacity of integration of all the teams, encouraging personal and group habilities.

As a result from the learning in this work another group worked on the "Recharge Your Ideas" project, where they developed a prototype to use an alternative source of sustainable energy at the University. With photovoltaic panels that convert solar radiation and transform it into electricity, being able to charge the electronics of campus community, such as cell phones, tablets and notebooks among others. In order to reach the results, it was necessary the support of several disciplines of the Electrical Engineering course, that were capital to achieve the desired outcomes. With regard to the operation of the system, it became a goal of the team to develop a voltage controller for the solar panel to obtain continuous energy to power the battery of smartphones and notebooks. The electronic circuit of the voltage controller was developed according to Figure 2.

The researches of the team occurred outside the class, which allowed greater team interaction. Group meetings initially had the purpose of acquiring the necessary knowledge for project and prototype development. Taking into account also the concern with the sustainability of the project, the researches were also focused on obtaining knowledge about clean and renewable energy, which allowed the team to interact more about environmental issues and their responsibilities as future engineers.

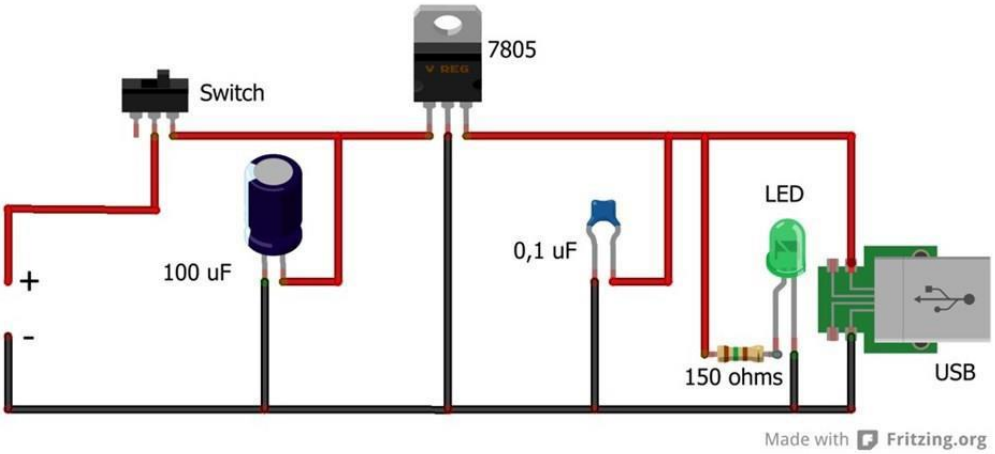

Figure 2 - Electronic circuit for the voltage controller of the solar panel. (From: www.tecmundo.com.br/area-42/60526-area-42-fazer-carregador-solar-celular-video.htm).

During the course of this work, the students were able to socialize knowledge of diverse areas allowing a wide, applied and interdisciplinary knowledge thus achieving one of the objectives of the proposal, as outlined in Figure 3.

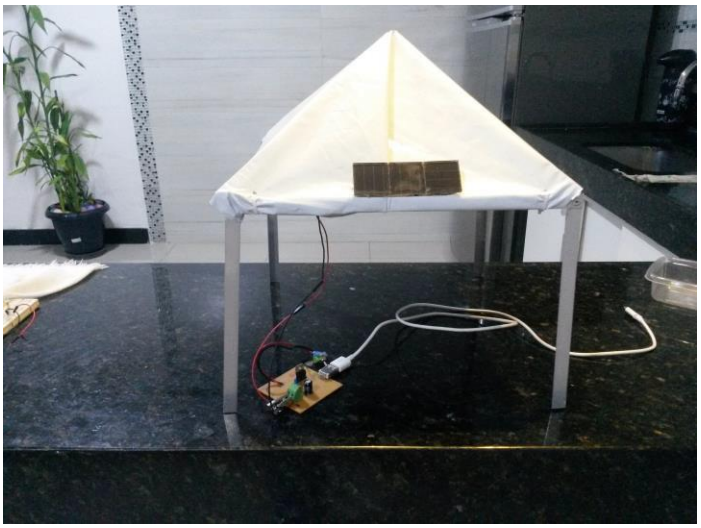

Figure 3 – Team's prototype of the solar energy system.

The group concluded that research on this type of use of solar energy is fundamental to provide infrastructure as points of electronic loading widely used daily for the entire academic community in university campus as a source of clean and renewable energy. Thus, it will be possible, besides offering convenience, an intense awareness of respect and preservation of the nature of those who use this type of energy to charge their electronic devices.

A third group developed a prototype of solar heater to serve low-income communities. According to the group the project was able to provide the evolution of the skills of teamwork, as well as the development of critical thinking regarding sustainability and the commitment of those involved with social responsibility.

5. Conclusions and Recommendations

It is perceived that what was pleaded for more than a decade is still a real demand and of great impact in the teaching process learning of all areas of knowledge. It is only from new educational perspectives that stimulate the capacity to learn in a broad way, the development of thought and consciousness, that we will be collaborating in the development of new generations of more ethical, creative, autonomous, cooperative, being able to lead with uncertainty, to the complexity in the decision making and to be more responsible for the decisions taken in different situations in the academic and professional tasks.

The learning by projects together with an interdisciplinary approach favors the relationship among contents, facilitating to the students the construction of their knowledge with the integration of the different disciplinary knowledges, looking for a meaningful learning. That is, take as a starting point students' previous knowledge for building / expanding knowledge and make them aware of their learning process, as they learn to learn, developing their capacities of choice, decision, planning, take on responsibilities and being agents of their learning.

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It Takes More than One but a Village: Learning Support for First Year Students in Interdisciplinary Study Projects

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Abstract

The shift from teaching to learning requires new teaching and learning methods such as the introductory interdisciplinary study projects at Technische Universität Darmstadt in which social, technical, interdisciplinary and intercultural learning is intertwined. In order to deal with the distinct needs and large study cohorts in these PBL-courses, an academic "village" was developed to support first-year students in complex, interdisciplinary problem solving.

Emphasizing the role change from teacher to learning guide, the two main personas of the support system are the team and technical advisor. The team advisor has the role of a coach in the group with a focus on team development, teamwork and project management. The technical advisor is a facilitator with a focus on the professional problem analysis and solving. Team advisors are advanced students from the humanities with a special training for team support. Technical advisors are scientific staff from engineering or science departments.

To clarify the impact of the different advisors, the advising model was systematically reduced in a large project course with 660 students. The field-experimental set-up revealed a partly competitive, partly complementary relationship of the different advisory support. Whereas technical advising can compensate a reduction of team advising regarding the technical quality of the final solution, it cannot replace team advising with respect to team competences. Full team advising clearly increased team integration and participation of all team members, especially of restrained and dominant team members and minorities, e.g. discipline, gender.

These findings allow for adaptation of the support model in regards to the intended learning outcomes, contexts and constraints of the study organisation, e.g. research, practice, personal development. Whereas the combination of team and technical advising remains the basis for the teams' success, the proportion of team and technical advising defines a more technical or more team learning outcome.

Keywords: interdisciplinary study projects, tutorial support, technical advisor, team advisor, adaptability for different learning outcomes

Type of contribution: Best practice paper

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1 Introduction

Around the turn of the millennium, the study reform debate of the Bologna process in Europe with its shift from teaching to learning, the ongoing criticism of industry and unions of an impractical engineering education, the concern about high drop-out rates in engineering studies, and the increasing heterogeneity of students resulted in an increased demand for more active and practical learning in higher education, especially for project-based teaching and learning in engineering education [Wolf & Hampe, 2006; Wildt, 2004; Barr & Tagg, 1995].

The expectations were that project-based teaching and learning would facilitate deep learning as opposed to merely superficial and receptive learning engagement, connect theoretical and practical knowledge and enrich academic qualification with generic and professional competences such as communication and teamwork skills, project management and interdisciplinary problem solving methods [Kek & Huijser, 2017; Davies, De Graaff & Kolmos, 2011; De Graaff & Kolmos, 2003].

Based on extensive tests and evaluations of project courses since the 70-ies, the Technische Universität Darmstadt (TU Darmstadt) introduced obligatory project courses for freshmen in all engineering degrees as a first step in meeting these expectations [Wolf & Hampe, 2006; Abele, Böhm, Görts & Tschannerl, 2002]. In a second step, the thus far monodisciplinary project courses were transformed into interdisciplinary and partly international study projects and implemented in all departments of the university [Dirsch-Weigand et al., 2015; Pinkelman et al., 2015].

The experiences and evaluation of 24 interdisciplinary study projects with 9700 students from 2011 to 2016 confirm the desired learning outcomes: Students gain technical competences and strengthen their intrinsic motivation for their field of studies [Koch et al, 2016]. They develop a professional identity along with readiness and skills for interdisciplinary collaboration and take responsibility within the team and for independent problem solving. Students and teachers network and socialize beyond the project courses [Dirsch-Weigand et al. 2015].

The positive learning outcomes are due to a mature overall concept with an appealing and reasonable task assignment, deliberate project schedule, efficient event organization, integration of study projects into the curricula and especially, a unique tutorial support system for the student teams [Eger, 2011].

The paper at hand examines this tutorial “village” of different advisors that was developed to support first-year students in complex, interdisciplinary problem solving. It describes the different support roles as well as their impact on the technical and professional performance

and on the integration of students within their teams and deduces starting points for a focussed modification of the complex system for more technical or more team learning goals.

2 The Model of Interdisciplinary Study Projects at TU Darmstadt

The model of introductory interdisciplinary study projects at TU Darmstadt is a typical problem-based and project-oriented learning (PBL) format. All study projects have in common the placement in the first to third study semester, the cooperation of several departments, the multifaceted and complex task assignment, the intensive tutoring of the students and the close combination of professional, social and personal learning. They differ in student numbers, formats and the number of partners. The range extends from project courses with 120 to 800 students or rather 12 to 80 teams, from project weeks to semester projects and from cooperations between two departments to cooperations between five departments and international partner universities. This paper focus on the format of the introductory interdisciplinary project week which has been the prototype and blueprint for all other interdisciplinary study project formats and already described in more detail in [Dirsch-Weigand et al., 2015; Pinkelman et al., 2015; Eger, 2011; Hampe, 2001].

2.1 Curricular Integration

The integration of study projects in the regular curriculum was an explicit goal of the introductory process, whereas the embedding of the tutor qualification in the curricula of arts and humanities, psychology and pedagogy was a practical consequence of the demand for a sufficient number of tutors for project courses up to 800 students.

Table 1: Learning outcomes for the interdisciplinary project week in the department of mechanical and process engineering of TU Darmstadt [Module Handbook, 2016]

Course Title: Introduction to Mechanical Engineering			Form of teaching: Project work		
Credit Points: 2 CP	Work load: 60 h	Contact hours: 44 h	Individual study: 16 h	Assessment methods: Presentation	Grading system: Pass - fail
Learning Outcomes: On successful completion of this module, students should be able to: 1. Produce a goal-oriented solution through interdisciplinary teamwork. 2. Comprehend and work on an interdisciplinary assignment using design principles of mechanical engineering. 3. Moderate team processes. 4. Plan, organize, and carry out tasks independently. 5. Discuss possible solutions and reach an informed decision based on relevant criteria. 6. Analyse the various aspects of an assignment by acquiring various methodological competencies. 7. Present and discuss the outcomes of their work before an auditorium. 8. Reflect on the greater social consequences of scientific action.					

Currently, the interdisciplinary study courses in the first to third study semester have been embedded in 23 of 28 bachelor programs at TU Darmstadt. In 15 bachelor programs, the projects are implemented as compulsory modules, in seven, they are realized as elective modules. The project modules describe defined learning outcomes (see an example in Table 1) and are 2 or 3 European (ECTS) credit points for a workload of 60 or 90 hours, respectively. The curricular integration of interdisciplinary study projects is supported by the quality assurance system. In 2016, the University Senate of TU Darmstadt decided that the implementation of interdisciplinary study projects should be a quality issue for the accreditation of study programs.

The qualification of team tutors is an intense training and implemented by the Centre for Educational Development. It is an elective module in the graduate degree courses of psychology, pedagogy, social sciences, liberal arts, secondary teacher education and electrical engineering. Students can achieve between 6 and 15 ECTS credit points for the module – depending on additional academic achievements such as term papers or extended reports and reflections about their practical experience as team advisors.

2.2 Concept

In the interdisciplinary project week, students of engineering, natural and social sciences, arts and humanities work in project teams from 8 to 12 students on an ill-defined, challenging and societally relevant task with an open solution, which they can solve only with the competences of all disciplines and close collaboration. Over the week, students keep a basic schedule with milestones of problem definition, requirement analysis, creation of solution ideas, assessment and selection of ideas, specification and elaboration of the chosen concept, and finally the presentation of the concept to a jury. They autonomously organize the distribution of tasks and responsibilities and the work in small groups or plenum sessions.

The quality of the task assignment is an important factor [Noordzij & Wijnia, 2015]. The ill-defined problem and a wide solution-space without a sample solution are crucial and characteristic for problem-based learning and orientation to inquiry and research. In order to motivate students, the task should be realistic, challenging but feasible and as holistic as possible.

Some examples from the year 2016 may illustrate the task assignment:

Students of architecture, history, physics, mathematics and materials science explored neglected public spaces in the city of Darmstadt, analyzed former and conceived future usage, and designed new architectural solutions for a revitalization of that public space, such as abandoned parking decks, ignored pedestrian underpasses or forgotten plazas.

In a cooperation of the biology, sociology and philosophy departments, students were tasked to design a “vaccination mosquito” on the basis of synthetic biology. Along with the biotechnological concept, they had to work out the bioethical and societal restrictions for a real-world use of these vaccination mosquitos in case of a pandemic.

In a third example, students of mechanical engineering and sociology from TU Darmstadt worked with medical students of the Johannes Gutenberg University Mainz in order to design an innovative instrument for laparoscopic diagnosis and surgery.

2.3 Support System

Interdisciplinary problem solving is demanding and challenging, especially for students in their first semesters. Therefore, student teams are comprehensively tutored by different advisors and experts in a support system, which can be addressed metaphorically as an academic village.

As children in a village are educated by many different teachers with different responsibilities and roles, the students are supervised, guided, constructively criticized, aided and supported by different didactic actors in different roles. The different tutor and advisor roles in the "academic village" are: technical advisor, team advisor, supervision, helpdesk, experts and jury.

The technical advisor works in tandem with the team advisor. Their roles are complementary, and they coordinate with each other content-related as well as schedule wise and alternate in student teams. Each of them is present for about two hours in the morning and afternoon in the groups. The technical advisors are mostly scientific staff or advanced master students of the participating engineering and natural sciences faculties, whereas the team advisors are mostly students of psychology and education sciences,

Technical and team advisors for their part are backed by technical and team supervisors, especially in critical situations in the student teams.

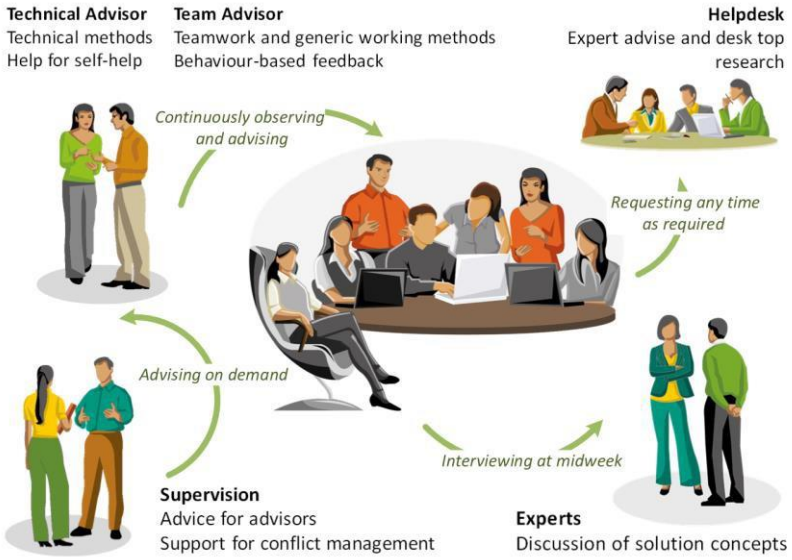

Figure 1: Students in the center of the „academic village"

The helpdesk is a contact point where students can actively seek specific information material or data and methodical help in desktop research and scientific inquiry. The helpdesk staff include scientific assistants from all participating fields of studies.

The experts are professors, scientific assistants or external professionals and scientists. They are on-site available for half a day at midweek in order to review and discuss the ideas and solution concepts of students and give further technical advice. In order to help, the experts expect well-prepared short reports and specific questions that require their expertise.

In the jury, the experts evaluate the final solution concepts and outcomes that have been demonstrated in the presentations or poster sessions. They assess the quality of the problem

solving, rate the degree of innovation as well as the economic and ecological feasibility and judge the professionalism of the presentation based on a given list of indicators for the learning outcomes which were defined in the modules. In some interdisciplinary study projects, technical and professional results are additionally assessed on the basis of project reports as in the further examined study project.

3 From Teacher to Advisor: Advisor's Roles, Competences and Qualification

In contrast to the classical school teaching or classical recitations at universities and colleges, technical advice and team support are assigned to two separate types of tutors in the model of study projects at TU Darmstadt: team advisers and technical advisors. They play the main roles in the support system - emphasizing the shift from teaching to learning and from teacher to learning guide.

On the one hand, the model of the two different types of advisors is motivated by more practical and performance reasons: A separate qualification for technical and team advisors allows for recruiting of students from non-technical departments for team advising and thus expands the pool of available tutors. Splitting the roles allows the distribution of the workload during the study projects from one to two persons. Furthermore, the cognitive load is easier and the performance is better if the advisors can focus their interest and attentiveness either to the teamwork and team process or to the progress in task processing and technical problem solving.

On the other hand, the specialisation is due to a different relationship of team and technical advisors to the student teams: The acceptance of team advisors strongly depends on a trusting and helping relationship between the team advisor and the team whereas the authority of the technical advisors includes a more corrective and instructive responsibility.

A third reason is that different advisors make the type and objective of feedback clearer for students. Feedback from the team advisor can more easily be decoded as appeal and advice to change the team's behaviour whereas feedback from the technical advisor can clearly be categorized as support of the academic and scientific effort.

3.1 Roles and Competencies of Team and Technical Advisors

The role of the team advisor is the role of a coach and guide with a focus on team development and working methods such as creativity techniques and visualisation, discussion and moderation, decision making and conflict handling in teams. The advisory goal of the team advisor is to empower the team for better teamwork which always touches individual behaviour. Thus, a relationship of trust and acceptance is crucial without losing professional distance and turning into fraternization. Team advisors prefer a more confident and supportive communication style in contrast to technical advisors who follow the disciplinary culture which might include more authoritative, critical and assessing attitude and therefore, authentically demonstrate professional practice.

Team advising requires specific knowledge, skills and competences. Team advisors know and reflect on phases of team development and complex problem-solving as well as the impact of feedback for developing team competences. They are able to observe, analyse and assess team processes and teamwork on the basis of defined indicators and criteria. They can moderate

reflection-processes in teams and give encouraging and constructive feedback on teamwork and problem solving methods. They know how to motivate teams to discuss effectively, moderate participatorily and manage conflicts constructively. They have an amateurish understanding of the technical task assignment in the respective study project.

The technical advisor has the role of a professional sparring partner for the students [Bøgelund & Dahl, 2015]. They are facilitators in the context of problem analysis and problem solving, providing technical methods and theories. They support the teams according to the principle of "minimal help" [Zech, 1977] or with other words: the principle of help for self-help. Their assistance starts with strengthening the motivation and self-confidence of the team, changes to general strategic advice for problem-solving and ends with instructing help if needed.

Their knowledge and skills cover an in-depth understanding of the task assignment and possible solutions including the interdisciplinary approach, project management and specific technical methods. They know and recognize the different stages of problem-solving in the team and apply the didactic principle of minimal help for technical advice according to the progress of task processing in the team. They are able to express themselves in a language understood by students [Schmidt & Moust, 2000] and are ready to support the student team´s own ideas and approach according to the philosophy of help for self-help.

Both technical and team advisor must be able to decide the right moment of intervention without disturbing the on-going process of self-regulated learning and problem-solving in the teams [de Graaff, 2013].

3.2 Qualification of Team and Technical Advisors

The different competence profiles of team and technical advisors require a different qualification and preparation.

The qualification of team advisors by the Centre for Educational Development has been aligned to a systematical formation of competences in five multi-day block seminars with a workload of 180 hours. In the basic seminar, students learn the fundamental pedagogical and psychological theories of communication and group processes and reflect on their own roles in teams and groups. In the following seminar "Teamwork", the participants train practical skills for resource- and goal-oriented discussion, moderation and problem solving in the position of a team member. In the subsequent third seminar "Team Training", the participants change from the role of a team member into the role of a team trainer. They learn how to effectively convey and instruct methods and tools for constructive teamwork, which they have practiced in the previous module. In the fourth seminar "Team Advising", the participants change roles again. They exchange the role of an instructor with a position as an observer and advisor of the group. They practice monitoring and analyzing team behaviour and guiding and coaching the groups with behavioural and situational feedback. Special attention is given to the training of criteria-based observation and assessment of teamwork. In the final seminar "Team Diversity", the participants deepen communication and intervention competencies for dealing with cultural, professional, social, individual and gender diversity in groups and learn to develop constructive options for challenging situations and conflicts in teams.

Technical advisors are upper level master students, assistant lecturers, academic tutors, post docs or PhD candidates, who are qualified by the Centre for Educational Development in a short workshop on advising. The training by the Centre for Educational Development focuses on the application of the principle of "minimal help" for technical advice.

After the role-specific preparation, team advisors and technical advisors prepare jointly for the project week in the so called simulation. In this rehearsal, the advisor tandems train their cooperation in a lifelike setting. The complete support crew of a project course - team advisors, technical advisors, supervisors and helpdesk - meets for two or three days and simulates the program of the project week. Analogously to the real project week, they form several project teams and install team and technical advisors and a helpdesk. Since the personas of students and advisors rotate, everyone has the opportunity to practice advising and tandem work. Supervisors act as personal coaches for the advisors and correct and adjust their practice by giving feedback. By working through the very task of the project week the support crew familiarizes with the body of knowledge underlying the topic of the project and is prepared to supply help if requested.

4 Evaluation of the Impact of Team and Technical Advisor

The overall evaluation of the model of interdisciplinary study projects at TU Darmstadt has proven to be an effective learning format for combined technical, professional, social and intercultural learning [Dirsch-Weigand et al., 2015; Pinkelman et al., 2015] and an effective teaching and learning approach in order to strengthen the motivation of students and their academic engagement [Koch et al., 2016]. It is obvious to attribute a large share of these positive results to the joint team and technical advisory as it has been verified for other settings and contexts such as business consulting [Königswieser, Sonuç & Gebhardt, 2015].

Since the double advisory is personal intensive, there is justifiable interest in differentiating the effects of team and technical support. From an intuitive perspective, the roles of team and technical advisors are complementary. But the roles might also be competitive or compensating. The clarification of the interrelation between the two roles is important in order to find possible starting points for an adjustment with the least possible loss of quality.

4.1 Experimental approach

To clarify the impact of the two different advisors, the advising times for each role was systematically reduced in a large project course with 660 students, 30 team advisors and 30 technical advisors. The data set included 626 participating students in 60 teams which were advised by a tandem of a team advisor and technical advisor.

The statistical investigation of the underlying interdisciplinary study project was embedded in a field-experimental design. The students were randomly assigned to the project teams as well as to the field-experimental conditions. The four conditions below were varied systematically by time exposure of team advisory and technical advisory. However, a few concessions had to be made to the field setting and to the different approaches of behaviour-based team advisory versus technical advisory, that follows the principle of minimal help. The time variation by condition is as follows (percentages are rounded to 5% steps):

- Condition 1 is the **standard model**. In this condition, the tandem of team advisor and technical advisor were responsible for two student teams, alternating in each team half a day per day over the whole project week (100%). Condition 1 was tested with 14 teams of 151 students.
- Condition 2 **reduced the technical advisory** resulting in a total advisory time of rounded 70% during the project week. Condition 2 was tested with 14 teams of 141 students.
- Condition 3 **reduced the team advisory** and resulted in a total advisory time during the project week of rounded 75%. Condition 3 was tested with 14 teams of 147 students.
- In condition 4, **both advisors were in the reduced condition** resulting in rounded 55% of the standard advisory time. Condition 4 was tested with 12 teams of 129 students.

Data on the assessment of advisory, team development and teamwork were collected in daily reflection sheets for students and both advisors via the learning management system, Moodle. The online questionnaires were structured in three parts: In the first part, students only reported the perceived quality of the team and the technical advisory. In the second part, both participant groups, students and advisers reported on the team climate using the items of the Team Climate Inventory by Anderson and Brodbeck [Andersen, 1994; Brodbeck et al., 2000]. Since team and technical advisers are trained to diagnose team problems such as restraint or dominant behaviour of team members or exclusion of minorities, advisers' assessments works as a corrective for the self-report of student teams. In the third part, the students and advisers reported on the working style in the teams. All scales in the questionnaires were designed as five point Likert scale [Likert, 1932] and labelled with Rohrmann's descriptors of agreement ranging from "strongly disagree (1)" to "strongly agree (5)" [Rohrmann, 1978]. Data were analysed on a descriptive level.

Data on the technical and professional quality of the final solution include the assessment of the oral presentation by the jury and the graded project reports of the teams

4.2 Evaluation Results for technical and professional performance

The technical and professional performance of the teams was determined by a combined evaluation of the presentation and the project report and summed up as a "team's summary assessment score". Oral presentations were rated by different jury panels on a scale from 0 (poorest) to 10 (best). Mean values of teams' scores are put as relative values and are normalized to each other by the factor jury panels. Teams' project reports were critically assessed. These scores were also put as relative values. Finally, both values are added for the teams' summary assessment score. The assessed scores range from 0.39 to 1.06. Overall, the average teams' summary assessment score was M=0.68 (N=60 teams, SD=0.138). Differentiated by the four varied conditions, it can be seen that the condition 3, "reduced team advisory," combined with "standard technical advisory" led to the highest mean in regard to teams' summary assessment scores (see figure 2).

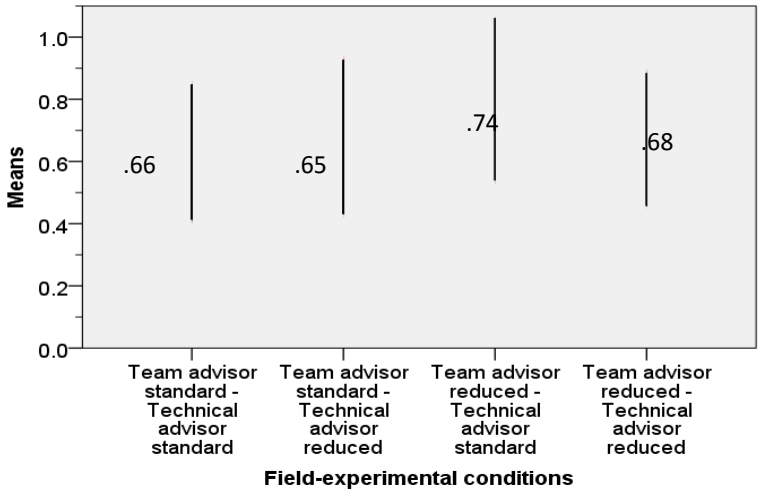

Figure 2: Shows intra-class connected ranges of team means.
Besides, there are means of each field-experimental condition.

In summary, there are differences between teams' summary assessment scores related on the varied time exposure of team advisory and technical advisory, and the combination of standard technical advisory and reduced team advisory led to the highest score in regard to the technical quality of their solution concept.

4.3 Evaluation result for team integration

The impact of team advisory was explored further by examining the integration of project teams which was operationalized in the questionnaires by the items on **restrained behaviour of team members,** e.g. showing little involvement in discussions or avoiding exposed roles such as moderator, **dominant behaviour of team members,** e.g. overlong monologues, interruption of the counterpart, discriminatory language or interventions, and **listening to a minority's opinion** with the following results in figures 3, 4 and 5. A five point Likert scale was used ranging from "strongly disagree" (1) to "strongly agree" (5).

The broad view of **restrained behaviour of team members** (see figure 3) shows mean values on a moderate scale level. On Monday, the mean values range around M=3.5 for teams of both conditions and from M=3.4 to M=3.9 for team advisors. On Thursday, teams' self-reports differ with $M_{\text{Diff.}}$=0.3. Equally, team advisors' reports are more similar to each other (M=3.1 and M=3.3). Regarding the development over the week, teams report a marginal decrease of M_{Diff}=0.2 in the condition of standard team advisory but a decrease of M_{Diff}=0.6 for teams in the condition of reduced team advisory. Team advisors' observational reports of both conditions decrease in parall and with exactly the same differences in means. The figure shows remarkable differences between teams' self-reports and team advisors' report in the condition of reduced team advisory. The reports of teams and team advisors in the condition of standard model seem to be more balanced and with less dynamic in data between Monday and Thursday.

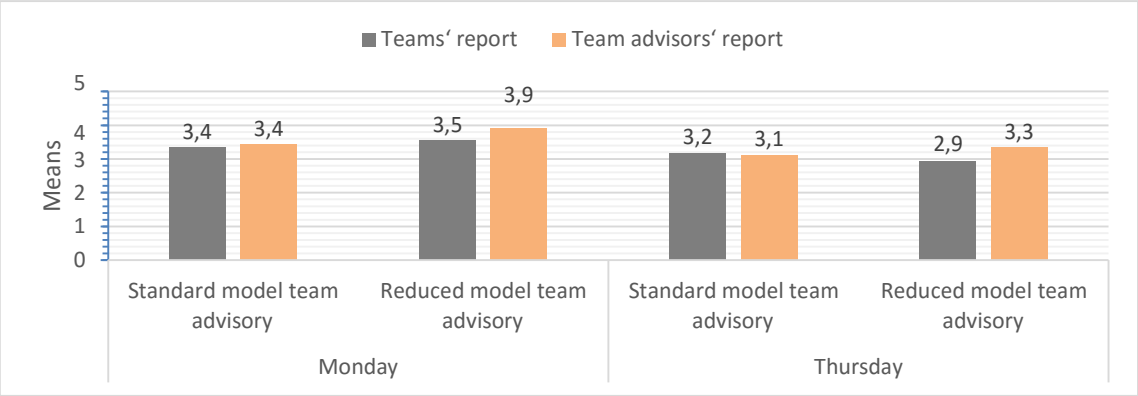

Figure 3: Mean values of restrained behaviour of team members by day of project week (Monday vs. Thursday) and by team advisory (standard vs. reduced model)

In sum, figure 3 shows two remarkable differences:

- First, on Monday after the first day of team advisory, the team advisor reports differed a half scale unit between the standard and reduced team advisory model. Therefore, teams with reduced team advisory were observed to have more restrained behaviour of team members (*M*=3.9) than teams with standard team advisory (*M*=3.4). Or, in other words, standard team advisory seemed to be more successful in reducing restrained behaviour of team members than reduced team advisory.
- Second, there were higher differences of reported mean values between teams and team advisors regarding the condition of reduced team advisory compared to the reports in the standard team advisory condition. This applied as well for each record day as well as by comparison over the week. This can be interpreted as lower sensitization for restrained behaviour of team members in teams with reduced team advisory compared to teams with standard team advisory.

The trend of **dominant behaviour of team members** (see figure 4) shows mean values on a moderate scale level and an overall decrease of dominant behaviour. On Monday, dominant behaviour of team members is reported by teams in both conditions with *M*=3.4. Mean values of the advisors range around *M*=3.7 or *M*=3.8. On Thursday, teams of both conditions rated *M*=3.0, whereas the team advisors' mean values differ nearly half a scale unit: On average, team advisors of the standard model rated *M*=2.9 and team advisors of the reduced model rated *M*=3.3. In regard to the development over the week, there is an equal course between Monday and Thursday: Teams of both conditions report a decrease of dominant behaviour of $M_{\text{Diff.}}$=0.4. Starting from higher scale values around *M*=3.7 respectively *M*=3.8, the team advisors also reported a decrease of $M_{\text{Diff.}}$=0.8 to *M*=2.9 (standard model of team advisory) and a decrease of $M_{\text{Diff.}}$=0.5 to *M*=3.3 (reduced model of team advisory).

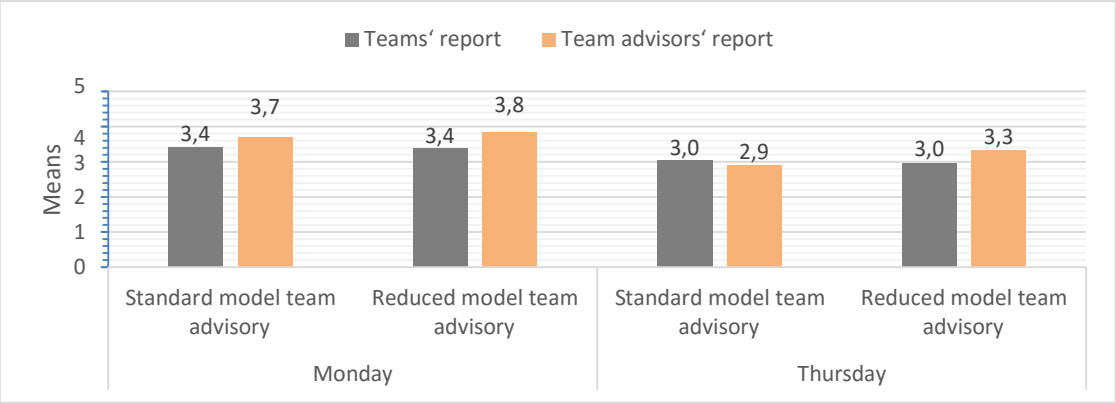

Figure 4: Means of dominant behaviour of team members by day of project week (Monday vs. Thursday) and by team advisory (standard vs. reduced model)

In summary:

- On Monday, there were differences in teams' self-report versus team advisors' report regarding dominant behaviour of team members. On Thursday, there were a nearly perfect matching of teams' self-report and team advisors' report in the condition of standard team advisory. This indicates a convergence of the teams' and team advisors' benchmark for dominant behaviour within the team in the standard team advisory condition and can be interpreted as an indicator for a regulating impact of the team advisors' interventions.
- In contrast, the average ratings of team advisors for teams with reduced team advisory showed a slower decrease of dominant behaviour of team members over the week than teams in the standard team advisory condition.

The broad view of **listening to a minority's opinion** (see figure 5) shows higher average values. On Monday, teams of both conditions rate their listening to a minority's opinion on a mean value of M=4.5. Team advisors in the condition of the standard model reported a mean value of M=4.3 whereas team advisors in the condition of the reduced model reported a lower mean value of M=3.8. On Thursday, teams' self-report slightly decreased on average to M=4.3 (standard model of team advisory) and to M=4.4 (reduced model of team advisory). Regarding the observational reports of team advisors, there was a slight increase of the standard model average value from M=4.3 to M=4.4 over the week. In contrast, team advisors in the reduced model of team advisory maintained their average rating of M=3.8. Thus, the developments over the week showed a marginal decrease in mean values for teams of both conditions. Comparing team advisors of standard conditions with team advisers of reduced conditions, there is a continual difference in means of M_{Diff}=0.5 (Monday) and M_{Diff}=0.6 (Thursday). In our evaluation data, this finding is meaningful.

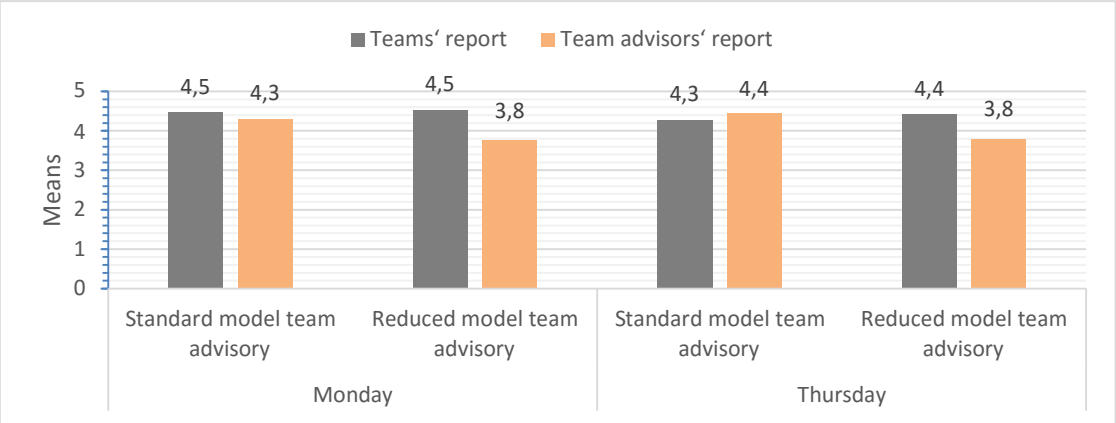

Figure 5: Means of listening to a minority's opinion by day of project week (Monday vs. Thursday)and by team advisory (standard vs. reduced model)

To summarize:

- Team advisors reported higher mean values and a slight increase of listening to a minority's opinion over the week for teams with standard team advisory, whereas they reported lower mean values and a stagnant rating over the week for teams with reduced team advisory.
- The slightly stronger decrease of self-assessment in teams with standard team advisory may indicate a stronger sensitizing of these teams with regard to the participation of minorities compared to teams with reduced team advisory.

4.4 Conclusions from empirical results

The intuitive understanding that team and technical advisory are always complementary in the support model of interdisciplinary study projects at TU Darmstadtd must be revised after the field-experimental evaluation of a large project course with 660 students. The evaluation showed a partly competitive, partly complementary relationship of the different advisory support. Whereas technical advising can compensate a reduction of team advising regarding the technical quality of the final solution, it cannot replace team advising with respect to team competences. This particularly applies with regard to team integration and participation of all team members, especially, participation of minorities, e.g. discipline, gender. It could be shown that:

- standard team advising was more successful in reducing restrained behaviour of team members than reduced team advisory.
- reduced team advising was less successful in regulating dominant behaviour of team members than standard team advisory
- standard team advising slightly improved participation of minorities in teams whereas reduced team advising had no effect on the participation of minorities, e.g. students of other disciplines or gender.

These findings allow for adaptation of the support model in regard to the intended learning outcomes, contexts and constraints of the study organisation, e.g. research, practice, personal development. Whereas the combination of team and technical advising remains the basis for the teams' success, the proportion of team and technical advising defines a more technical or more team learning outcome.

Thus, if the learning outcomes of an introductory study project focus on the technical quality of results, the combination of standard technical advising and reduced team advising is adequate. If the acquisition of technical and of team competences are equally important, team advising must not be reduced. If competent teamwork is the most relevant learning outcome, technical advisory can be reduced.

A time reduction of approximately 30% for technical advisory or alternatively of 25% for team advisory – depending on the learning goals – are our guiding values in the given support model of an "academic village". If the effort of both roles should be reduced, our examined limit is a reduction to the 55% level of advisory time ensuring to offer enough team-oriented and task-oriented support to student teams in their first semester challenges and future perspectives.

5 Challenges and Future Perspectives

Initial discussions of the evaluation results with the departments of TU Darmstadt show that faculties do not want to opt for an alternative focus on team learning or technical learning. They try to equally maintain both learning outcomes but want nevertheless a significantly larger reduction of tutorial support: The aim is to reduce the availability of tutors to about 20% of the project time in contrast to the 55-75% of tutored project time which was examined in the field-experiment.

Against the background of the presented model and evaluation, it seems evident, that such a radical reduction of support time needs a change of support methods. If there is hardly an opportunity for participatory observation in the student teams, team advisors will have to replace behavioural feedback by less observation-intensive appoaches and more directive instruments like project status talks and instructional input. The challenge here is not to slip back from an advising role into a teaching role and thus undermine the shift from teacher to learning guide and from teaching to learning. The Aalborg model where students call for meetings with their advisors and discuss their issues on demand might be an appropriate option.

Currently, the tutored time is reduced to 50% of the project time in some project weeks in parallel with a methodological change for team support. Evaluations will show if this variant of support model provides sufficient assistance for successful teamwork and professional results.

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Five Years of Project-Based Learning Training Experiences in Higher Education Institutions in Brazil

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Abstract

Implementing Project Based Learning (PBL) is a challenging enterprise both for students and for teachers. PBL demands a changing process in which teaching is about being able to work with other teachers in an environment open to uncertainty, with creativity, improved communication and engagement. Considering the need to support teachers to implement PBL, a group of researchers delivered 19 workshops since 2010 in 16 Higher Education Institutions in Brazil. These workshops were delivered using a PBL approach and most of them had 20 hours of training. This study aims identifying the impact of these workshops and discuss the contribution of staff development strategies to improve engineering teaching practice. The methodological approach carried out for this study was based on an online questionnaire exploring the participants' perceptions about their experience in the workshop and the impact on their teaching practice using active learning strategies (difficulties, motivations, etc.). The questionnaire was sent to 367 participants' active email addresses. The findings, from the 67 answers received, point out that 95% of respondents said that the workshops have had an impact on their teaching practice, and in general, they are applying what they have learned in the workshops. The participants' motivation came from the interest in learning new teaching strategies, sharing experiences, improving student learning, innovating and even just out of curiosity. Concerning to teachers' training, more than 75% of the respondents' claimed they have felt the need of pedagogical training at the beginning of their career, and more than 70% stated that they keep on participating in events to improve their professional practice as engineering teachers. It is important to point out all respondents consider important or very important the existence of a professional teachers' development program in their institutions, and the pedagogical training was highlighted as the most needed, followed by the formation of practice communities and research groups. Based on the participants perceptions it was possible to present a short list of general recommendations for the development of engineering teachers training opportunities.

Keywords: Project-Based Learning; Active Learning; Staff Development; Engineering Education

Type of contribution: Research paper

1 Introduction

Active learning strategies are associated with meaningful contextual experiences, where the student is in the centre and actively engage in the learning process, being able and having the opportunity to reflect upon what they are learning (Bonwell & Eison, 1991; Felder & Brent, 2003; Prince, 2004; Prince & Felder, 2006). Although learning could be seen as a synonym of active learning (Christie & de Graaff, 2017), there is a set of innovative student centred methods (Lima, Andersson, & Saalman, 2017) that potentiate students' success

(Freeman et al., 2014). Among active learning strategies in engineering education, Problem and Project-Based Learning are some of the most common approaches refereed in journal articles (Lima et al., 2017).

Engineers are professionals that design solutions to solve society problems through the execution of projects. Considering this perspective of the engineering profile, it is expectable that active learning approaches for engineering education are strongly related to Problem and Project-Based Learning (PBL). In such approach, teams of students cooperate for solving open-ended problems linked to the professional activity (Edström & Kolmos, 2014; Graaff & Kolmos, 2003; Powell, 2004; Powell & Weenk, 2003).

All around the world, higher education (HE) teachers are not prepared to become teachers. Usually, having a PhD in a specific technical knowledge area is enough to become a teacher in that area. Even though in some countries during their postgraduate studies they do some classes related to pedagogical issues (Cargnin-Stieler, Teixeira, Lima, Mesquita, & Assunção, 2016), their preparation is low or inexistent in relation to what (Zabalza, 2009) defines as fundamental processes to improve teaching quality: methods, content selection, learning environments, student support learning support materials, teachers' coordination and evaluation. Therefore, training higher education teachers will provide them with competences that can improve the quality of the teaching and learning processes, namely communication, teamwork and planning (Sadler, 2012; Tigelaar, Dolmans, Wolfhagen, & van der Vleuten, 2004; Zabalza, 2009).

Considering that most of the current higher education teachers did not have active learning strategies during their undergraduate and graduate training, they do not have experience with these approaches, not even as learners. Thus, supporting teachers for implementing active learning strategies is a need for changing the teaching and learning processes. This need created a demand for cooperating with several institutions and since 2010, a set of 19 teacher training workshops in PBL were delivered in 16 Brazilian higher education institutions. These workshops were delivered using a PBL approach and most of them had 20 hours of training. With this study the authors aim to identify the impact of these workshops and discuss the contribution of professional development to improve engineering teaching practice.

2 Research Background

L. R. Fernandes and Silva e Filho (2015) say that industry in Brazil expects engineers with personal abilities that transcend the reasoning skills, traditional on STEM graduate courses, and one important suggestion they present in their work is the incentive of innovation projects. Thus, it is important to include some active learning strategies within the engineering curriculum (Loder, Nakao, & Filho, 2014; Mesquita, Flores, & Lima, 2015; Mesquita, Lima, Flores, Marinho-Araujo, & Rabelo, 2015). These strategies could be very positive because with more engaged and motivated students, it is supposed to have less dropouts and students tend to be engaged in their own learning process (S. Fernandes, Mesquita, Flores, & Lima, 2014).

In addition, to satisfy the labour market expectations, engineering schools in Brazil need to be more attractive to students. According to Engenharia Data Annual Report (Salerno & Lins, 2015), although engineering is still one of the most attracting areas, a reduction in the number of freshmen was observed in 2013 and the dropout rate was about 22%. Dropouts are a waste of educational resources and a waste of student's resources (Kolari & Savander-Ranne, 2002). This report, organized by Salerno and Lins (2015), also remind us that Brazil forms only 2.93 engineers per 10.000 habitants, while Finland makes 34.02 and Portugal, for example, 25.40. The data cited above indicates the need for a change in engineering education in Brazil. It is important to point out that this improvement is not only about curriculum development and technological improvements, being also essential to develop studies about engineering education changes, and research

engineering teachers' training programs to support all the required changes (Mesquita, Lima, et al., 2015; Villas-Boas, Booth, Mesquita, & Lima, 2016).

Teaching is a complex activity and both teachers and institutions need to be aware of this fact, it requires multiple knowledges that need to be carefully prepared and understood in their relationships. Besides, the teaching-related issues are behind cognitive barriers, such as methodologies, terms, among others. The university pedagogy is a space of connection of knowledge and cultures (Cunha, 2009). University professors do not have training focused on the teaching-learning processes, for which they are responsible in their academic life (Almeida, 2012; Gaeta & Masetto, 2013).

In the context of higher education, active learning involve students in the development of activities and make them think about what they are doing. Students get involved and engaged in the proposed activities, feeling motivated while developing analytical, synthesis and evaluation skills (Bonwell & Eison, 1991). Students learning process using active learning techniques is more efficient, because the student are engaged in activities that are similar to real situations, many of which are situations that an expert engineer faces daily at work (Freeman et al., 2014).

The advantage of this approach is that students learn how to interact with each other and the community around them, developing competences related to their professional contexts, acquiring knowledge, and developing attitudes and behaviours that enable them to better deal with real scenarios after finishing their studies. Project Based Learning facilitate students to experience the relationship between science and the reality of the labour market, and enhance interdisciplinarity (Graaff & Kolmos, 2003; Lima, Dinis-Carvalho, Flores, & Hattum-Janssen, 2007; Powell, 2004; Powell & Weenk, 2003).

On the same line of thought, Dahms (2014) argues that

"(…) the learning process in a PBL environment takes its point of departure in an ill-structured real-life problem – and this approach has a very strong motivational impact on students' learning processes. One of the recognized strengths of PBL is that, apart from professional engineering competences, students also develop methodological competences in areas such as project management, teamwork, negotiation, communication, problem solving".

The shift from a traditional teaching environment, usually teacher centred, to an active learning PBL environment, which is student centred, requires the transformation of several elements in the institution. It is necessary to make modifications in several areas of the curriculum and teachers training is a value starting point (Schneider & Preckel, 2017). Understanding how PBL is works is an essential phase for all students and teachers. The role of the teacher must be modified, and he or she must be able to deal with learning processes with less control of the situation; they should know how to help student's to develop transversal competences, for example. Teachers must be able to create and lead active learning environments that will contribute to the formation of more creative engineers with the profile expected by the labour market (Lima, Mesquita, & Flores, 2014; Mesquita et al., 2016; van Hattum-Janssen & Mesquita, 2011).

3 Context of the Study

The first four workshops were delivered from September to December 2010, starting with the need to support the Industrial Engineering and Management program at the University of Brasília, Brazil. This program was created one year before with Project-Based Learning (PBL) principles but there was no specific implementation plans at that point and teachers had a lack of previous experience and training on PBL.

Table 1 presents a summary of the workshops delivered since 2010. The 19 workshops were delivered by Trainer A. All of the workshops are planned to be delivered by two trainers, and only if this is not possible, one trainer will deliver the workshop. Only two of those workshops were delivered just by one trainer (A). Fifteen workshops were delivered by Trainer A and B and two workshops were delivered by Trainer A and C. Trainer A has background of Engineering and Trainers B and C have background from education sciences. The three trainers have research experience with PBL education environments. The participants were mainly volunteers and the registration in the workshops was managed by the institutions.

Regarding the workshop themes, the great majority of the workshops were adapted to the institution needs centred on Project-Based Learning implementation. These workshops are planned for teams of participants to deliver a PBL plan at the end. The project that is asked from the participants, should be based on an interdisciplinary project that will join several courses and its teachers and students. In 20 hours workshops, this plan should include the project theme, project phases, curriculum alignment, learning outcomes of the project, assessment model, and results that students should be able to deliver. The 8 and 12 hours workshops are intended to make an introduction to PBL implementation, and the result will be based on a poster illustrating the project implementation proposal. In shorter workshops it will not be possible to explore the assessment model and the curriculum alignment issues.

Table 1. Summary of workshops

Institution	Local	Workshop	Duration	Date1	Date2	Trainers
UnB	Brasília	PBL	20H	2010.10.05	2010.10.11	Trainer A; Trainer C
UNESP	Bauru	PBL	20H	2010.11.16	2010.11.18	Trainer A; Trainer B
UnB	Brasília	PBL	20H	2010.11.21	2010.11.28	Trainer A; Trainer B
PUC-SP	São Paulo	PBL	20H	2010.11.29	2010.12.02	Trainer A; Trainer B
UnB	Brasília	PBL	20H	2011.06.28	2011.06.30	Trainer A; Trainer B
USP-SC	São Carlos	PBL	12H	2010.10.10	2010.10.11	Trainer A
UCS	Caxias do Sul	PBL	20H	2012.02.27	2012.03.02	Trainer A; Trainer B
IDAAM e UNINORTE	Manaus	PBL	20H	2012.03.09	2012.03.11	Trainer A; Trainer B
UFJF	Juiz de Fora	PBL	20H	2012.07.31	2012.08.02	Trainer A; Trainer C
UCS	Caxias do Sul	PBL research	20H	2012.08.14	2012.08.17	Trainer A; Trainer B
UNINORTE	Manaus	PBL	8H	2013.03.08	2013.03.08	Trainer A; Trainer B
UFRN	Natal	PBL	20H	2013.03.12	2013.03.15	Trainer A; Trainer B
USP	Lorena	PBL	20H	2013.08.05	2013.08.09	Trainer A; Trainer B
MAUÁ	São Paulo	PBL	8H	2013.08.23	2013.08.23	Trainer A; Trainer B
UNISAL	Lorena	PBL	8H	2013.08.30	2013.08.30	Trainer A; Trainer B
FATEC	Guaratinguetá	PBL	20H	2014.01.29	2014.01.31	Trainer A
IDAAM	Manaus	LO	12H	2014.10.24	2014.10.25	Trainer A; Trainer B
UFRPE	Recife	PBL	20H	2015.05.11	2015.05.14	Trainer A; Trainer B
UFPA	Belém	PBL	20H	2015.05.18	2015.05.22	Trainer A; Trainer B

In summary, these Workshops are organized as an active, cooperative, participative and participant-centered teaching-learning process, which include pedagogical, project design and management issues. Management of change was discussed but was not the central aspect of the workshops. The workshop sessions are designed with an inductive enquiry approach, using Problem and Project-Based Learning, and some active learning methods (e.g. think-pair-share). The main approach throughout the workshop is based on project teamwork activities for the development of the project proposal. These activities allows to simulate an environment that teachers can replicate in their own practice.

In this model it is intended that the participants acquire competences to design, plan and control the development of students' projects. In order to develop these competences, they will have to grasp the

essential concepts of project-based learning and reflect on the advantages and constraints of building a workable plan for a project as a team. It is intended, therefore, that the training results in a plan for implementing a student project in a specific semester of a program.

4 Methodology

This study aims to identify the impact of the PBL workshops carried out in Brazil between 2010 and 2015 and discuss the contribution of staff development strategies to improve engineering teaching practice. This is a qualitative study aiming to make a description and interpretation of the type of impact those workshops had, and the perceptions these participants have about professional development. This study was oriented by two research questions:

- What is the impact for teaching practice of PBL workshops carried out in Brazil in several higher education institutions during 2010-2015?

- What are the perceptions of the teachers enrolled in the referred workshops regarding professional development?

This study was based on a survey mainly with open questions. The survey starts with an introduction and ethical considerations, presenting the context, objectives and ethics of the study. After this introduction the participants find three sections:

- Section *Participant profile*. This section collect information about participants' gender and age, professional experience, area of knowledge and level of academic education.
- Section *Workshop*. Gathering the participants' motivation for participating in the workshops and other professional development opportunities. Additionally, the survey collect information about the impact of the workshop.
- Section *Professional development training*. This section aims to understand if the participant has other experiences of professional development training, and what type of training modes could be more appealing and more effective in the participants' opinion.

The survey was developed with Google forms and a link was sent by email to 369 unique email addresses of participants of the workshops. From this 369, it was only possible to reach 338 participants, because other addresses were not valid. The number of respondents was 67, which means that this survey got a 19.8% answer rate. This answer rate allow a confidence level of 90% with a margin of error of 10%.

Less than half of the respondents (42%) were female, with ages from all respondents ranging from less than 30 years (one) to more than 60 (9 respondents). It is worthwhile noticing that more than 80% of the participants work full time period as higher education teachers. Table 2 presents the number of years of experience as a higher education teacher.

Table 2. Number of years of experience as a teacher

Years of experience	Frequency	Percentage
<5 years	8	11.9%
5 to 10 years	14	20.9%
10 to 20 years	17	25.4%
>20 years	26	38.8%
I am not a teacher	2	3%

The participants are mainly from the Engineering, Science and Technology fields, except 14 of them that are from fields of social sciences, like education, management, marketing or law. Two of these fourteen are responsible for pedagogical support in the higher education institutions that organized the PBL workshops.

5 Findings

The findings were organized in two sections. The first one is related to participants' perceptions about the workshop carried out (motivation and impact). The second section is related to participants' opinions about teachers' professional development (pedagogical training relevance and activities). Based on the findings presented some recommendations for engineering education will be also discussed.

5.1 Perceptions about the *Workshop*

Most of the participants argued that the main motivation to attend to the PBL workshop was the opportunity to develop competences related to teacher practice: How to prepare learning environments that can be interesting and attractive for engineering students? How to support students for the development of competences aligned with the engineering practice? How to create meaningful experiences for students in terms of their engagement for learning? The focus on student is the main motivation for the teachers who need to deal with the demands and complexities of teaching and learning process in engineering, particularly in the first years (e.g. student dropout and lack of students' motivation). In order words, changing the ways of teaching is changing the ways of learning. For that reason, the participants' motivation for the PBL workshop is to improve and innovate their teaching practice, learning how to do different and how to be different, as stated by this participant:

"Willing to learn and how to be a different teacher, in order to get better results in engineering education".

The participants also mentioned other kind of motivations to attend the PBL workshop: curiosity about the theme, exchange of experiences and development of knowledge in this area.

Considering the approach used in the workshop (active, cooperative, participative and participant-centred), one of the key questions is the impact of this experience on teaching practice. For 95.5% the workshop had impact at different levels, as showed in the following examples. Two researchers made the analysis of one open question related to the impact of the workshop, creating after the first reading, a set of classes that were used to collect the main evidences that are presented here.

- Changing the practice in the classroom:
  "I modified some dynamics in class, improving the relation of the student with the content of the discipline."

  "Establishment of discussion groups of practical problems in the classroom."

  "It helped me to motivate the student to work and build his/her own knowledge on some subjects."

  "I tried to pass the concepts to the students by presenting 'mini cases' and / or real problems to solve."

  "After the workshop, every semester (my classes) were planned and executed with topics that were of interest to the students and that had meaning for them. In team activities, I began to propose the students to solve their daily problems, related either with professional activities or research. I called other teachers, from sequential disciplines to mine, to join me to propose problems to be solved, so that the theme could be deepened. More integration workshops and challenges were planned and implemented. The assessment of student performance start do be done during the construction of knowledge and not at the end of something."

- Changing and reviewing curriculum approaches:
  "The workshop had a lot of impact on my teaching career. With what was absorbed, I and a group of teachers created two fully integrative and industry-oriented electives that work only with active methodologies. In all my courses I incorporated the use of active methodologies."

  "... helped clarify about the PBL and raise awareness among colleagues, and today we are proposing the inclusion of PBL in our undergraduate curricular reform of the course (Production Engineering)."

- Changing the mindset about engineering education:
  "It changed my view about teaching and students. It allowed to identify other teachers who seek this same goal. I became more reflective about teaching practice. It inspired me, made me dream of a new Production Engineering course for my university."

  "It brought me new ideas on how to put into practice some actions that I believe are important in the actions of the teacher and the students."

  "The workshop has changed my understanding of engineering teaching."

During the workshop the participants were challenged to create a PBL proposal to be implemented in a real context. For that reason, the participants of this study were asked about if those proposals were effective implemented and 64.2% responded affirmative. Nevertheless, 35.8% of the participants responded negative. It is possible to identify two main reasons. The first reason, is the curriculum organization which is inflexible and for that reason does not allow to create interdisciplinary environments, making it difficult to overcome some constraints (e.g. number of students, number of hours per course, etc.). The other reason is regarding to the lack of teachers' collaboration and engagement to make PBL happen.

5.2 Perceptions about *Teachers' Professional Development*

In terms of professional development, the perceptions of the participants' highlights some interesting issues that might be important for further research. For instance, after the PBL workshop 47.8% did not attend to similar workshops. The main reason I the lack of training opportunities for active learning contexts, including PBL. Among participants that continue to pursuit engineering education training (52.2%), most of them are involved in an international consortium with a Higher Education Institution from the USA, and had the opportunity to attend workshops about peer instruction, flipped classroom, team based learning, amongst other. A few participants from two Brazilian universities also had the opportunity to attend to specific activities carried out inside their institutions. Nevertheless, 74.6% of the participants attend to conferences that contribute for their professional development in engineering education, mainly because is an opportunity to do research and learn with others. There are four conferences highly mentioned by these participants: COBENGE (*Congresso Brasileiro de Educação em Engenharia* – national conference about engineering education in Brazil), PAEE (Project Approaches in Engineering Education), ALE (Active Learning in Engineering Education) and SEFI Annual Conference.

All participants highlight the importance of pedagogical training in their professional development. In fact, 83.6% consider pedagogical training as very important and 77.6% of the participants refers that they missed this kind of support in the beginning of their careers as teachers. One of the participants states that "teaching engineering should not be (considered) intuitive", in terms of preparing a class, defining the evaluation model and using active learning strategies for students' engagement. In this regard, the pedagogical training is considered an added value for teachers' professional development. These are the priorities topics presented by the participants of this study, in fact, as most relevant for their teaching practice. Nevertheless, other

topics were also mentioned, such as effective communication, curriculum design, educational management, scholarship of teaching and learning and professional profile and competences. In terms of the type of training, 71.6% of the participants prefer specific workshops where is possible to be focused in one topic. Other options were also considered, namely tutorial sessions with experts (37.3%), intensive training programs (32.8%), post-graduation programs (17.8%) and informal training with peers (9%). In terms of the way of training, 62.7% prefer a mix approach (face-to-face and distance) and 37.3% prefer a face-to-face approach. None of the participants choose an approach solely based in distance learning, which reinforce the importance of personal contact in these contexts. Besides the pedagogical training, there are also other activities regarding to teachers' professional development that may add value to teaching practice. For instance: communities of practice (working groups); organizing events related to teaching practice; and developing research groups.

6 Final Remarks

This study aimed to make a description and interpretation of the type of impact a set of 19 workshops delivered from 2010 to 2015 in higher education institutions had on its participants. Additionally, it aimed to discuss the importance of teachers' professional development based on these participants' perceptions.

Considering the findings presented, it was possible to increase the understanding about the two research questions. Regarding the impact of the PBL workshop at different levels, the participants referred impacts on their practice in the classroom, on curricular changes and on changing their mindset about engineering education. In fact, the nature of the workshop, based on an active learning environment, allows the participants to "feel" the implications of it: working under pressure, dealing with the unknown, working in teams, searching for information, amongst other competences that is possible to develop within this context. Regarding the professional development in engineering education, the lack of research on this topic reinforce the importance to develop more empirical and theoretical studies about it. In other words, it is important to understand how teachers can improve their practice in order to change how engineering students can learn. In this sense, it is crucial to discuss alternatives and opportunities for engineering teachers' professional development, particularly pedagogical training activities as presented in the findings of this study. From the participants perceptions it is possible to conclude that most of the teachers prefer training models based on specific workshops, but they are open to enrol in tutorials with experts and intensive training programs. In short, some recommendations may be considered for teachers' training in engineering education:

- Design training programs based on active learning principles, mixing face-to-face and distance learning;
- Define an approach which takes into account the teachers' constraints (e.g. lack of time for different activities: research, management, etc.);
- Explore opportunities to develop distance tutorial approaches for improvement of experiences during a semester.

This work is based on the perceptions of the respondents of a questionnaire sent to participants of several workshops developed in higher education institutions. Although the number of respondents can be considered relevant to represent the participants, the main limitation of the study is related to the fact that these respondents cannot be representative of the higher education teachers as a whole. Nevertheless, it is an important number of teachers interested in the improvement of teaching and learning processes and their participation can help to understand the type of impact a pedagogical training workshops on PBL can have on the teaching practice. Additionally, their perceptions about professional development training can be

considered has interesting starting points to develop specific sessions or programs for higher education institutions.

7 Acknowledgements

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Possibilities of a Project Oriented – Problem Based Learning curriculum for the training of natural science teachers

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Abstract

The different academic scenarios, have recognized the need to establish curricula that promote scientific competences in the school environment and that respond to the social needs identified by the different countries through UNESCO (Gil Pérez et al., 2005; Rivarosa & Astudillo, 2013; Roa, 2006). To address this challenge, a Master's program in Education has assumed the curricular model Project Oriented- Problem Based learning (PO-PBL) (Hernández et al, 2015, Kolmos et al, 2004; Vithal et al., 1995) as a possibility for curricular and pedagogic innovation. In this context, the course called: "Pedagogies for the development of scientific thinking" was designed to improve the pedagogical practices of teachers of natural sciences and mathematics through the investigation of their own classrooms (Stenhouse, 1987). According to this, the question that guides this research is: what are the contributions and possibilities of the PO-PBL curricular proposal used in the training of science teachers?

This is a qualitative research, in which information was collected from the course through four sources: Entrance survey, Virtual forums, Projects developed, and intermediate and final evaluations of the course. The analysis of the information was done through a triangulation of data; the process of systematization was developed through NVivo software.

The results show that the development of the project allowed the teachers in training to integrate the theory and their practical experience in three levels: Appropriation of the theory studied in the course, incorporation of the topics addressed in the projects to classroom innovations, and main skills developed. In addition, it proposes three types of spaces (virtual, face to face and collaborative work) where meanings are negotiated in different ways, allowing the participants to deepen their learning based on their experience. Moreover, it enables the re-contextualization of these experiences in their particular teaching contexts with their students.

Keywords: teacher training, teaching natural sciences, PO- PBL

Type of contribution: Research paper

1 Introduction

Studies in the field of education in natural sciences (Abd-El-Khalick, 2012; Adúriz-Bravo, 2006; Lederman, 2006) suggest that in great part of the curricula of teacher training programs there is still a prevalence of approaches based on the transmission of concepts with a decontextualized view of science, which reduce its understanding.

In his analysis of teacher training curricula, Loya (2008) identifies very diverse curricular proposals with no specific orientation as regards to the most appropriate pedagogical models to obtain the best preparation for the practice. In the specific case of science teacher trainings, Furio (1994) identifies two curricular models.

The first one, the academicist, is based on the approach of disciplinary knowledge that can be applied in practice; and the second, the innovative and constructivist, which conceives professional knowledge as an integration of theoretical and practical knowledge through educational research processes (Furió, 1994).

In the Colombian context, teacher training programs in natural sciences often reproduce the academicist model (Rengifo, 2012). This means that teachers are mainly trained in the disciplinary knowledge, and the domain of curricular, pedagogical and didactic knowledge is deficient. This results in the permanent reproduction of this model in the new generations of teachers with the consequent predominance of pedagogical practices focused on content and characterized by the transmission of concepts (Gallego Badillo, Pérez Miranda, Gallego, & Nery Torres, 2004).

During the last decade, the discussion about the training of science teachers has gained importance in public policy, education faculties, and the research on the subject has increased. However, a study carried out in 2015 identified two obstacles for the permanent solution to the problem (Cofré et al., 2015). The first one is the lack of epistemological clarity regarding the nature of science (Franco, 2011; Gallego, Perez, & Franco, 2014; Gallego Badillo et al., 2004), and the second one is the high prevalence of pedagogical practices characterized by the oral transmission of content in the training programs. These two obstacles continue to promote teacher-centred teaching practices focused on content that do not promote scientific and critical thinking as essential in science education (Alcocer & Pardo, 2012; Gallego, Pérez, Gallego, Torres de Gallego, & Amador, 2003; Garcia, Maldonado, Perry, Rodriguez, & Saavedra, 2013).

On these grounds, it is necessary to consider alternative approaches that favour the transformation of science teachers' trainings. From this perspective, promoting curricula based on the Project Oriented- Problem Based learning (PO-PBL) approach is a clear opportunity to transform traditional pedagogical practices that still predominate in today's education. For this reason, this research study poses the question: what are the contributions and possibilities of the PO-PBL curricular proposal used in the training of science teachers?

2 Description of the PO-PBL model and its curricular components

The Master's program in Education in the area of natural sciences of Los Andes University assumed the PO-PBL curricular model (Hernández et al, 2015, Kolmos et al, 2004; Vithal et al., 1995). This model is characterized by a student-centred and experiential-based approach, under the view that every individual is different and hence two individuals cannot experience the same situation in the same way (Posner, 2005). Thus, the program generates the necessary conditions for the students to build learning according to their own interests. In this way, they experience diverse participation trajectories that help them to develop a more critical, reflective and participative identity, as well as a more holistic vision of education. During the two years of the program, students participate in two project-oriented courses, a one-year thesis project and other four courses (one per each semester) that support the projects through a methodological perspective or through the disciplinary contents.

In practice, the PO-PBL consists of defining a problem that guides the learning process through the development of a project with special emphasis on the formulation of questions as part of the process. The development of the project involves the teachers in training in a complex process of negotiation of meanings between the aspects of the course and their learning interests. This negotiation occurs at individual and collective levels among the members of the course and the teacher. From the teaching point of view, the PO-PBL model provides learners an active learning experience that crosses disciplinary boundaries promotes

recognition of other forms of teaching and learning. It provides elements for the transformation of traditional practices currently prevailing in different educational levels and from different subject areas.

In this context, the project-oriented course called: "Pedagogies for the development of scientific thinking" was designed to improve the pedagogical practices of teachers of natural sciences and mathematics through the investigation of their own classrooms (Stenhouse, 1984). The specific purposes established for this training were: i) Understand and critically analyse epistemology and the nature of science from a sociocultural perspective; ii) associate and understand the foundations of scientific thought and its significance in the teaching and learning of natural sciences; iii) analyse the curricular and pedagogical stand that enables scientific thinking in formal education; and iv) develop research skills and academic writing to participate in a research project of short duration. These particular projects were aimed at promoting natural sciences and mathematics curricula contextualized to the needs of today's society, introducing pedagogical practices based on sociocultural views of learning and science.

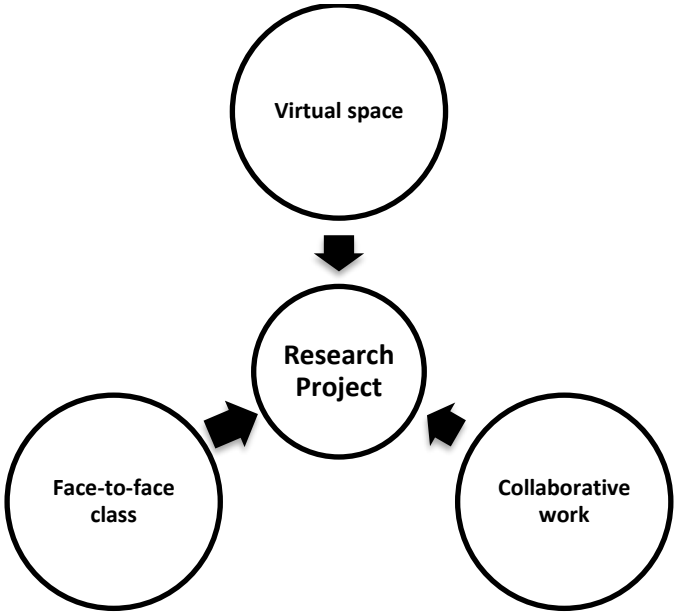


Figure 1. Workflow of the executed project and the different training scenarios.

The course is structured in a Blended mode comprising three types of learning environments: first, a face-to-face class scenario consisting of the activities carried out in the classes; second, a virtual space and, finally, an environment where collaborative work is developed. These three environments are crossed by a group research project. In the virtual space, through different forums the teachers in training discuss in depth the materials of reading of the course. In face-to-face sessions there is the possibility of closing virtual dicussions and the teacher can clarify key conceptual elements as well as develop different activities are carried out to strengthen reflection on these topics. In the collaborative work, the teachers in training must develop a draft research in groups, addressing the specific matter of the training. Then, the teacher has virtual meetings with every group every 15 days to advise on the progress of their projects. The projects address problems related to the teaching of science in the classroom and all the scenarios mentioned above permanently contribute to the development of the project (See figure 1).

Finally, the evaluation of the course includes three aspects: Activities related to the execution and presentation of the research project (65% of the total final grade), Individual participation in virtual discussion forums organized in six Modules (25%), and a final reflection document expounding the lessons learned in the project preparation, readings and group discussions (10%).

3 Methodology

This is a descriptive study from a critical and hermeneutic perspective. This perspective, enables understanding a phenomenon both globally and in detail, which strengthens and consolidates a valid and pertinent discourse in relation to the reality of the subject studied (Alvesson & Skoldberg, 2009; Goetz & Lecompte, 1988).

The participants of this study were 20 teachers enrolled in the Master's Program at the Faculty of Education from Los Andes University in Bogota, Colombia. They were selected by means of a fixed sampling method: all the teachers in training enrolled in the course: Pedagogy for the development of scientific thinking, 2015–2016.

The teachers voluntarily accepted to participate in the study, after being informed about the purpose of the study, use of the results, time to respond, confidentiality of their name in the results, and their right to ask questions and to withdraw from the study at any time. To address ethical and reliability issues, all participant teachers signed an informed consent to be part of the data collection process.

Data was collected by means of four sources:

- *Virtual forums:* The information was taken from the virtual records (moodle platform) of three types of forums: Meta-reflection forums, which provided information on the status of the discussion, specific learning, arguments related to the course theory, the class materials and the project developed in the pragmatic forums. This exercise involved associating ideas and arguments of the authors studied and their colleagues in a short writing. Pragmatic discussion forums in which the participants exchanged ideas and arguments related to the topics and readings assigned for each module. Last but not least, the reflection forums were a key scenario to strengthen learning by sharing their experience in the module, highlighting the usefulness of what they did, the difficulties they went through and their expectations for the rest of the course.

- *Projects developed*: The projects provided information on problems identified, assimilation of theoretical concepts, relation with the pedagogical practice, and relevance and impact in the context studied.

- *Intermediate and final evaluation of the course:* the evaluation provided information about the perceptions on the proposed PO-PBL model.

- *Entrance survey:* this was an initial diagnosis that assessed the knowledge of the teachers in relation to the key concepts of the course before they started the training.

The data collected from the different sources was analysed by the method of content analysis, which is one of the most common qualitative data analysis methods. According to Bardin (1986), the content analysis applies to diversified discourses. It is a type of hermeneutic analysis based on the deduction of codes that are then categorized. For reliability, the researcher has experience in the field and in

qualitative research methods. Additionally, a process of triangulation of the data obtained with support of NVivo software was performed.

4 Results and Discussion

The results are presented under three categories established in the content analysis from the different sources of information and their subsequent triangulation. The categories of analysis are related to the contributions and possibilities of the PO-PBL curricular proposal used in the training of science teachers. These categories are: Appropriation of the theory studied in the course, incorporation of the topics addressed in the projects to classroom innovations, and *main skills developed by the PO-PBL model.*

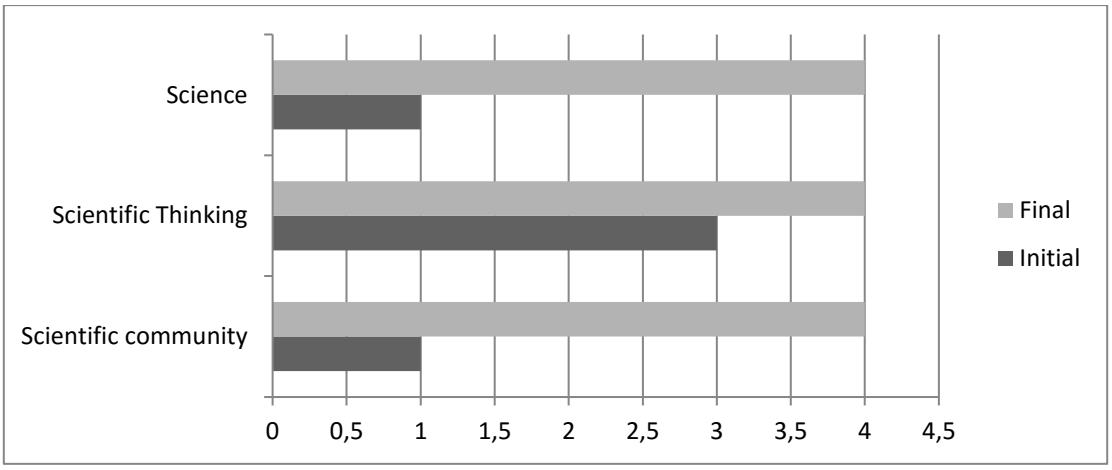
Appropriation of the theory studied in the course.

This category addresses the understanding developed by teachers in training after their experience with the PO-PBL model. According to the analysis, the curricular design under study responds to the needs identified in training of science teachers, contributing to two specific aspects: First, it transforms the vision of science and the Specific disciplines taught by the teachers in training, fostering a critical stance in relation to epistemology and the nature of natural sciences. Second, it favours the teaching and learning practices of scientific thinking from broader perspectives, and contextualized to the needs of our society.

This was evident in the analysis of the learning outcomes. The results show a transformation of the teachers' understandings in 4 aspects: i) Understanding of science; ii) Understanding of scientific thinking and scientific community; iii) Relation between scientific thinking and pedagogical practice; and iv) Development of research skills. The information was collected in activities developed in two moments of the course: the diagnostic survey applied at the beginning of the course, and discussions and final written reflections at the end of the course.

The aspects one and two were analysed according to the four levels of analysis proposed by Porlan (1998): 1. Rationalism, which considers that knowledge is a product of the human mind generated through logical rigor and reason. 2. Radical empiricism, which suggests that the observation of reality allows objective and true knowledge by induction. 3. Moderate empiricism, proposing hypothesis and experimentation as the core of the scientific process in replacement of observation. 4. Alternative, which brings a new image of Science as a socially and historically conditioned activity carried out by a scientific community, in which knowledge changes and develops permanently (Porlán, Rivero, & Martín, 1998).

Graph 1 shows the changes in the visions of science and scientific community, through the analysis of the number of ideas incorporated by the teachers in training to the understanding of the concepts studied. Then, Table 1 shows the same information in detail, through a summary of the ideas expressed throughout the training process. According to this analysis, teachers went from having rationalistic visions to having alternative visions. This means that the epistemological foundation of the curriculum generated a change in the understanding of the teachers in training about science and teaching of science. Similarly, in the component on scientific thinking, there is evidence of a shift from the level of moderate empiricism to the alternative level.



Graph 1. Frequent ideas of Scientific Thinking and Scientific Community at the beginning and at the end of the training process, based on Porlan's (1998) levels. Source: Own production.

Table 1. Transformation of concepts from the training process

Concepts	Initial understandings	Final understandings
Science	Set of accumulated knowledge; path to truth; it is a way of thinking; develops individually and in groups.	It is a set of clusters of knowledge that men have built in response to contextual needs; It is the product of a rigorous and systematized work; it enables the construction of knowledge; theories and even paradigms are developed in community; it is a socio-cultural construction that responds to contextual needs.
Scientific Thinking	Scientific method, problem-solving and problem-solving skills; ways of understanding topics and concepts; explanation of the world through theory and experimentation.	Human intellectual activity; allows abstractions, answers to questions such as: what? how? why? What for? Scientific thought requires objectivity; rationality and systematization; It drives curiosity and inquiry; Favours divergent thoughts and gives us a new vision of the world; Enables the ability to question, share knowledge and experiences.
Scientific community	Responsible for transmitting science; sharing a type of thinking; producing knowledge and taking it to non-scientific communities.	Group of people who question, ask and share knowledge and experiences. They validate scientific knowledge through interaction between its members and other communities; Pose and re-examine theories creating paradigms that explain scientific phenomena.

Source: Own production.

By the end of the course, in aspect number three -relation between scientific thinking and pedagogical practice- the teachers in training identified an evident extension of the relation. At the end, they expressed complex relations such as: community and practice relations, curricular development and pedagogical strategies based on active learning.

Incorporation of the topics addressed in the projects to classroom innovations.

This category encompassed the analysis of the relations between the projects developed during the course and the problems of science teaching in the classroom. Moreover, it assessed the exploration of possible innovation in the pedagogical practice. The analysis of the seven research projects and their development shows a relation between the relevance of the projects, the purposes of the course, and the incorporation to the pedagogical practice of the teachers in training. The topics addressed by the projects respond to the specific interests of the participants, involve the particular disciplines they teach and consequently their pedagogical practices.

Table 2. Relation between the projects developed and the purposes of the course

Project	Purposes	Results
Analysis of the development of scientific thinking skills in statistics class.	- Integrate the history and epistemology of statistics into the pedagogical practice. -Develop scientific thinking skills from sociocultural perspectives.	The students were able to live a new learning experience. Not only did they participate in an active learning process, but they also were able to understand the statistical contents of a broader and integrated with their real context.
Development of scientific thinking skills in an engineering program	Determine what kind of scientific thinking skills are developed by the students in the curriculum of a biomedical engineering program.	Through this project the professors identified the development of scientific competences in the students of the program of biomedical engineering. They analyzed the differences between students of 1, 5 and 9 semesters in solving scientific problems. These problems integrated skills such as: observation, hypothesis approach, argumentation etc.
Pedagogical strategy for the construction of meanings: environment and nature, for the development of an environmental culture	- To promote the construction of meanings: environment and nature in a participatory way through the design and implementation of a pedagogical strategy in students of seventh grade	The reflection on the concepts of nature and the environment allowed the teachers to find a more pertinent way of teaching them. The strategy that was proposed managed to significantly transform the understandings and the motivations of the students

Example of course projects. Source: *Own production*

In the advisory sessions of the research projects (carried out every 15 days), there was great motivation and a permanent effort of the students to deal with the issues addressed in the projects. This attitude is materialized in all the products delivered: progress document, support and final document, and in the comments expressed in the intermediate and final evaluations of the course,

> E1: "The investigative approach allows us to critically analyse the disciplinary concepts we are teaching and the development of classes within the school classroom in primary and secondary"
>
> E8: "The course promotes student research and provides important material. I have focused better on what I should know in my area of teaching"
>
> E7: "The activities carried out help me to evaluate my teaching practice and improve it"

From the evidence collected in class recordings, ideas identified in the field diary and in the institutional evaluations of the course (intermediate and final), it is clear that the teachers in training were immersing in a world of unknown ideas. These ideas have been ignored for years and now become a great contribution to their practice. In this sense, the curriculum implementation shows more strengths than weaknesses.

> E11: "... Taking into account that my concentration is CTIM, the content of the subject allows reflections about the work of science teachers. Moreover, the class promoted a direct relation with the development of the thesis. In my case, it is about the pedagogical application for the learning of concepts related to science ".

This category accounts for the transformation of the participant teachers' comprehension of teaching and learning. According to the results, the teachers in training developed views of teaching based on the active learning.

Main skills developed by the PO-PBL model.

The final reflections and course evaluations reveal processes of reflection on problems identified in their own practice and strengths in skills such as: identifying a problem, designing a relevant methodological strategy to study the problem, identifying relevant variables or categories to answer a research question, and arguing results from evidence.

Training teachers agree in their final thoughts on the importance of developing research projects for professional growth. Most of them recognize that the exercise of developing them develops skills that they did not have before and encourages the transformation of their practice from research processes such as the one they experienced through this proposal.

> E7: *"Mainly the ability to reflect on my own educational practice and secondly the formulation of research projects"*.
>
> *E15: "…at the end of this training process, my greatest achievement is the conceptual change that I went through experiencing from my own reflection about science, its teaching and the development of scientific thinking from the everyday experience in the classroom… There is an evident need to be*

a reflective teacher, able to incorporate elements of the context and the reality of the student's future through the inclusion of scholarly scientific problem solution".

E8: "As regards to the project that we are developing, I think it gives us a lot because it allows exploring ways to develop innovations in our practice. I think this has been very positive since we have been able to re-think our pedagogical practices".

Finally, the PO-PBL model used in the training of natural science teachers is a strategy that encourages transformation processes in classroom practices (Labra et al., 2011). *The learning experience of the teachers in training during the course showed four concrete possibilities: i) Motivates permanent processes of self-criticism and reflection; ii) Develops skills to identify issues arising from the teaching and learning processes; iii) promotes learning and collaborative team, y iv) Favors creativity and pedagogical innovation.*

These possibilities open the way to promote work in the classroom. Many of the teachers who participated in the proposal expressed their knowledge of the theory behind active learning and the PBL model. However, they had not had the opportunity to live it and to think of it as an alternative that can be applied to the interior of their practice. This suggests the need to transform the curricula of initial and postgraduate teacher training.

5 Conclusions

The proposed PO-PBL curriculum favours highly experiential courses. The project-oriented courses from this perspective promote active learning of their students through the approach to real problems from that educational context, generating a negotiation between the own course content and the interests of teachers in training. A scenario like this fosters decision making in terms of research, systematization, reflection and academic production. In this context, teachers in training need to propose solutions and improvements integrating the skills and pedagogical disciplinary knowledge. Thus, the curricular experience living allows the teachers in training to achieve a more holistic development within their teaching practice.

The analysis of the learning outcomes shows a very positive experience. After the development of all activities, teachers in training expressed significant transformations in their understandings of science, scientific thinking, scientific community and the relationship between scientific thinking and pedagogical practice. The analysis of their understandings also shows the incorporation of important and numerous elements of sociocultural visions of science and learning.

The proposed learning strategies are reasonable, productive and effective according to the advantages they offer to teachers in training. These advantages consist of offering an experiential curriculum based on a PO-PBL model that allows giving greater meaning to the work developed. In addition, it proposes three types of spaces (virtual, face to face and collaborative work) where meanings are negotiated in different ways, allowing the participants to deepen their learning based on their experience. Moreover, it enables the re-contextualization of these experiences in their particular teaching contexts with their students.

Finally, four possibilities were identified: Motivates permanent processes of self-criticism and reflection; Develops skills to identify issues arising from the teaching and learning processes; promotes learning and collaborative team, and stimulates creativity and pedagogical innovation. These possibilities open the door

to a whole new scenario of teacher training. This scenario will leave behind traditional teaching and open space for active and innovative science teachers.

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Training of researchers through a Project Oriented –Problem Based Learning curriculum: an analysis from the teachers' perspective

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Abstract

In 2013, during the accreditation process of a Master's Program in Education with emphasis on research, it was found that many of its courses developed research competences and abilities by working on projects. On these grounds, the program was reformed to formally establish and strengthen a Project Oriented Problem Based Learning (PO-PBL) curriculum (Kolmos et al., 2004; Vithal et al., 1995). This proposal was contextualized to the local conditions. During the two years of the program, students participate in two project-oriented courses and a one-year thesis project. The other four courses (one per semester) support the projects by providing information on methodological approaches or disciplinary contents.

This paper presents the master's program teachers' perceptions about the opportunities and challenges of training researchers through a PO-PBL curriculum. This paper is part of a wider research on the implementation of the reform mentioned above.

This is a qualitative research and the information was collected through semi-structured interviews with 7 teachers of the program who participated in courses and directed master's degree theses. This material was transcribed, categorized and analyzed with the help of Atlas.ti software.

The results show that from the teachers' perspective, this curriculum decentralizes the research teaching processes and generates a more comprehensive curriculum that develops research abilities and competences in the students. Moreover, students are empowered to use these abilities and competences in their contexts, developing their identity as researchers in their practice and improving the quality of their teaching.

The challenge now is doing a permanent revision of the methodological courses so that these can contribute better to the development of skills such as categorization and analysis of results.

Keywords: Training of researchers, Research, PO-PBL, Curriculum.

Type of contribution: research paper.

1 Introduction

It is well-known that one of the paths to improving the quality of education is a proper teacher training. In this regard, authors like Stenhouse (1984), Carr and Kemmis (1986) and Elliot (1993) propose a view of teachers as researchers of their curriculum and their pedagogical practice,

which enables their own professional development and generates strategies to improve classroom processes in a systematic and reflexive way.

Consequently, since 2001, Los Andes University offer a Master's Program on Education addressed to a wide variety of professionals interested on education –no matter what their graduate background is- that qualifies their professional practice by means of constant reflection and research in their practice.

The previous is in line with Dewey (1938), who states that as individuals we never stop learning because we can always go deeper in our experience and come to new conclusions that will ideally improve our practice. Hence, the educative process must develop plasticity, which means "the ability to learn from experience, the power to modify actions based on the results of previous experiences" (Dewey, 1938, p. 49).

In 2013, during the process of national accreditation of the Master's Program in Education, the actors of the program –including teachers- were asked to evaluate it. This process showed that many of the elective courses of the program used projects to develop research competences and abilities in the students. This finding resulted in a program reform aimed at establishing and strengthening a Project Oriented – Problem Based Learning (PO-PBL) curriculum as proposed at the Aalborg University in Denmark (Hernandez et al. 2015; Kolmos et al., 2004; Vithal et al., 1995), contextualized to the local conditions.

The reform established that the program would consist of two project oriented courses that lasted two years, one thesis project that lasts one year and other four courses (one per semester) to support project-oriented courses with methodological approaches and disciplinary contents. This approach tried to keep the Danish proposal of using at least than 50% of the students' time in developing the research projects.

Another important change was establishing criteria for the implementation of the project oriented courses in the practice. The characteristic of these courses is that the project developed by each group is the main learning activity and the main topic in the class sessions. A project-oriented course must meet the following conditions:

1) The learning process must start by the definition of a problem –either theoretical or practical- that is pertinent in accordance with the interests and needs of the students and the teacher.

2) The students are actively and directly involved in the formulation of the problem to be solved or the question to be answered.

3) The solution to the problem or the response to the question can be either theoretical or empirical, based on the relevant disciplinary theories and is built using methodologies typical of such disciplines.

4) There is a close and constant mentoring of the research process by the teacher, in which the negotiation of meaning of two things: the concepts of the disciplines that can be used to solve the problem and the pertinent research methods –information collection and analysis- to come to the solution. The teacher also mentors the process of writing the final research report. This evaluation can be complemented by an oral sustenance.

5) At least 60% of the final course mark corresponds to evaluations of the research process in accordance with clear and public criteria —informed to the students on the first day of class. It is important to keep the rulebook of the university in mind, which says that a single evaluation cannot add more than 35% to the overall score.

Finally, it was agreed that the mandatory course of the first semester would be the first one oriented by project, so that all the participants in the program would appropriate the basic principles of this curricular model during their first experience in the course.

At the beginning of 2014, a research project developed by one of the faculty teachers started. This project had the objective of characterizing the development of research abilities and competences fostered by this PO-PBL curricular model, by means of a longitudinal study that includes an assessment of the actors (teachers and students), the processes and the learning products. This paper expounds one part of that research, limiting the analysis to the perceptions of the teachers of the program.

Conducting this kind of research is important because –as reported by Kiley (1999)- the difference between the conceptions of research among the supervisors and the students is a risk factor for post-graduate students to quit their doctorate or master's programs.

In 2005 Kiley and Mullins developed an additional qualitative study to inquire on the conceptions of research in a group of post-graduate thesis directors. They analyzed 53 online questionnaires in which they identified various conceptions of what research is and what is good research, organized in four emerging categories: i. Research as a technical process: it refers to the rigorous application of systematic methods to properly define problems of a disciplinary context; ii. Research as relevant/innovative: it refers to the applicability and utility of the results of the research process; iii. Research as creative/innovative: this one considers the method is important, but creativity is fundamental at the moment of building knowledge and new approaches to it; iv. New ways of seeing research: it considers that research opens new paths to understand phenomena and enables the construction of new perspectives for research itself.

In addition, the teachers that answered the questionnaires assured that knowing the conceptions of the students about those topics was important to guide their process better during the writing of their thesis.

During the longitudinal research of the master's program in 2015, a first study was conducted to assess the view of the teachers of the program about teaching research (Rey, 2015). For this, 11 semi-structured interviews with teachers of the faculty that were working for the program were analyzed.

In this study, two relevant results were found. The first one is that there were three views of research in education among the group of teachers: two of them were similar to those reported by Kiley and Mullis (2005) i) research as a technical process (2 teachers) and ii) research as a creative/innovative process (3 teachers); and a third one that is very typical of a community where research is a long, changing, systematic and rigorous process that transforms the educative practice by means of the knowledge generated in and about it (6 teachers). This last perspective is quite related to the epistemological position of the program itself.

The second result was identifying that to teach research in education the view of the teachers about learning and how to promote it in their students is even more important than their view about research. In this sense, teachers manifested that research is learned by researching, and that collaborative processes deeply favor these dynamics. In consequence, the change towards a curriculum in which the students are permanently involved in research processes from the beginning of the program and participate in different research processes (even short-term ones) was very well received and there was very little resistance to change.

In addition, the knowledge built pertains to the specific social context (Berger & Luckmann, 1973). Researching the perceptions about teaching and learning is a matter of interest in the current educative research on teacher's professional development processes (Hernandez, Maquilón, García & Monroy, 2010; Marshall, Summers & Woolnogh, 1999; & Vilanova, García & Señoriño, 2007). For this particular research, the concept of perception refers to "eclectic mental constructs that come from different sources: personal experiences, prejudice, judgments, ideas, intentions" (Aparicio & Hoyos, 2008). These mental constructs are highly subjective and vaguely delimited. Nonetheless, they give meaning to the acts of teachers in the classroom. In this case the teacher's perceptions on how and what the students must learn have an influence on the curriculum put into practice -that is to say the operative curriculum.

And consequently, after two years of the implementation of the reform, this second study on teachers' perceptions was conducted to identify possibilities and challenges in the training of researchers by means of a PO-PBL curriculum. In the next section we will explain the methodology used for this study.

2 Methodology

This is a qualitative research in the terms of Creswell (2013), who states that a qualitative study is designed and implemented when a problem or topic needs to be explored or needs full comprehension. Furthermore, Stake (2010) suggests that this kind of studies emphasize on personal experiences in specific situations, and hence they intend to study the way things work to know and understand what happens in a specific context, in a particular moment and with the actors of such contexts and moments. In this sense, understanding the challenges and opportunities of educating researchers by means of the PO-PBL curriculum from the perspective of the teachers who implement the program enables a better comprehension of teaching research.

Semi-structured interviews were done with 7 teachers of the program that had been involved in it for at least 5 years, and who had taught courses and directed theses in both curriculum proposals. Six of these teachers have doctorate degrees related to education and all of them had vast experience in the training of researchers in education. Seven of them were interviewed in the first study conducted in 2015 and they voluntarily accepted to participate in both phases of the study.

The semi-structured interviews enable the construction of pre-established questions that guide the conversation between the interviewer and the interviewees, giving the chance to the latter to answer freely and to the former the possibility to inquire in related topics that arise and deserve to be explored in depth (Bryman, 2004).

This material was transcribed, and the information was categorized in Atlas.ti software. The main aim was to identify agreements or tensions in the teacher's views of program. Relevant fragments of the teachers' interviews were translated from Spanish to produce an English narrative about the process. The results are presented and discussed in the following section.

3 Results and Discussion

According to the analysis of the interviews, all the teachers considered that the proposed change effectively strengthened the development of research skills and competences in the program students.

> *"In the end, seeing the students more capable and feeling more empowered to transform what they do in their practice is totally worth it" (Professor 1)*
>
> *"The PO-PBL model has developed research competences in the students that, although still need to be refined, have eased the adoption of the research project and this makes the thesis direction process much easier, giving the chance to progress and take advantage of it in the short time there is"(Professor 5)*
>
> *"In particular, many students of the master's program consider that the research problems are outside their duty and part of what the program promotes is that they can research in their area of work and in their classrooms; this means that it is not only about researching about education, but in education, and this process of getting involved in particular projects of their context helps in meeting the objectives that we have established."(Professor 2)*
>
> *"So they learn to search for that knowledge and implement it with better criteria and to respond better to the needs of their students; and I don't think that they will become researchers, but as they develop projects they learn to make better decisions about their practice, with better foundation either in theory or in previous experiences or in eagerness to put something to the test and permanently asking ourselves if we are doing it right or not. So in that sense, it is valuable because the research experience helps them to think their pedagogical practice in a different way and make different decisions in relation to it."(Professor 7)*

In this sense, assuming a PO-PBL curriculum implies a specific way of the epistemological position of the program regarding learning to research by participants researching their own practices. In addition, by means of this program, the teachers achieve the objectives established for the master's program in a clearer way, given that the students assume a different attitude towards researching. Thus, in many cases they move from a view of research as something external and conducted by other people, to the view of research as an activity typical of teachers. As suggested by Stenhouse (1984), thanks to the results they get in their projects they feel empowered and more capable of working and permanently improving their educative practice.

The PO-PBL model places learning in the hands of the students, as they develop skills and knowledge beyond the teachers' intentions by means of their projects. This enables authentic learning in the sense that the students are the ones that define the agenda of what they want to learn while they develop short research projects. This fact is consistent with the claim from

Montoya, Castellanos and Fonseca (2011) when they argue that "professional education programs should extend the possibilities for teachers-researchers to develop research projects not as field testers but as authentic knowledge producers" (p.1).

This has implications in the teachers' work as they become mentors and guides of the learning processes and of learning how to research, which brings challenges in assuming and understanding what PO-PBL means.

> *"The program makes you focus your activities on mentoring the students' processes rather than on developing your own curriculum. I almost feel that my curriculum is now secondary, complementary in relation to a curriculum that is in their hands; finally, it is them [the students] who are learning in the course by means of the projects they are developing. So I think this implies a completely different way of doing the teacher's job […] The class is the least important; what is relevant is the group meetings and being able to advice each group individually" (Professor 5)*

In this sense, this approach has changed the dynamic of teaching research as compared to a curriculum in which only certain courses provide all the tools for this process

> "*Given the reform of the program, all the courses could assume a stand in the development of research skills in the students of the master's program, dividing the weight between all the courses instead of overloading one or two courses in particular. In this moment all the students have the chance to learn to research in all the courses. Either by developing projects or by courses that are specifically meant to teach research" (Professor 4)*
>
> *"That is something that I have done a lot in the research courses, as in the projects that they work in the electives areas. The focus has been making them formulate, use ideas from previous research studies, current educative problems, their own experiences, theoretical ideas and, of course, being able to support and justify why they ask those research questions and knowing how to solve them the best way possible, within their possibilities."(Professor 6)*

This situation is of benefit for teachers that diversify the processes of teaching to research, and even assume different roles in this activity; in turn, students can experience a greater number and type of experiences about learning to research. Nonetheless, as all the courses are working on developing research abilities, the students are exposed to a great diversity of positions in relation to research and its purposes, which can generate tension in the development of the program.

> *"This tension will exist anyway, and it is part of diversity; sometimes the students get confused and they decide writing a paper using ethnography, for instance; since they are learning, if another teacher tells them that they are doing it wrong and that they should do it in this other way, they get confused; they don't know the methodologies or don't understand them completely, so they start mixing one thing with another; they get confused" (Professor 3)*
>
> *"Great part of the research potential that I feel they have in their classroom or in their work environment is their practice. Sometimes I feel that the messages they receive in some research courses are very oriented to quantitative research, to research that*

> *covers big populations and sometimes they come to me with concerns like wanting to do something but working in a school that does not have a population big enough for that, so they suggest contacting another school... So I ask them: 'Why are you concerned about that?' It is as if they had transferred them the concern about statistic representation and they were not actually addressing the problem they really want to work on with the proper tools they have to address it, but with the idea that they need to do a lot of surveys with a lot of students for the project to be valid" (Professor 6)*

This can represent a problem because the students are new in the field of research and if they are confused, the progress of their projects is at risk. This situation also shows their lack of critical thinking and poses one of the challenges of the program, which is helping the students to deepen in the development of their own criterion, strengthening their autonomy.

At the same time, this evidence supports the idea that it is more important for the program and actors that students learn to investigate by investigating, rather than developing a single conceptualization about research (Rey, 2015).

On the other hand, the teachers identify how the program is now more organized

> *"My elective courses are based on the experience that the students had in Curriculum [the mandatory course of first semester oriented by projects] and in Research Foundations, because the students bring part of that research experience here to work on the project of the elective course and what happens in this course can easily become their paper."(Professor 7)*

> *"I think that the fact that the students have been doing research exercises from the beginning of the master's program obviously favors them at the moment of building their research project for their paper, because they have a much wider view of research." (Professor 4)*

Additionally, they consider that the students' learning process is strengthened and they can go deeper in the development of their thesis

> *"Anyway, I think that the projects are too short; semesters are short and although they have completed their processes or precisely because the process is complete, everything is in small doses. I think that it is necessary to do a more rigorous analysis, a more rigorous methodological design; it is a trade-off: on one hand, I think they already have the idea and know how to do it, but on the other they are used to do it in a rush and have not necessarily understood the dimension of it, the depth that each decision and stage should have (…) writing the thesis I ended up helping them to go deeper into those things that they have not completely understood"(Professor 2)*

It was also clear for all that the proposals that they build for the theses are different from the proposals in the previous curriculum. Many of the teachers consider that the current processes are more effective

> *"Before they start Thesis 1, they take a course by project of the elective of the elective area and that makes them progress much quicker in their Thesis 1 process. Although at the beginning they normally don't have a theoretical framework and the research design is just emerging because they only have the draft, the previous experience of*

> *working in projects helps them to go faster in the definition of the problem and in the consistent selection of methodologies to address it, so we manage to complete it in the time we have for that." (Professor 1)*
>
> *"A difference that I noticed as soon as I started directing thesis in the new curriculum is that... It is not that they do it right from the beginning (laughs), but it is evident that they have developed research competences that make the process much easier and fluent. Sometimes I teach the first course of the program and I think that now I do the same thing I had to do with the others [students of the previous curriculum] and I see how they struggled to formulate the question and to understand what they are doing... Now they go through this in the first course, and when they start Thesis 1 I notice that they are not struggling that much. It is not that they have it all sorted out, but it is much easier to guide them and they are more aware of the entire process."(Professor 5)*
>
> *"Now they have more progress in formulating the problem and collecting information, but one of the aspects that I identified is that we still need to reinforce working on data analysis; they categorize and write the results, but I think we can still do it better, they are still missing something in that aspect"(Professor 3)*

In this sense, the teachers identified that one of the most refined skill is the formulation of actual and relevant research questions for their contexts. This facilitates their approach to their master's thesis as well as the appropriate choice of theoretical and methodological perspectives that support their research problem. The main challenge identified was that although the students categorized and analyzed the information collected, they can still improve this ability and hence attain a better development in the discussion of the results.

Other teachers identified that although the students develop the entire research process in their Thesis course, they would prefer if the students got to this point with a more structured project proposal

> "*I think that they get to Thesis 1 a little less prepared than before, because before they had to develop the entire proposal in one of the previous courses. Now they get there less prepared in terms of the document they have to submit at the end, but they progress faster. They formulate projects that are enough for the expectations of a Master's program thesis with the time they have to develop it, but I do miss that first document that is more structured and that now they don't develop in any of the previous courses"(Professor 7)*

What is more, an interesting aspect is that we identified three different views of research in the first study conducted, and in this group of people we notice that these views are still permeating the curriculum. These fragments show that although the students are achieving the expected knowledge, there is still the challenge of making teachers absolutely comfortable with the entire process. This is an invitation to make the necessary adjustments and take better advantage of the methodological courses to strengthen these abilities that still need to be developed and that become evident in the development of the projects, particularly the thesis project.

4 Conclusions and final considerations

In the analysis of results we identified that the teachers consider that the PO-PBL curriculum offers an important strategy for the students to develop research abilities and competences, and empowers them to use them in their contexts. Thus, the program encourages their students to improve the rationality of a particular practice by enabling them to refine that reasonableness for themselves (Schwandt, 1996) and the students develop the identity of researchers of their practices, which improves the quality of the education they offer.

The other interesting aspect is that this curriculum decentralizes the teaching of research from some courses and teachers, expanding it to all the actors of the program. This provides more learning opportunities, generates a more consistent program and improves the quality of theses. In addition, this decentralization offers a learning environment which empower the students research about their own practice, so they have the possibility to transform themselves from being field testers to be authentic knowledge producers (Montoya, Castellanos & Fonseca, 2011)

Then again, two challenges were identified: First, the teachers think that the diversity of opportunities shows a poor criterion of the students; hence, there is the need to build this criterion and strengthen autonomy in the students. Second, the teachers cannot help comparing both curriculums and they still miss some elements of the previous one –i.e. writing a more formal thesis draft. This is an invitation to review the object of the courses that are not project-oriented in the current curriculum to achieve a better fit to the entire process and strengthen other skills like the analysis of results.

Finally, this kind of studies clarify the expectations of the teachers regarding the program and show the progress made, giving the chance to make adjustments to strengthen the current curriculum.

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Student evaluation of the flipped classroom instruction method: is it aligned with Problem-Based Learning?

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Abstract

The flipped classroom approach is an instructional method that has gained momentum in the last years. In a flipped classroom the traditional lecture and homework sessions are inverted. We believe that the flipped classroom, which employs computer-based individual instruction outside the classroom and devotes classroom time to group activities with the teacher as facilitator is well justified by the core principles of Problem-Based Learning (PBL) and therefore we applied for two consecutive years the flipped classroom approach to an undergraduate statistics course during a whole semester. This paper presents data from the second year, where we conducted a survey study among students participating in the flipped statistics course. This study consisted of two surveys designed to gather student perceptions on the out-of-classroom preparation material (videos and quizzes) and the flipped classroom in general. The videos were considered by students as providing nice explanations and improving understanding and they were valued for being available at all times and providing the option to watch them on one's own pace. The main challenge with the videos was some production issues. The quizzes were valued for helping with testing, memorizing and applying knowledge, while their main weak points were that they were too short, too easy and they contained in some cases unclear questions. Finally, the main strong points of the flipped classroom approach according to students were that it focuses on self-directed learning and individual learning paths and that one gets help during exercise time. Regarding the weak points, students reported the challenges of students coming to class ill-prepared, or students skipping class, and the amount of time spent on preparation. In the final part of this paper, we discuss the aforementioned results through a PBL perspective and we project them in a PBL context.

Keywords: flipped classroom, online videos and quizzes, student evaluation, mathematics, PBL

Type of contribution: research paper

1 Introduction

The flipped classroom approach is an instructional method that has gained momentum in the last years (Bishop & Verleger, 2013). In a flipped classroom the traditional lecture and homework sessions are inverted. Students are provided with online material in order to gain necessary knowledge before class, while class time is devoted to clarifications and application of this knowledge. The course content, which is provided for self-study, may be delivered in the form of videos and/or pre-class reading and exercises, while class time is mainly used for group work activities. The hypothesis is that there could be deep and creative discussions when the teacher and students physically meet. This teaching and learning approach endeavors to make students owners of their learning trajectories, and relies heavily on current technology.

Various researchers and instructional designers have sought to investigate the advances in flipped learning environments, e.g. (Bergmann & Sams, 2012; Strayer, 2012). According to such studies, students were very

positive about their experience and instructional video components in flipped classrooms and suggested that flipped classroom approach (1) provided them with an engaging learning experience, (2) was effective in helping them learn the content, and (3) increased self-efficacy in their ability to learn independently. While the aforementioned approaches report on benefits of the flipped classroom, there are also critics to this approach (Kellinger, 2012; Nielsen, 2012). Concerns include among others: criticism about the accessibility to online instructional resources, the growing move towards no homework, lack of accountability for students to complete the out-of-class instruction, poor quality video production, and inability to monitor comprehension and provide just-in-time information when needed.

Taking into consideration the reported strengths and weaknesses, we applied for two consecutive years the flipped classroom approach to a university statistics course during a whole semester. During the second year, we conducted two survey studies among students attending this statistics course. In this paper, we report and discuss students' responses in these two surveys regarding learning with online videos and quizzes and the flipped classroom as an instruction method.

2 Background

There have been various attempts to evaluate the flipped classroom and its accompanying online material in educational environments. Tune et al. contacted a study to assess the effectiveness of a traditional lecture-based curriculum compared to a “flipped classroom” curriculum of cardiovascular, respiratory, and renal physiology delivered to first-year graduate students (Tune, Sturek, & Basile, 2013). Students in both courses were provided the same notes and recorded lectures. However, students in the flipped classroom were required to watch the prerecorded lectures before class and then attend class, while attending lectures and watching the prerecorded lectures was optional in the traditional curriculum. In the flipped classroom, students received a quiz or homework covering material in each lecture, while there were no quizzes in the traditional curriculum. The effectiveness and student performance were evaluated by having students in both courses take the same multiple-choice exams and blinded student surveys. The results indicated that students in the flipped course performed better in the final exams and that the use of homework and in-class quizzes were critical motivating factors that likely contributed to the increase in student exam performance.

Love et al. compared a classroom using the traditional lecture format with a flipped classroom during an applied linear algebra course (Love, Hodge, Grandgenett, & Swift, 2014). Students in the flipped classroom environment had a significant increase between the sequential exams compared to the students in the traditional lecture section, but they performed similarly in the final exam. Moreover, the flipped classroom students were very positive about their experience in the course, and particularly appreciated the student collaboration and instructional video components.

Yoon and Sneddon surveyed students on their use of recorded lectures in two large undergraduate mathematics courses (Yoon & Sneddon, 2011). In this survey study, they investigated patterns in student use of recorded lectures and live lecture attendance, how and why they used recorded lectures and how this use was associated with their final grade. The results suggested that the practice of missing live lectures intentionally because the recordings were available was not associated with final grade. However, those respondents who intended to watch more recorded lectures than they actually did achieved significantly lower grades.

Bates and Galloway conducted a practice-based case study of curriculum redesign in a large-enrolment introductory physics course (Bates & Galloway, 2012). The course followed a flipped classroom approach, where lectures were transformed to guided discussion sessions, with focus on peer instruction techniques and discussion facilitated by extensive use of clicker questions. Their results suggest student engagement with pre-class reading and quiz tasks, positive student perceptions of this different instructional format and evidence for high quality learning.

In this paper, we present the results of a survey study that investigated student evaluation of online videos, quizzes, and the flipped classroom approach during a flipped undergraduate statistics course. More precisely, the study aimed at answer the following research questions:

- What are the strong and weak points of online videos and quizzes used in a flipped classroom according to students?
- How do students perceive the flipped instruction approach?

Our hypothesis was that the videos and quizzes would be perceived as contributing to the understanding and self-directed learning by students. In regards to the flipped classroom approach, we hypothesized that it would be perceived as an instruction method that helps students to take responsibility of their learning and improving the learning process.

3 Methods

In the last two years, we have introduced the flipped classroom approach to a statistics course in the fourth semester of the bachelor program in Media Technology at Aalborg University Copenhagen, Denmark. To provide students with instruction outside of the classroom (before the lectures), we created video recordings with the teachers of the course and a list with online resources about the topic of each class. Before classes, students had to study this material and also read suggested parts of the course book. Moreover, students had to submit their answers to short quizzes (multiple choice questions or short exercises) before attending each class. The questions and exercises covered the preparation material. We used these assignments in order to observe student understanding, misconceptions and common mistakes, and in order to motivate students to do their preparation. During class, a question round took place, in order to clarify aspects that students found challenging. Then, students were provided in-class assignments to reflect on, discuss, and practice what they had learned. The classroom activity was mainly not teacher led; instead, students in groups worked on the assignments while the instructor provided individual guidance as needed. The in-class activities were structured so as to provide students with a variation of the tasks they completed when watching the video, providing opportunity for both practice and transfer of learning to new situations. After each class, students had to submit what they did in classroom. This was an obligatory submission. The information exchange between the teacher and the students (i.e. resources for out of classroom preparation, assignments, news forum) and the hand-ins were facilitated by the Moodle VLE system.

During the first year, we conducted two survey studies and two focus group interviews in order to investigate student behaviors and perceptions in the statistics flipped classroom. The data gathered and the conclusions of the first year are reported elsewhere (Triantafyllou, Timcenko, & Busk Kofoed, 2015). These results have informed adjustments on the preparation material (videos and quizzes) for the second year. This paper presents data gathered during the second year, where we conducted two survey studies

among fourth semester students. These survey studies were designed to gather student perceptions on the out-of-classroom preparation material (videos and quizzes) and the flipped classroom in general.

The first online survey asked students if they had watched at least some of the preparation videos and if they had taken at least some of the preparation quizzes. If the answer to any of these questions was positive, the students were provided with two open-ended questions on the strong and weak points of videos and/or quizzes. In case the answer was negative, the students were asked the reasons for not watching the videos and/or taking the quizzes. Finally, there were two open-ended questions on the strong and weak points of the flipped classroom approach in general. This survey was distributed to the students present in class after four classes using the flipped instruction model. We collected responses from 25 (response rate=69.4%) students. The second online survey was distributed to the students present in the last class of the semester (after thirteen flipped classrooms). Eighteen students (response rate=60%) responded in the second survey, which was identical to the first one.

The answers to the open questions were analysed using an inductive approach for qualitative analysis (Miles & Huberman, 1994). During this data analysis, consensus on findings was sought among all authors of this article in order to ensure a deep reflexive analysis and to strengthen the validity of the findings. Furthermore, two of the authors were actively involved in the course, which greatly assisted in interpreting students' answers and experiences. In the following section, we present student responses in the two surveys.

4 Results

4.1 First Survey

In the first survey study, all students (100%) reported that they had watched at least some of the videos before class, while 92% (two students) reported that they had taken at least some of the preparation quizzes. One of the students who did not take any of the quizzes argued that s/he didn't feel prepared enough to take the quiz before class, while the other did not provide any reasons for that.

The student responses concerning the strong and weak points of the online videos are summarized in

Table 1, while the responses on the strong and weak points of the online pre-class quizzes are shown in Table 2. Finally,

Table 3 summarizes the student responses on the strong and weak points of the flipped classroom approach. For building these tables, we have grouped answers with the same meaning but different wording.

4.2 Second Survey

In the second survey study, there was only one student out of eighteen who reported that he neither had watched any video nor had taken any of the quizzes (94.4% had watched at least some videos and taken at least some quizzes). This student argued that he did not have the time so far to study for the course but he would start studying in the coming weeks.

Table 1: 1st survey responses to the questions: "What are the strong/weak points of the videos?" (N=25)

Strong points of videos		Weak points of videos	
Provide nice examples/explanations	28%	Production issues (viewer, readability, language, camera, browse)	36%
Sum up main points well	28%	Should be longer to cover the book/be similar to a lecture	20%
Easy to understand/follow/learn	24%	None	12%
You can pause, rewind	20%	Too long/too slow	12%
Contain slides you can follow	16%	Not engaging/boring	8%
Help understand/memorize the book content	15%	Lectures similar to videos	8%
To the point/clear	12%	Not able to ask questions	8%
Videos and book complement each other	8%	Hard to prepare for class during "free time"	4%
Someone explaining to you	8%	Reading the book/internet is better	4%
Available at all times	8%		
Faster than lectures	4%		
Not as boring as the book	4%		

Table 2: 1st survey responses to the question: "What are the strong/weak points of the quizzes?" (N=23)

Strong points of quizzes		Weak points of quizzes	
Test your knowledge	47.8%	They are too short	21.7%
Re-inforce learning	13%	Too easy	17.4%
Help to memorize knowledge	13%	None	13%
They are short	13%	Formulation of questions	13%
Not hard, not easy	8.7%	I don't know	8.7%
Active thinking	4.3%	They don't always cover the video content	8.7%
Able to apply the knowledge	4.3%	Trick questions	4.3%
Prepare for class	4.3%	Not able to see the previous answer	4.3%
Help to focus on important aspects	4.3%	Not able to see the right answer	4.3%
Not mandatory	4.3%	They are boring	4.3%

Table 3: 1st survey responses to the question: "What are the strong/weak points of the flipped classroom approach (FL)?" (N=25)

Strong points of the FL approach		Weak points of the FL approach	
Get help during exercise time	36%	Challenging if you don't prepare	16%
Deep discussions in class	20%	Too much time on preparation	12%
Preparation and repetition on own tempo	20%	No reason to go to class if you study on your own	8%
Re-enforces learning (learn before, during, after)	20%	None	8%
Motivating/Challenging	20%	Different tempo of solving exercises in class	4%
Focuses on self-directed learning	16%	Self-directed learning is risky	4%
I don't know	8%	I don't like it/don't learn that way	4%
No repetitions in class	4%	Repetitions during class time	4%
Application of knowledge	4%	Lectures sometimes not well-structured	4%
		Difficult to catch up with exercises if you miss a lecture	4%
		I don't know	4%

The student responses in the second survey concerning the strong and weak points of the online videos are summarized in Table 4, while the responses on the strong and weak points of the online pre-class quizzes are shown in Table 5. Finally, Table 6 summarizes the student responses on the strong and weak points of the flipped classroom approach.

Table 4: 2nd survey responses to the questions: "What are the strong/weak points of the videos?" (N=17)

Strong points of videos		Weak points of videos	
You can pause, rewind	35.3%	Not able to ask questions	29.4%
Easy to understand/follow/learn	29.4%	Production issues (viewer, readability, language, camera)	17.6%
Provide nice examples/explanations	23.5%	Too long/too slow	17.6%
Available at all times	17.6%	Similar to book	17.6%
Sum up main points well	11.8%	None	11.8%
Contain slides you can follow	11.8%	Do not cover everything in the book	11.8%
To the point/clear	11.8%	Not concise	5.9%
Help understand/memorize the book content	5.9%	Book/internet is better	5.9%

Table 5: 2nd survey responses to the question: "What are the strong/weak points of the quizzes?" (N=17)

Strong points of quizzes		Weak points of quizzes	
Test your knowledge	64.7%	They are too short	17.6%
Re-inforce learning	17.6%	I don't know	17.6%
Able to apply the knowledge	11.8%	Formulation of questions	17.6%
I don't know	5.9%	Can get good grades by trial & error	11.8%
Active thinking	5.9%	None	11.8%
None	5.9%	Hints not very helpful	5.9%
Help to memorize knowledge	5.9%	Not able to see the previous answer	5.9%
They are short	5.9%	Not available before next lecture	5.9%
Prepare for class	5.9%	Overwhelming amount of questions	5.9%
		They were not discussed during lectures	5.9%
		Cover material not included in videos	5.9%

5 Discussion

Based on the results presented in the previous section, we can argue that the majority of the students watched at least part of the videos and took at least some of the online preparation quizzes. Compared to our previous studies on the flipped classroom, these percentages are relatively high. This fact can be partly attributed to stricter admission rules imposed at the Media Technology program one year ago and partly to the improvement of the flipped course design, since this was the second iteration.

Regarding the strong points of the online videos, the same topics appeared in both surveys. The most recurrent topics were that videos provide nice examples and explanations, they sum up main points well, and they are easy to understand, follow, and learn with. Moreover, students included as a strong point the option to pause and rewind a video as many times as needed. Regarding the weak points, there were also similarities in student responses between the two surveys. The weak points mentioned as dominant in both surveys were various production issues (problems with the viewer, readability of the slides used in the videos, language issues and the camera position) and the videos being either too long or too slow. However, in the first survey students also mentioned that the videos should be longer in order to look like a video-recorded lecture. In both surveys, about 12% of students mentioned that the videos had no weak points. Finally, although the fact that students were not able to ask questions while watching the videos was the most popular weak point in the second survey and it has been also mentioned in our previous studies on learning with online videos, only 8% of the students mentioned it in the first survey.

As far as the strong points of the online quizzes are concerned, the most popular aspects among responses in both surveys were that the quizzes help to test student knowledge and to apply and memorize knowledge. Moreover, the students mentioned that they re-inforce learning. One student mentioned as a strong point that the quizzes were not mandatory, which was not true. We hypothesize that this was due to the student's misunderstanding. Regarding the weak points of the quizzes, students mentioned in both surveys that they were too short, too easy and the formulation of the questions in the quizzes was sometimes confusing. In both surveys, about 12% of the students reported that there were no weak points in the quizzes.

Table 6: 2nd survey responses to the question: "What are the strong/weak points of the flipped classroom approach (FL)?" (N=18)

Strong points of the FL approach		Weak points of the FL approach	
Apply knowledge in practice	38.9%	No explanation round in class	33.3%
Get help during exercise time	33.3%	None	16.7%
Online videos helpful	27.8%	Challenging if you don't prepare	11.1%
Re-enforces learning	11.1%	Self-directed learning is risky	11.1%
Follow without being present in class	11.1%	Communication problems	11.1%
Motivating/Challenging	5.6%	Same as lectures	11.1%
Preparation & repetition on own tempo	5.6%	Too much time on preparation	5.6%
Focus during lectures because of prior preparation	5.6%	No reason to go to class if you study on your own	5.6%
		I don't like it/don't learn that way	5.6%
		Too much time on recapitulation	5.6%

In both surveys, students were asked about the strong and weak points of the flipped classroom approach. As strong points, the possibility to get help during exercise time, and the ability to provide individual learning paths and re-inforce learning were popular topics present in both surveys. In the first survey, students also mentioned that they valued the fact that this approach focuses on self-directed learning, and that deep discussions were taking place in class. In the second survey, these aspects were not mentioned. One of the main advantages of the flipped classroom, which is that one can follow the course without being present in class, was only mentioned in the second survey. Regarding the weak points of the flipped classroom approach, the main points included the challenges of students coming to class ill-prepared, or students skipping class, and the amount of time spent on preparation. However, the most popular weak point according to student responses in the second survey was the lack of an explanation round in class. This is a point worth investigating with the teachers of the course, since the course design included an explanation round at the beginning of each class. However, this point is mainly connected to the specific implementation of the flipped classroom approach and not the flipped classroom in general. Finally, 8% and 16.7% of the students participating in the first and the second survey respectively mentioned that there are no weak points in the flipped classroom approach.

6 Projection on a PBL context

In the literature, there have been used various theoretical frameworks to justify the flipped classroom and support the design of in- and out-of-class activities. Such theoretical frameworks typically argue for the benefits of student-centred and collaborative learning (e.g. active learning, problem-based learning, peer-assisted learning) (Bishop & Verleger, 2013). Throughout our research, we are inspired and guided by the Problem-Based Learning (PBL) pedagogy, which is applied at Aalborg University since its establishment in 1974 (Barge, 2010). PBL is a student-centered instructional approach, in which learning begins with a problem to be solved. Students need to acquire new knowledge in order to solve the problem and therefore they learn both problem-solving skills and domain knowledge. 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." (Hmelo-Silver, 2004). The results presented in this paper show that the flipped classroom is well aligned with the PBL core principles, since students reported that this instructional approach contributes to self-directed learning and increased motivation (Table 3). Moreover, students favoured quizzes for contributing to applying knowledge in the context and for helping them in problem solving.

At Aalborg University, PBL is also combined with group work (Kolmos, 1996). While working in groups, students try to resolve the problem by defining what they need to know and how they will acquire this knowledge. This procedure fosters the development of communication, collaboration, and self-directed learning skills. Moreover, group work in PBL may enable students to experience a simulated real world working and professional environment, which involves process and communication problems and even conflicts, which all need to be resolved to achieve the desired outcome. The students, who participated in our survey study, were asked to work in groups during in-class activities but not all of them followed this instruction. We thought that this would come naturally to students, since they were already divided in groups for working in their semester projects, but this was not the case for everyone. We believe that the classroom setting did not help to this direction, since the in-class activities took place in a traditional lecture room. Moreover, not all students were present in the in-class sessions, so there were students without their group members.

Finally, PBL represents a paradigm shift from the traditional one way instructional methods. In PBL, the teacher is not an instructor but rather a tutor, who guides, supports, and facilitates the learning process. The tutor has to encourage the students and increasing their understanding during the problem-solving process. Therefore, the PBL teacher facilitates and challenges the learning process rather than strictly transmitting domain knowledge. The flipped classroom that employs computer-based individual instruction outside the classroom and devotes classroom time to group activities with the teacher as facilitator is well aligned with the teacher's role in PBL. The goal of a flipped classroom is to let the student study individually at her own pace while providing the appropriate support material for out-of-classroom instruction and then come into class, where groups of students engage in group activities facilitated by the teacher. The student responses have also underlined these aspects of the flipped classroom (Table 3 and 6).

7 Conclusion

This paper presented data from the second year of a flipped statistics course implementation, where we conducted a survey study among students participating in this course. This survey study consisted of two surveys designed to gather student perceptions on the out-of-classroom preparation material (videos and quizzes) and the flipped classroom in general. In general, the student responses in both surveys express positive feelings about the flipped classroom approach and the preparation material used in this flipped course. Moreover, we observed that the same topics in both strong and weak points of videos, quizzes, and the flipped classroom appeared in both surveys. The videos were considered by students as providing nice explanations and improving understanding and they were valued for being available at all times and providing the option to watch them on one's own pace. The main challenge with the videos was some production issues. The quizzes were valued for helping with testing, memorizing and applying knowledge, while their main weak points were that they were too short, too easy and they contained in some cases unclear questions. Finally, the main strong points of the flipped classroom approach according to students were that it focuses on self-directed learning and individual learning paths and that one gets help during exercise time. Regarding the weak points, students reported the challenges of students coming to class ill-

prepared, or students skipping class, and the amount of time spent on preparation. These results showed that the flipped classroom approach is well-aligned with the PBL principles and can be used to enhance learning in PBL context. We believe that the results of this study may be used to inform future designs and implementations of the flipped classroom approach, and especially the production of preparation material. However, more research involving larger student population is required in order to be able to generalize the results of this study for other contexts.

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Exploring experiential learning environments: mechatronic laboratory as case of study

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Abstract

It is becoming increasingly difficult to ignore that nowadays employers need workers who are more highly skilled and more multi-skilled than in the past. The technological skills are not enough if an organization wants to respond effectively and speedily to changes in its environment. Softer skills such creativity, the ability to take initiatives, to solve problems, to identify where improvements can be made and others are also needed.

Many educational institutions offer experiential education programs such as internships or fields projects, others offer classroom experiential learning exercises to add a direct experience component to their traditional academics studies. Pascual Bravo University Institution is one of these. There has been a need for educational methods that can translate the abstract ideas of the academia into concrete practical reality and in the recent years. There has been an increasing interest in PBL as one of the most use experiential educations methodologies that can combine to know what, to know who and soft skills development.

It was decided that the best method to adopt was to implement laboratories of practice and research. One of these laboratories was a mechatronics providing learning environments and spaces in which students can exercise and improve their understanding of the theory and the judgments they make should enable them to produce consistently better solutions to problems that the projects can present, this entire conjunction whit a PBL didactics.

For the purpose of measurement which soft skills were develop 13 of the students assess to a questionnaire based on team work, communication, time management, creativity and innovation, scientific rigor, interpersonal relationship and decision making that they can make during the project execution in the mechatronics laboratory. This questionnaire has found that generally to combine PBL and learning spaces can revitalize the university curriculum and cope whit many of the changes facing higher education today.

Keywords: Experiential learning, soft skills, PBL, Co-curricular activities

Type of contribution: best practice paper.

1 Introduction

Educational institutions offer experiential education programs such as internships or fields projects. Others offer classroom experiential learning exercises to add a direct experience component to their traditional academics studies. Pascual Bravo University Institution is one of these. There has been a need for educational methods that can translate the abstract ideas of the academia into concrete practical reality and in the recent years. There has been an increasing interest in Projects based learning (PBL) as one of the most use experiential educations methodologies that can combine to know what, to know who and soft skills development.

In order a mechatronic laboratory has been refurbish as a place for experiential learning and a place for use the PBL methodology. Even believing that virtual learning spaces will become increasingly important It is clear that physical learning spaces are needed (Bennett, 2007) .Students and faculty, experience building design at a personal level. They interact directly with the chairs and tables, look for convenient power outlets to connect their laptops, and view a projected image from a particular location in a classroom. (Milne, 2007).
The emergence of new kinds of learning spaces makes it necessary to enlarge our concept of support of learning spaces by at least one more layer like support for faculty and students outside the classroom. As ambitions for teaching and learning expand, so too do the complexities of the projects that both faculty and students take on (Brown & Long, 2006). Is known that more time students spend preparing for class, working on campus, and participating in co-curricular activities, the more they report themselves as engaged in deep learning behaviors(Bennett, 2007).

The laboratory was design in a way that the teaching presence, the social presence and cognitive presence could be match and create an educational experience for the student and the community of inquire in general (Figure 1) even out from class time .

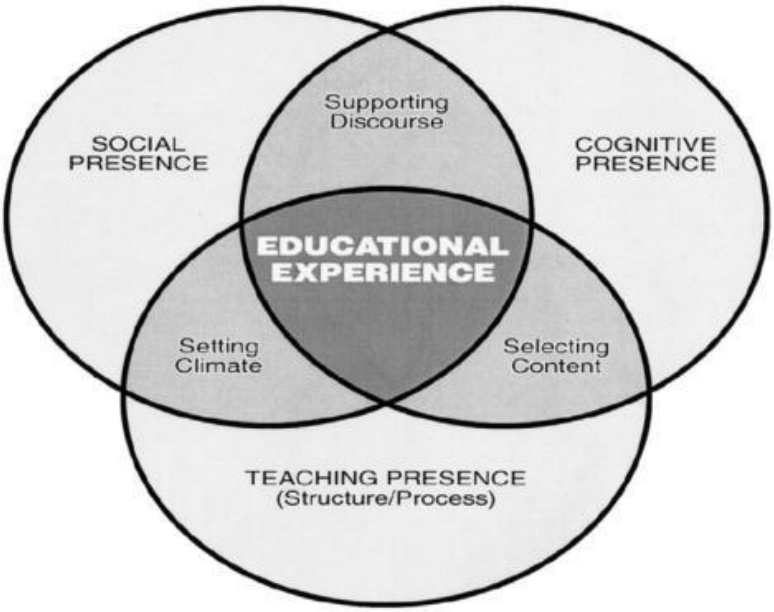

Figure 1: Tree presences in a community of inquiry (Yang, 2016)

1.1 The mechatronic laboratory

The mechatronic laboratory is used by students, professors and researchers. This laboratory incorporates spaces where is able to work different disciplines like mechanics, electronic, automation, control and design. At the mechatronic laboratory technology is natural. Computer and networking technologies that once might have appeared exotic (pervasive wireless networking, iPods, smart phones) or transformative are now considered mainstream. The technical infrastructure that supports campus and laboratories services includes networking hardware, server systems, and software packages. The laboratory space continues to evolve with the advent of voice over IP (VoIP), wireless networking, and emerging technologies.

The laboratory has place for leisure activities but is a time when the students, professors and researchers can interact and meet in an informal way allowing a social and collaborative learning. In another hand the elements and implements that exists at the laboratory let people from any level of knowledge use them (see Figure 2).

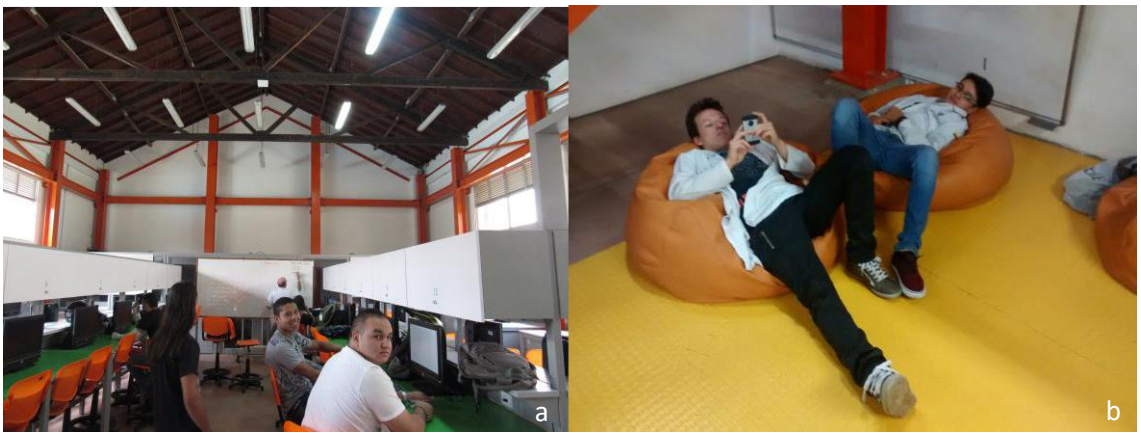

Figure 2: Spaces in mechatronic laboratory. 2a Students in collaborative activities. 2b Leisure place in the laboratory

2 Methodology

2.1 Experiential learning and the PBL

As universities have move into open enrollment program and expand educational opportunities for the poor and minorities, there has been a corresponding need for education methodologies that translate the ideas of the academy into concrete practical realities. According to (Kolb, 2014) in the field of higher education there is a growing group of educators, faculty and administrators who see experiential education as a way to revitalize the university curriculum. In that order faculty recognize a need to provide experiential learning opportunities into their courses and programs to make learning more relevant for their students (Cantor, 1997).

On another hand is the PBL that allows teaching activity emphasize learning, by doing and hands-on problem solving. Students should be encouraged to analyze, interpret and predict information and be supported to foster new understandings based on past experiences (Kolmos, Jensen, Du, & Holgaard, 2008) in that way projects have the potential to enhance deep understanding because student need to acquire and apply information, concepts and principles, and they have the potential to improve competence in thinking because students need to formulate plans, track progress and evaluate solutions (Blumenfeld et al., 1991).

Experiential learning activities include cooperative education placements, practicum experiences, and classroom-based hands-on laboratory activities (Cantor, 1997), this activities match whit the PBL projects methodology, and like the population of students in the Pascual Bravo University Institution are both full-time and part-time students and knowing the PBL as one of the most use experiential educations methodologies the students can combine to know what, to know who and soft skills development.

For reach the PBL goal the nine-step problem design process shown by (Hung, Jonassen, & Liu, 2008) is used at the mechatronic laboratory work let to operationalize the conceptual framework into a step-by-step process: Step 1. Set goals and objectives. Step 2. Conduct content/task analysis. Step 3. Analyze context specification. Step 4. Select/generate PBL problem. Step 5. Conduct PBL problem affordance analysis. Step 6. Conduct correspondence analysis. Step 7. Conduct calibration processes. Step 8. Construct reflection component. Step 9. Examine inter-supporting relationships of 3C3R components (the 3C3R model can be seen in Figure 3). All this in conjunction whit the experiential learning model according (Miettnen, 2000) that was develop by Kolb in 1984 (Figure 4).

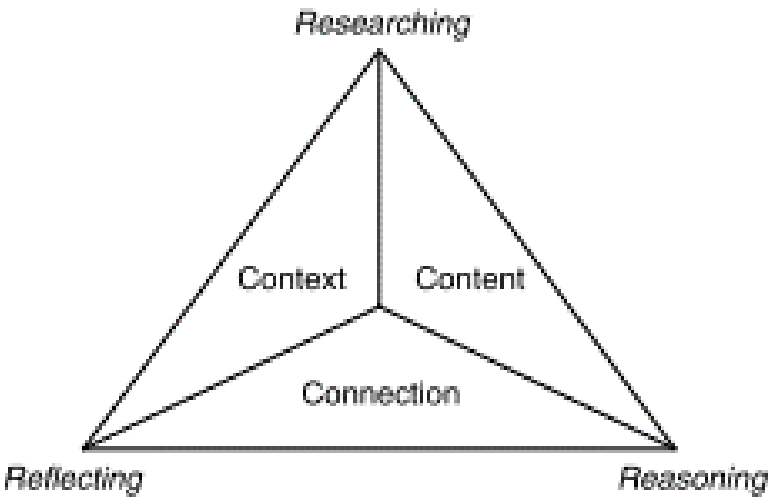

Figure 3 The 3C3R project-based learning problem design model (Hung et al., 2008).

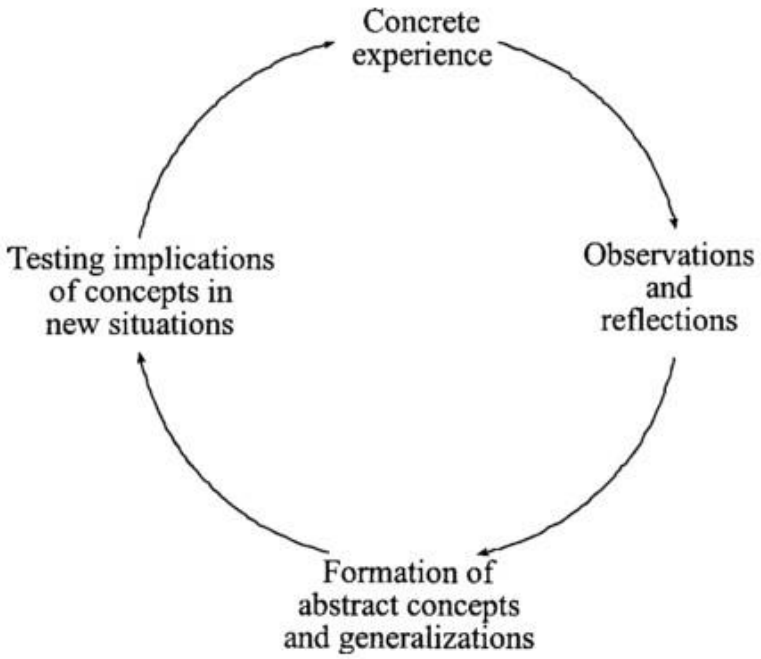

Figure 4 Experiential learning model (Miettnen, 2000)

Also college educators find experiential learning a valuable adjunct to traditional instruction in these disciplines (Cantor, 1997). The experiences outside of the classroom especially the hands on laboratory work provide the increasingly growing numbers of non-traditional learners with valuable opportunities to apply theory to practice and letting full-time and part-time students acquire a significant impact on learning outcomes. Another aspect is the character of collaborative learning is likely to be different in physical and virtual spaces. Successful collaboration is of course possible in both environments, but in physical space the sensory environment (say of body language) is richer, and personal negotiations are more direct and not complicated by mediating technology.(Bennett, 2007) enabling boost the soft skills.

Based on the 3C3R model the PBL in mechatronic projects the steps by steps process is as follows 1. Problem definition based on concrete experience, 2. Problem analysis, 3. Project theoretical design, 4. Simulation if is needed 5. Implementation and monitoring performance, 6 Presentation of the project 7. Synthesis of the project as an article in IEEE format, attaching the necessary documents and schemas, 8. Overall assessment and 9. General feedback.

As example the classification of animal species through an aerial device unmanned is shown. The topics developed are related to everyday aspects in our environment, in the case of classification of animal species through an unmanned aerial device. The projects intended to address a constant problem in the livestock environments and monitoring and control of livestock on large tracts of land requires high costs in time and skilled labor. Use the library of the institution, books, magazines, databases, etc. to obtain information on each stage of the analytical process associated with the problem. Then the methodology and the time to solve the problem in the schedule of activities are presented, both keys for project management and tutorial planning defining early goals as each of the stages of the methodology. Also the evaluation was defined in this case as the delivery of an algorithm that allows to establish the amount of cattle in a certain area and its approximate location in the field.

This project showed that with proper planning of activities, allocation of roles, and a mentoring program students can incorporate new knowledge.

2.2 Participants

The study included a convenience sample size of thirteen participants that were enrolled in the laboratory work along the semester 2016-2 between the ages of 16 to 55 years, male and female, inclusive of both full-time and part-time students.

3 Results

As a test from appropriation of knowledge using experiential learning and PBL thirteen students answered a questionnaire about the soft skills development in the laboratory work and the scientific rigor that their projects could arise, reply in a scale from 1 to 4 for each question.

Question 1. Considers that the laboratory work encourages teamwork?

The results from question 1 is shown in Figure 5

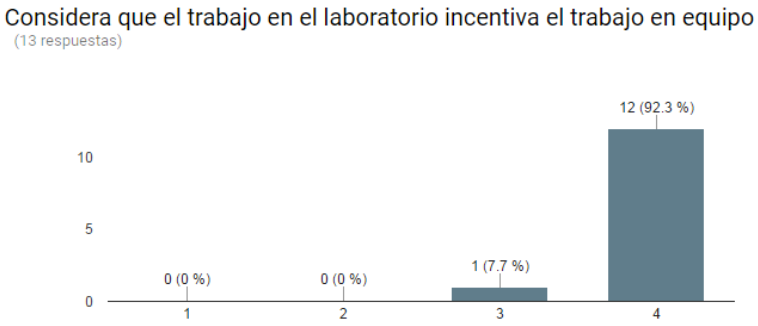

Figure 5 Results from question 1

Question 2. Considers that the laboratory work encourages communication?

The results from question 2 is shown in Figure 6

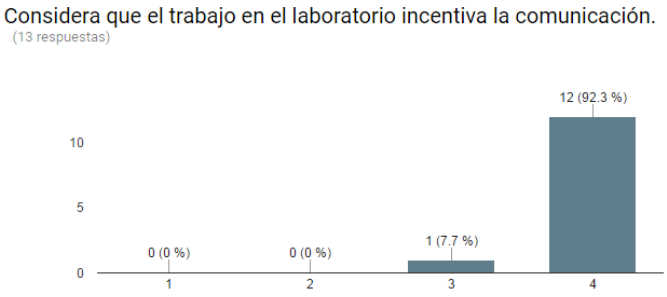

Figure 6 Results from question 2

Question 3. Considers that laboratory work assists time management?

The results from question 3 is shown in Figure 7

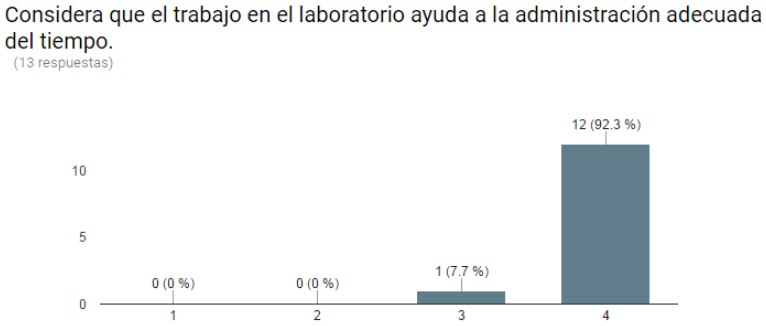

Figure 7 Results from question 3

Question 4. Considers that laboratory work collaborates with the development of creativity and innovation?

The results from question 4 is shown in Figure 8

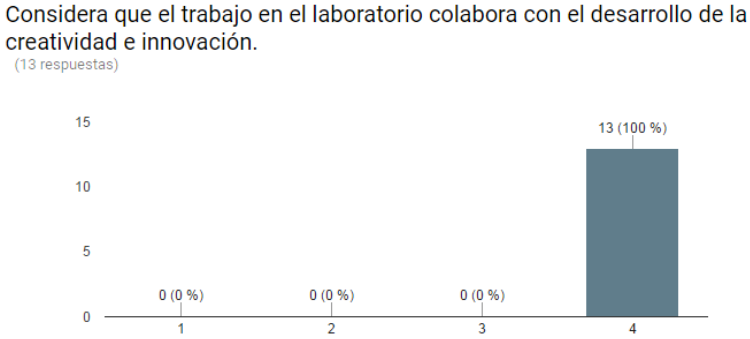

Figure 8 Results from question 4

Question 5. Considers that laboratory work encourages scientific rigor in the development of projects?

The results from question 5 is shown in Figure 9

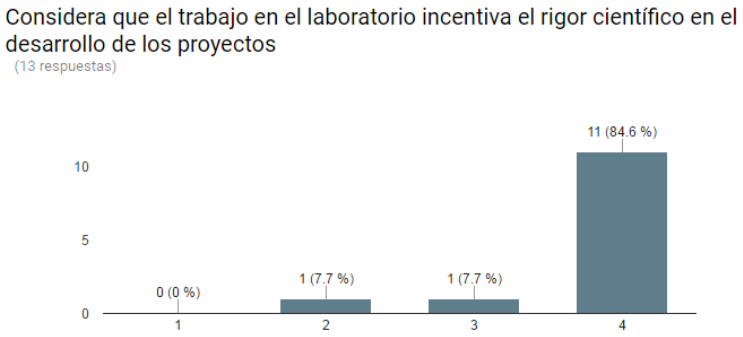

Figure 9 Results from question 5

Question 6. Considers that laboratory work helps improve interpersonal relationships with peers, teachers, and lab monitors?

The results from question 6 is shown in Figure 10

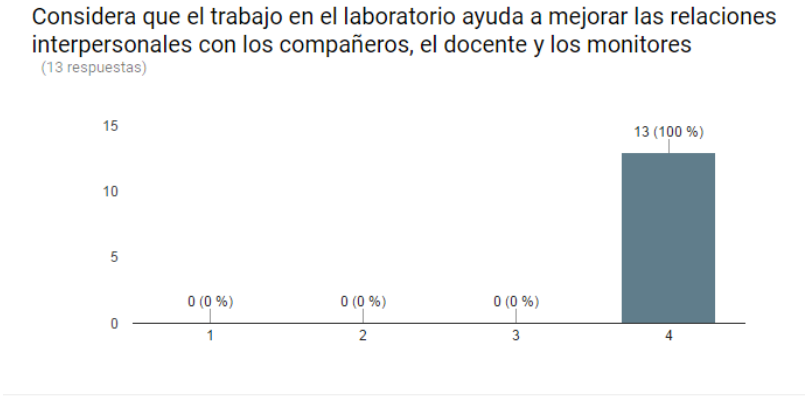

Figure 10 Results from question 6

Question 7. Considers that laboratory work encourages decision-making?

The results from question 7 is shown in Figure 11

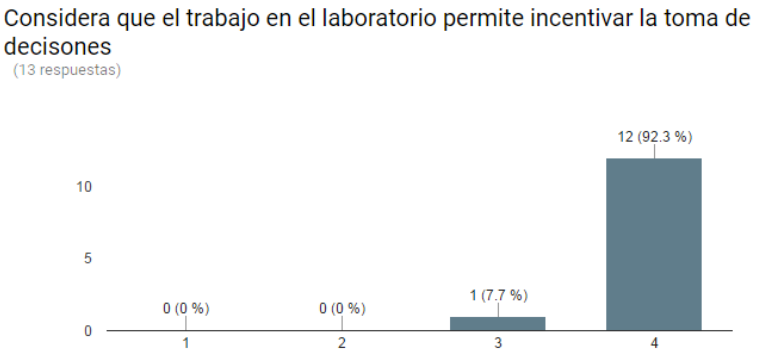

Figure 11 Results from question 7

As the Figures from 4 to 10, 92.3% answered that always can encourage the team work, the same percentage answered that the communications skills were increased, 100% used the creativity and innovation for solution the project, 7.7% think that the scientific rigor could be perfected and 100% got better personal interpersonal relationship, finally 92.3% considers that his ability to decision making is increased.

The projects develop skills for interpersonal relationships, stimulating the sense of collaboration, group dynamics work, and preparation of written report of experimental work and oral presentations promoting synthesis, leadership and Empathy throughout the process. Improvement of the teaching-learning quality through the integration of technologies, in this case identification of livestock by means of an unmanned aerial vehicle (Dron, Figure 12) which, using a camera and an artificial vision algorithm implemented in the

software MATLAB® (Figure 13) can establish the amount of cattle in a given area and its approximate location in the field (Figure 14) .

Figure 12 Quadricopter with which the project of classification of animal species was developed through an unmanned aerial device

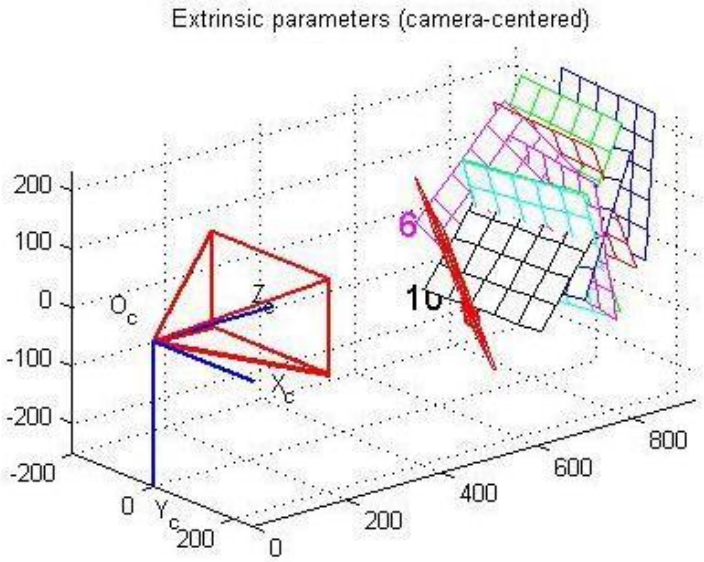

Figure 13 Extrinsic characteristics parameters of the camera

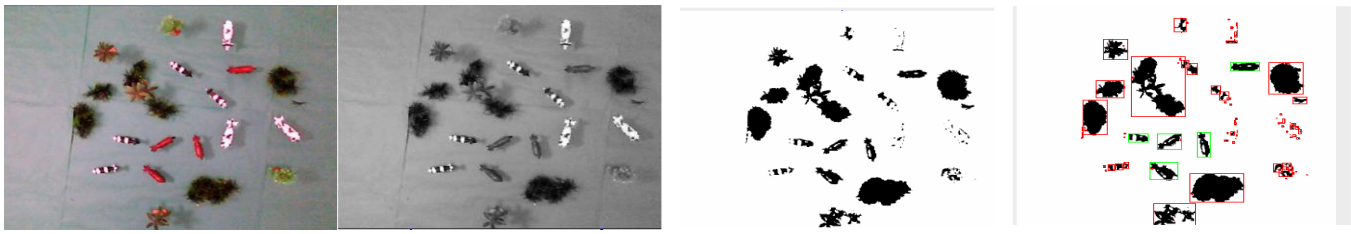

Figure 14 Results of the artificial vision algorithm.

4 Conclusions

Combine PBL and learning spaces can revitalize the university curriculum and cope whit many of the changes facing higher education today one of these the need to provide college students with opportunities to reinforce social and ethical values.

An on-campus social learning environment like the mechatronic laboratory offers exposure to multiple communities of scholars and practices, giving students broad access to people from different fields, backgrounds, and expectations, as well as opportunities for intensive study, all of which combine to form a creative tension that spawns new ideas, perspectives, and knowledge.

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Good practices learned from designing a more interactive project based visual analytics course

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Abstract

In the hyperconnected world that we live in, attention spans are constantly shrinking, and young students can't keep their engagement for more than 144 characters at a time. This distractful world presents a major challenge for university teaching, even more if the classes include complex topics such as computer programming. Computer enhanced classrooms that were created to better support students, can be actually detrimental for remembering when instructors are poorly trained (Klemm, 2007). However, even with highly trained professors, traditional methods seem insufficient for teaching dynamic topics like visual analytics that rely heavily on the production of interactive and web-based visualizations. This paper presents four good practices (GP) for teaching complex technological concepts such as Visual Analytics: GP1 Mixed (theory+application) classes, GP2 Web-based and modifiable slides that allow self pacing, GP3 Public visibility and open standards and GP4 Iterative problem-based feedback through different rythms. These best practices were acquired as a result of a three years collaboration the University of Los Andes (Colombia) and the University of Kaiserslautern (Germany) and although they aren't novel on their own (e.g. Albinson, 2016), used together they generated positive results when applied to a Visual Analytics course, as suggested by a post class survey.

Keywords: Project based learning in computing, Visual Analytics Course, Interactive web-based slides

Type of contribution: best practice paper.

1 Introduction

The challenges to design and execute advanced classes such as visual analytics are diverse and complex. Among others, the need for interactive analysis of data, the dynamic evolution of tools, and the high dynamic environment of this young discipline, creates an interesting playground for putting together international collaborations to tackle these challenges. In this paper we present four good practices produced as a result of an international collaboration aimed to explore better ways of teaching complex topics such as Visual Analytics. After three years of iterating different courses in the topics of Visual Computing and Visual Analytics, we present four good practices that applied together in our last course generated positive effects on our students as evidenced by our post-class survey. We believe that these good practices (GP) could be of use to the community, and therefore we report them extensively on this paper. Namely the good practices are:

- GP1 Mixed Sessions design that includes: one block of theory concepts presented as mini blocks of theory and practice, and one block of lab practice
- GP2 Web-based and interactive Class materials that allow for self-pacing during class.
- GP3 Web visibility, using open source philosophies, projects exposure and complete online availability of the resources.
- GP4 Iterative feedback loops, with different timings

These good practices were produced as one of the results of an international collaboration between two teams (one in Colombia, one in Germany) who worked together for three years putting competences and experiences. One of the objectives of this collaboration was to consolidate a common visual analytics course that incorporated the best practices of both teams, and which could be replicated on each institution. Moreover, this course was designed to enhance the added value of live sessions, and to integrate new hands-on techniques to increase the engagement and consequently foster the learning environment. The result of this process is a project based course (Bell 2010) with interactive sessions based on interactive web-tools applied to session subject, and web visibility for results of student team's process and results. This paper presents four good practices characterized from this consolidated course as a proposal for the community to reuse and build upon them.

A timeline of this collaboration outlining the courses imparted and the partial incorporation of each one of the good practices can be found on Figure 1.

Figure 1 Timeline of classes and activities

The Course website can be viewed in http://johnguerra.co/classes/isis_4822_fall_2016/, where the contents and tools can be visited. The projects can be visited too in http://johnguerra.co/classes/isis_4822_fall_2016/projects.html.

The rest of this paper is organized as follows. First we describe the related work and some of the characteristics of the international collaboration that gave birth to this project. Then the set of four best practices is presented, with details of their implications. Right after that, the results of a students' survey are presented and analysed. Finally we present the conclusions and acknowledgements

2 Related Work and Collaboration Process

The international collaboration supported by the German Exchange Academic Service (DAAD) aims to define a common Visual Computing curriculum for Master of Science level.

The course "*Introduction to Visual Analytics"* was selected as a use case for this collaborative building process. Our own previous experience was built on Colin Ware course and textbook (Ware 2010), Chris North contributions (Endert et Al. 2014), and Robert Spence book (Spence 2006).

Many efforts have been done in order to deliver more quality learning spaces in computing (Albinson, 2016) (Anslow 2015). The specific experiences in visual analytics referenced in the bibliography (Elmquivst 2012, Endert 2014, Keim 2010) provide general guidelines to build a common framework for the development of our proposal. Likewise, other international collaboration experiences show us some guidelines in order to get value of our experience (Chidanandan 2010)

The main concerns after a review of existent courses, including our courses, were:

- Low students' participation in-person sessions, and low level of engagement in the projects.
- Low ability to efficiently transition between the understanding of visual analytics challenges to hands-on and applied results. Low visibility of students' work.

To enhance the quality of our learning spaces in the graduate programs, we defined a road map to advance towards this goal:

1- First, the design and implementation in Colombia of a 2014 summer school international course (3 weeks - 45 hours) using the feedback and experience of our German partners.
2- From this experience as well as contributions based on previous Colombian experience, a second version of the course was defined and held in parallel in both Universities. One year later, a second iteration of the summer course was held with the active participation of two teams. The project-based structure was adopted and two training workshop projects and a team mini-project inspired on the IEEE VAST challenges (IEEEVIS 2017), were defined as part of the course activities.
3- We applied the new structure to a new course on scientific computing and visualization with very encouraging results (from the students' point of view).
   The current version of the Visual Analytics course (15 weeks, 45 hours), held in Fall 2016 in Colombia, includes web-live tools in the course sessions in order to have a more dynamical live sessions. The course evolves towards project-based learning and active learning sessions (briefing about the theory and hands-on activities based on web interactive visualizations with programming code manipulation challenges on the examples). We decided to introduce as textbook Tamara Munzner's book (Munzner 2014) to follow her proposed structure for the design of interactive visualizations "Why-What-How", which we find very close to our working method.

In the next section we present the four good practices that we learned from designing and executing the Visual Analytics course, which we think could be of benefit for the community.

3 Good practices for teaching an advanced computing course.

To improve on students' class immersion and provide better learning tools for our Visual Analytics course, we applied and crafted a series of four good practices for teaching an advanced computing course. These practices came as a result of a three years long international cooperation between "University of Los Andes (Colombia) and the University of Kaiserslautern (Germany). Each of these practices is probably not novel on its own, however considering the positive feedback that we obtained from our students we believe that there is value on applying them as a combined strategy. In this section we present those four practices in detail, and explain some of their implications in the class.

3.1 GP1: Mixed (theory + application) classes

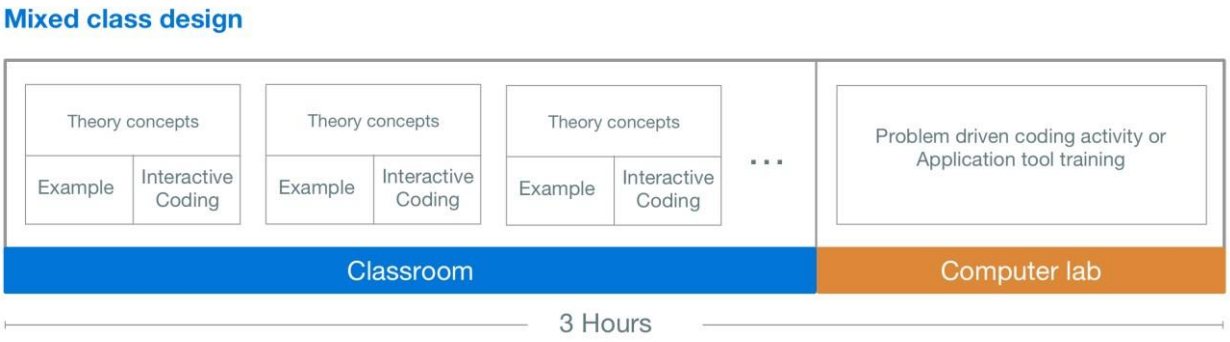

Figure 2 GP1 Mixed class design structure

The first good practice extracted from our experience was the design of our class sessions. We used a mixed approach that split the three hours session into two blocks, one main one in the classroom and the second one in the computer lab. This allowed students to first learn the concepts during the first part and then to reinforce their learnings during the laboratory session solving problem-based code activities, and learning real world tools usage. For both parts of the class, students were encouraged to discussed and collaborate among peers, but would work individually (on their own laptops in the classroom and using university lab's computers for the practice section). Moreover, during the first session in the classroom, students were faced with small blocks of a theory concept immediately followed by an example that could be code or non-code based. During these small blocks students were encouraged to discuss their implications (i.e. weaknesses and strengths) for the non-code based, and they were stimulated to modify the code and create new modified and publicly available examples for the other ones. This type of interaction generated a fruitful class environment, were students constantly presented new examples that were shared using a Slack backchannel during class. Figure 2 illustrates an example of how the class sessions were divided in a mixed structure.

Visual Analytics, as many others advanced computing concepts, is a concept that is learned better by practicing. However, a typical Visual Analytics or Information Visualization course can easily end up being a constant display of endless examples of visualization techniques, without time for interiorizing their strengths and weaknesses, left alone to learn how to code them. Based on our experience with this collaboration, we designed the course sessions to use a mixed (classroom + lab activity) approach that encouraged the constant interaction with coding examples. Moreover, given that the class slides were accessible during class on an interactive web page that allowed interaction and modification of the code examples, students were encouraged to modify the code and create their own adjusted examples. We describe the structure of the interactive and modifiable slides in Section 3.2.

It is important to note that the class duration (three hours) and weekly schedule (Tuesdays at 18:00) presented a limitation that was beyond our control. Given this restriction, we believe that the mixed class design helped students staying engaged and motivated. Moreover, by using the small theory + example blocks during the classroom sessions, we presented students with a more hands on approach that in our

opinion encouraged them to ponder on the strengths and weaknesses of each concept for the non-coding examples, or to better understand how to build them on the coding examples.

We don't claim that this mixed approach is novel, or that it was created by us. However, it was a useful technique to keep students engaged, to increase interaction, and a good solution for our long three hours sessions. Furthermore, the short concepts given during the classroom sessions that included theory + examples (code or non-code based), seems to be a good addition to the mixed approach that could be beneficial to the teaching community.

3.2 GP2 Web-based and modifiable slides that allow self pacing

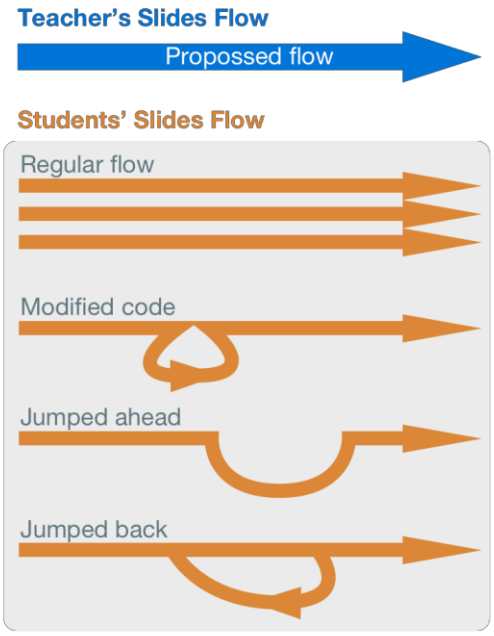

Figure 3 Students' slides flow

The second good practice identified learned from this project was to use web-based slides, which students could follow along or at their own pace, and which included interactive and modifiable code examples. A more basic version of this type of web-based slides has been proved beneficial in the past (Albinson, 2016), we improved upon this work by including interactive and easily modifiable code examples using Blockbuilder (Johnson, 2016).

D^3 (Bostock, 2011) is one of the most used libraries for creating interactive information visualizations for web. It is a standard the facto not only for creating visual analytics, but also for teaching it. One of its success could be attributed to the creation of bl.ocks.org (Bostock, 2010), a repository of visualization examples created from wrapping Gists (i.e. code examples published on the Github platform). bl.ocks.org contains thousands of examples that can be easily used as a boilerplate for creating new visualizations. Despite this, creating new bl.ocks (i.e. new examples in the platform) was a complicated procedure. To address this, Ian Johnson started a crowdfunding campaign to create a new platform called blockbuilder (Johnson, 2015) that allows developers to create and modify blocks directly in the browser. During our class we leveraged these two tools and displayed most of our examples embedding them on the web slides using blockbuilder. By doing this, we allowed students not only to see a running, interactive example on their

computers and mobile examples, but also to modify these examples and fork them, creating new bl.ocks with their modifications that were stored in their individual bl.ocks pages, and were therefore available to the general public as well.

Students could reference the slides later to find examples to use in their own projects. Further examples were proposed by students and the professor whenever a class discussion leaned towards a topic not discussed in the slides. For example, when discussing treemaps as a visualization technique, students asked for other real world applications of the technique and the instructor shared the example of the map of the market (FinViz, 2007) that uses treemaps to compare stock prices changes. Slack was used as backchannel to distribute these examples during class. Given the history and storage capabilities of the messaging tool, students could search back when they needed to find them.

The slides were created using Reveal.js (El Hattab, 2011) and were shared publicly both in the class homepage, and as source code on Github. Being on Github anyone can reuse these materials and build upon them. For the theory concepts, the slides built heavily on the materials published by Tamara Munzner (the author of the guide book) on her website. These materials are made available on PDF format, and because of that they had to be transformed as images to be used on the web slides. Moreover, the static examples on the slides were replaced with the aforementioned interactive and modifiable ones. Furthermore, new examples and topics were included on the slides too to demonstrate new techniques, illustrate more current examples or simply to enrich the materials provided by Tamara. Figure 4 and Figure 5 show examples of the slides used during class, the first one for the theory concept and the second one for the interactive and modifiable example.

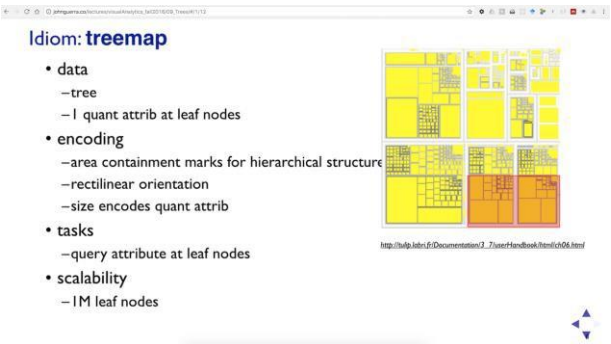

Figure 4 Slides theory example, based on Tamara slides. Available at

http://johnguerra.co/lectures/visualAnalytics_fall2016/09_Trees/#/1/12

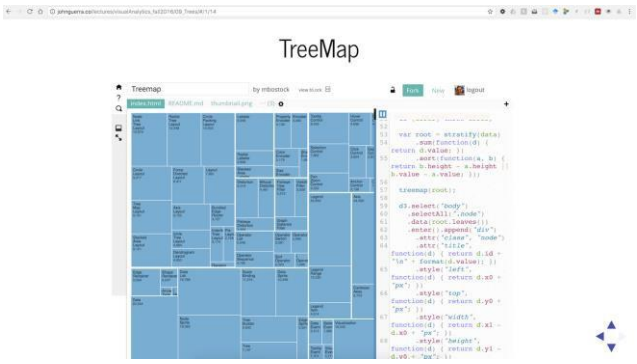

Figure 5 Slides interactive and modifiable demo example. Available at

http://johnguerra.co/lectures/visualAnalytics_fall2016/09_Trees/#/1/14

The concept of using web-based slides is not novel per se; however, we consider that the combination of the web slides with the blockbuilder examples can be new. More importantly, the class materials proved to be useful for engaging students during class. Furthermore, they seem to have helped students understand how the examples where built and could have facilitated the development of their own projects. Although,

further research is required to demonstrate those effects, we believe that this good practice could be of use to other educators teaching similar coding topics.

3.3 GP3 Public visibility and open standards

Our third good practice was public visibility of all the activities generated during the class both by the students and the instructors. Open standards and open source licenses were used to publish the materials. We believe that this helped motivating students to increase the quality of their work, while at the same time getting more visibility of it. Students could also reflect on how to better critique the work of other professionals, by knowing that their work could also be criticized by the public.

For the final presentations students developed a video demonstration, created a live demo and did a presentation that was streamed and advertised publicly. Furthermore, a dynamic subsection of the class homepage was created to showcase their projects. This page was built dynamically from a Google sheets that students built collaboratively. An interesting anecdote that suggested the effects of public exposure was that when students were asked initially to complete the sheet, they didn't complete it all in time, and the ones that did it, provided incorrect answers to questions like an URL that showed a thumbnail of their projects. However, when the page was made live and they could see the direct results of their changes and mistakes on a public facing page, and could see the better examples of their peers, they all completed the assignment or updated their responses to collectively build a better project page.

The project page can be accessed on http://johnguerra.co/classes/isis_4822_fall_2016/projects.html. The code that generates this page can be found on github https://github.com/john-guerra/homepageJohnGuerra/blob/master/classes/isis_4822_fall_2016/projects.html and is available for the community to use it.

For the smaller projects, and some of the class activities students created bl.ocks. These are small code snippets commonly used in the visualization community, specifically for those who work using D^3, the most commonly used visualization library for the web. For building these bl.ocks, students could use blockbuilder, a web-based tool that allows online editing and live previews. They commonly used class examples (which were also presented with blockbuilder) as a starting point for their projects, but they could also start from scratch or use any other public bl.ocks. Blockbuilder was a widely used among students that preferred it for building their projects over desktop based tools, at least initially. Finally all of these projects were made public on each student account. Slack was used again as the communication channel even when it was not during sessions. Students commonly shared their bl.ocks and other interesting results using it.

We believe that using open standards, public exposure and modern tools such as slack and blockbuilder enriched significantly the class. Most of the tools used aren't novel by their own, but we believe that the community could benefit for using them in their own lectures.

3.4 GP4 Iterative problem-based feedback through different rhythms.

Last but not the least, our fourth identified good practice was the constant application of feedback loops with three different rhythms:

- Immediate feedback for the activities during class,
- One week feedback for the short projects and homeworks,

- And longer feedback for the final and more extensive project that was developed during a two month period.

We believe that these three rhythms allowed students to constantly receive retro alimentation of their work, allowing for rapid prototyping, iteration and pivoting if necessary

For the immediate feedback, students will criticize and comment class examples as well as on the fly selected cases. Class discussion was highly encouraged and students were constantly inquired to explore different points of views and to use the learned concepts to produce less biased critiques.

In the case of the short projects, students were usually given one week to create visualizations using public data with real tasks. Students were then encouraged to give peer reviews of their work and to discuss it on class. This encouragement came from class discussions, and students overall performed them, however we did not measure them. Given that all of these materials were made public, it was an easy task to interchange opinions. Finally, it was a common practice to give the students datasets of visualizations that were created and published by other professionals, but without showing the students the existent visualization. Afterwards, students were asked to compare their results with the ones produced by professionals having to use the concepts learned in class to support their claims. This technique was used during the midterm exam, were students were first asked to visualize a dataset for specific tasks that they could define on their own. Then, they were presented two visualizations, one that was a professionally made piece, but that got a mixed reaction from the community. The second one, was a proposed fixed of the first one, created during a global initiative called #MakeOverMonday, that every morning invites professionals to “fix” a visualization that might have issues. Finally students were asked to compare the three visualizations (the one created by each student, the original one made by a professional and the final one created during the #MakeOverMonday) and argue which one was better for the defined tasks. We believe that these type of activities and constant feedback showed the students the community aspect of the visual analytics world.

Finally, for the long term project, students were task to find a real user, with real data and a real problem. The instructors made a call for projects among their contacts and collected a list of about 20 possible projects from which student’s selected their final project. This real user played a fundamental role as an expert in the project, giving students a taste of what it is to work with a real person with a problem, and that commonly doesn’t have skills of the theoretical concepts given in the classroom. Moreover, the real user’s feedback was considered as part of the grade. This idea was inspired in part by the information visualization classes of Dr. Ben Shneiderman at the University of Maryland, were one of the instructors pursued his PhD. The project was divided in four deliverables, which gave students significant feedback and allowed them to pivot if necessary. As mentioned in the previous sections all the materials were made available, and the experts were asked to help grading the students’ projects on their capacity to generate insights. The final projects were showcased in a section of the class home page, and are since then, been public with a video demonstration, a short paper and a full deployed demo with real data (even if it is anonymized). Experts were recruited from our academic and professional networks, and they were thrilled to participate as the students built small prototypes that would address their real world problems. These prototypes were released as open source software under the MIT license to allow for further usage and development once the project finished.

We are convinced that the constant feedback on the three different rhythms encouraged students to keep up with the pace of the class, while also learning the valuable lesson that visual analytics is a concept that needs to be learned in the context of the global community. Moreover the requirement of using real world

problems with real users that care about them seems like a perfect way of measuring the acquired skills while given students valuable field experience. We believe that this good practice could also be of great benefit to the community.

4 Effect of the good practices on the students

As a post course activity, we conducted a survey to explore the students' perception on the effect of the good practices described in this section to their learning process. The survey included ten questions, targeting the concepts used on each of the good practices. The questions asked were:

Q1. Each class sessions was divided in two 1.5 hours sections, one in the classroom and the second one in the lab. How useful do you think this division was for your learning process compared to your experience?

Q2. Each class session included an introduction reviewing and one take home message. How useful do you think these two were for your learning process compared to your experience?

Q3. During class concepts were presented in modules that included a theory description and an applied example (that could be code based or not). How useful do you think they were for your learning process compared to your experience?

Q4. During class Slack was used as a backchannel for sharing examples and for allowing students conversations. How useful do you think it was for your learning process compared to your experience?

Q5. Class materials were presented using web-based slides with interactive and modifiable demonstrations. How useful do you think it was for your learning process compared to your experience?

Q6. Class projects were conducted using a real world client as an advisor and co-evaluator. How useful do you think it was for your learning process compared to your experience?

Q7. The class was conducted with three learning rhythms: short term class concepts, two medium term short projects, and one longer term final project. How useful do you think it was for your learning process compared to your experience?

Q8. Slack (off class) was used as the main communication channel for questions and comments. How useful do you think it was for your learning process compared to your experience?

Q9. The class enforced the use of public web demos, videos and Github code sharing (open source). How useful do you think it was for your learning process compared to your experience?

Q10. The class page featured a public facing projects page showcasing students work. How useful do you think it was for your learning process compared to your experience?

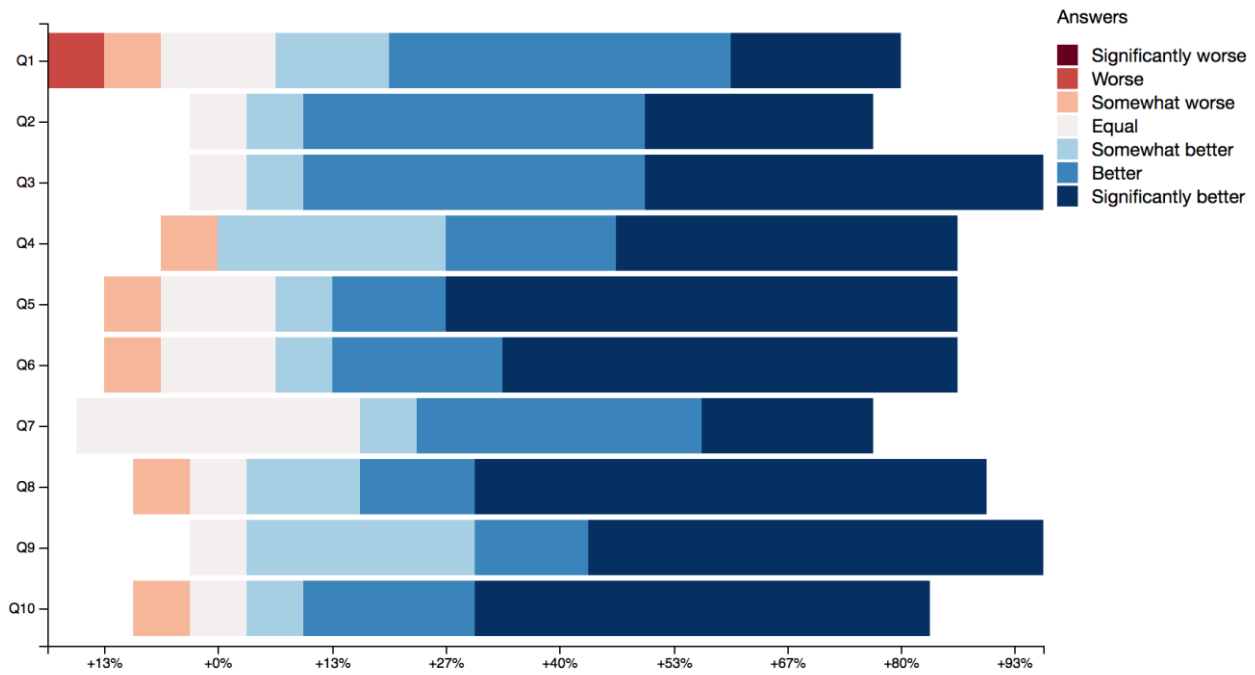

Figure 6 Students' survey results, not all answers add up to 100% because an option of N/A was given as answer

This survey was answered by 15 students (10 Graduate students and 5 senior undergraduates). As observed in Figure 6 the most positive student perceptions were towards GP2 (Web-based and interactive Class materials) (Q2, Q3, Q5), and GP3 (Web visibility, project exposure) (Q6, Q9, Q10).

We found interesting that GP1 and GP4, related with the sections of one session and different timings in the course activities (Q1, Q7), and received a more distributed answers nevertheless positives. We found that these two good practices were less evident for students in the quotidian activity. In other hand, the use of asynchrony, informal communication channel (Slack) in and out of classroom (Q4, Q8) was positively perceived by students.

Overall, the survey's results corroborated our belief that the good practices identified during the class were perceived as beneficial for the learning process of students by themselves. Moreover, it showed us some points to enhance our course in next fall term.

5 Conclusions

We have presented a set of four good practices extracted as the result of an international collaboration to design a visual analytics. Although these practices alone weren't completely novel on their own, they showed to be beneficial during our class when used as a whole, as suggested by our survey results and personal experience. We believe that these practices could be replicated by the community on similar scenarios, and therefore shared them on this paper.

Based on our experience during this collaboration, we will be continuing on improving our course design to iterate and enhanced the good practices identified. We found of special interest the added value of interactive web-tools during the sessions, and the different project-based activities in the course. In the same note, we believe that the client-driven projects and the visibility of course activities were key success factors.

6 Acknowledges

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Blended Learning and Problem Based Learning in a multinational and multidisciplinary setting

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Abstract

The paper presents the results from the second year of the Erasmus+ Strategic Partnership "Collaboration and Innovation for Better, Personalized and IT-Supported Teaching", where seven universities and three companies work together on the joint course "Future Internet Opportunities" (5 ECTS). In the project and the course, we intend to tackle some of the major challenges we experience with university teaching today: An increasing number of students and more diversity among the students enrolled, an increasing pressure to ensure that the students are ready for the labour market after finishing university, and at the same time the challenges faced when it comes to adopting new technologies.

The course consists of two parts: A course module part with 10 modules, which provides the students with broad knowledge on "Future Internet Opportunities" from social, technical and business perspectives, and a project part where the students work in groups across nationalities and disciplines on real-world projects posed by companies.

This paper presents the evaluations carried out by all participating students, and discusses the experiences with the different learning components including different features of the Learning Management System Moodle, which was used for the modules. Moreover, it introduces the concept of just-in-time resources for Problem Based Learning, where we tackle the challenge of providing the students with methods and tools to be used in the projects just when they need it.

Type of contribution: Best Practice Paper

1 Introduction

The traditional university is struggling with both internal and external factors, calling for changes in the way we conduct teaching and design learning activities. In the first part, we will introduce some of the factors, and discuss how our approach of blended and problem based learning in a multidisciplinary and international setting can contribute to meeting some of the challenges we experience.

First, our universities are faced with an increase in the number of students who would previously not have chosen a university education. This tendency is especially outspoken in some of the more technical areas of engineering, where it has become hard to recruit students, often leading to a broad intake of students in order to satisfy the needs of the labour market. The challenge is not just to accommodate them in the universities, but also to make sure that they become as qualified for the labour market as those who would traditionally choose a university career. At the same time, there is a pressure to ensure that the students not only become skilled academics, but that they are also ready to take on the challenges experienced in the labour market after graduation, which requires not only good technical skills, but also collaboration

skills, project management skills, presentation skills etc. In other words, we need to educate students to solve problems rather than (just) equations (Walther et al., 2011), (Crawley et al., 2007), (Walther et al., 2007).

As a third point, traditional universities are being challenged by technology, and need to find their position in a world where Massive Open Online Courses (MOOCS) are becoming increasingly popular (Martin, 2012), and where even students in our own universities sometimes prefer to follow online courses rather than courses offered locally (Wulf et al., 2014), (Christensen et al., 2013). With the interactive, highly relevant, and professionally produced content of some of the courses, it is not surprising that a single lecturer giving a similar course cannot keep up to speed here – and often the use of new technology, including the many features of modern Learning Management Systems (LMS), is left to the individual teacher to explore and use. To address this challenge, universities need to define their own roles and value propositions, and decide how and for what virtual learning platforms and other technologies should be used. Lastly, also companies are dependent on good university education, as students are future employees. So, it is of interest for companies that students face real-world challenges already at university and that they get prepared for the labour market during education.

In this paper, we address these challenges through describing a new approach to learning, and the results achieved by trying it out in a joint course between seven European universities and three enterprises. We also present and discuss our experiences with different features of the LMS Moodle used for the course.

The paper is organised as follows: Section 2 provides an overview of our approach of the course, including a description of how the modules and projects are organised. In particular, we discuss the experiences from the first year of the project, and the changes for the following year as a result. Section 3 provides an overview of the evaluations and a discussion of what adjustments and changes should be made in the future. In section 4 we provide a discussion on the just-in-time resources for problem based learning (PBL) principle, and finish the paper with discussions in section 5 and conclusions in section 6.

2 Overview of the course

The course is organised during the spring semester, and offered jointly by all seven universities. The overall theme of the course is “Future Internet Opportunities“. It consists of two parts: A course module part, which provides the students with knowledge on "Future Internet Opportunities”, and a project part where the students work in groups across nationalities and disciplines on real-world projects posed by the participating companies. After a virtual phase of module work, all students and teachers meet for one week (April) to finalise the module work and start the project work, and after a virtual phase of project work the participants meet for one week (July) to finalise the projects and conduct exams. The overall time plan is shown in Figure 1. In 2016, 30 students followed the course.

2.1 Initial timing considerations

Timing the choices of modules, the formation of groups, and the distribution of projects is a puzzle with several possible solutions.

In the first-year edition of the course, the students chose modules based on interest, recommendations and requirements from local coordinators by the time of signing up for the course, and since students could choose up to four advanced modules, all modules had a fair number of students. For the projects, the groups were announced during the midway seminar (the groups were formed to reflect distributions in

background, modules, nationalities, and gender), and projects were randomly distributed between the groups.

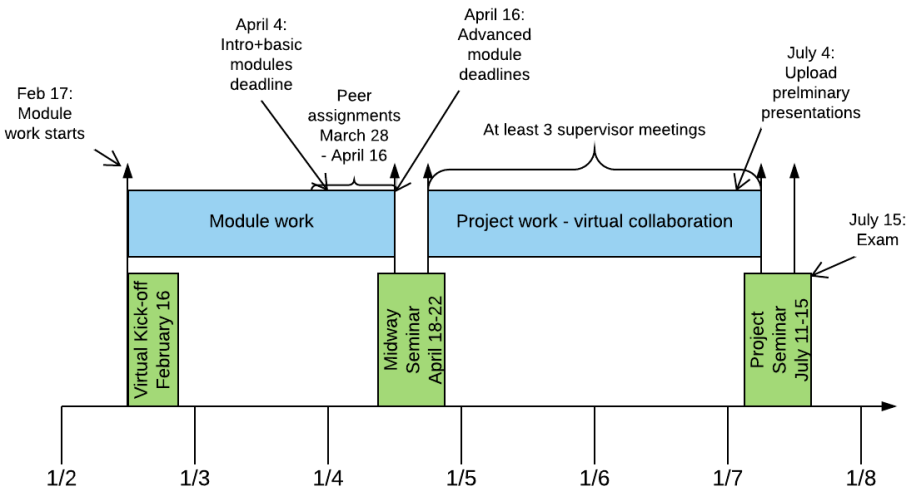

Figure 1: Detailed time plan of the course.

In the second-year edition, this scheme was revised to allow the students to get to know each other at an earlier stage, and to ensure that all groups covered all topics even with fewer modules for each student. The groups were already announced during the virtual kick-off meeting, and the selection of basic/advanced modules was coordinated in each group during the first weeks of the course. The projects were again announced during the midway seminar for several reasons: Announcing the project without the presence of company representatives and supervisors could lead to unnecessary misunderstandings and frustrations, and potentially, the students could start working in a wrong direction. In addition, the teachers again distributed the projects rather than letting the students select themselves. This was not done randomly, but based on a "matching" between student's choices of modules and required/recommended modules for each project. The distribution approach ensures that all projects are chosen, and that not more than one group works on the same project, avoiding potential conflicts or disagreements.

2.2 Virtual kick-off

Starting a course that mixes virtual and physical mobility requires some considerations, one of which is whether to begin with a virtual meeting where all participants are present at the same time, or to simply "open" up the course. With the student groups being announced from the beginning, it was decided to have a synchronous virtual meeting with all participants being present, and use this opportunity to let the student groups discuss with each other (previous experience from last year showed that simply asking people to work together without facilitating some kind of introduction was hard). It was organised with four components:

- A presentation by the coordinator (transmitted in real-time by Adobe Connect).
- A presentation round, where each student would present himself/herself.
- A group quiz exercise, where each group had to coordinate their group work by themselves. Here the students were free to decide which conference/chat systems to use, however an Adobe System conference was setup for each group for those who would like to use it.

- A round with questions and answers.

Presentations and presentation rounds with multiple people distributed over 10 different physical locations was not easy to get to work with in a decent quality. Quality issues were also apparent here: Having discussions in this manner was difficult due to a combination of latency as well as varying audio and video quality among different participants. Moreover, it was hard to tell whether it was a local problem or system problem, and whether it was related to users (e.g. microphones not muted) or equipment (e.g. malfunctioning microphones). However, for a presentation that was mainly one-way, and for a short presentation round, everything worked out satisfactory.

For the group quiz, it needed to be considered whether the students should have more support/control and to which degree they should be left to their own. The Adobe conference provided an initial channel for everyone.

2.3 Modules

Each student follows 10 introductory, 4 basic and 2 advanced modules. This is based on a total workload for module work of 50 hours: Each introductory module takes around 1 hour, each basic around 5 hours, and each advanced around 10 hours. Compared to the first year, this second year implementation means doubling of the workload of each advanced module, which allows for more group work and peer learning activities included in advanced modules. The introductory modules are based on students interacting individually with the learning platform Moodle (Moodle, 2003), and the basic modules add more activities including assignments revised by the teachers. This seeks to increase flexibility (students can study many of the topics when they want, without a need for synchronisation) and reduce complexity as each student does not have to keep track of too many diverse tasks.

In the previous year, two things retarded the module work for the students:

- All modules were shown on the same page in Moodle, without the possibility for students to hide activities they did not have to undertake.
- No activity tracking was set up, so the student had to keep track of which activities he had done already.

In combination with not being the usual platform for most students, this made it hard for them (and for the teachers) to maintain an overview of which activities to undertake, and which had already been completed.

This was updated in the second year, so each student would only see the activities he/she should work on. Moreover, completion tracking was implemented helping students to keep track of their progress. However, completion tracking is not that simple to implement. In Moodle, two types of tracking (Zhang & Almeroth, 2010), (Hijón-Neira & Velázquez-Iturbide, 2006) are supported:

- The student marks an activity as completed manually.
- The system automatically marks an activity completed based on criteria, which can be specified depending on the activity.

When implementing this feature, the question arises whether it is a tool to help students monitor their own progression, or a tool for the teachers to be able to monitor the progression of the students. The answer might be that it is a bit of both. The manual approach has the obvious weakness that a student can easily tick all boxes, so that the activity seems completed (even if the teacher can see the timing of activities for each student). The automatic approach on the other hand suffers from the fact that it is hard to decide

when an activity is completed. For interactive elements such as a quiz, it works well, but for others (papers, watching videos etc.), an activity is completed when a student has watched it. This does not say much about completion, and for students who download or look through all materials before starting the module it offers little help in keeping the overview. Another consideration is which activities should be marked, for example when the same material is offered in different formats. In general, we tried to use the automatic approach, informing the students that they should themselves ensure the understanding of each part before moving on. In case of elective elements, manual marking was used.

Figure 2 shows an example of a typical introductory module, where the core is a combination of 5 – 10 minutes videos, and a quiz after each video. Besides there are some literature studies expected as well. Each module starts with introducing the learning objectives, and ends with a final quiz that marks the end of the module. While all students are required to finish all introductory modules before the deadline, it is not formally conducted as an exam, which would require a different technical/legal setup. So, at this stage it is very much a matter of trust (there is no control that the student is doing it on his own, and there is no limited number of attempts to finish the quiz) as the quizzes serve for auto-evaluation of the learning process.

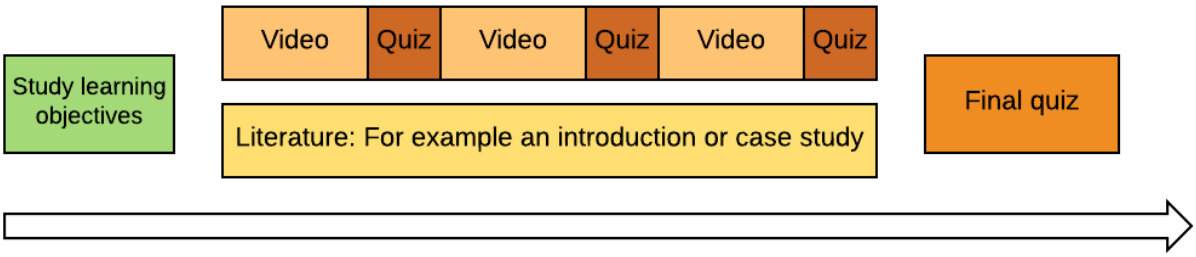

Figure 2: Example of an introductory module.

Figure 3 shows an example of a basic module. As in the introductory module, it starts with studying the learning objectives and ends with a quiz. The literature elements, video and quizzes can also be found. A Q&A forum is included for discussions and questions both among students and between students and teachers. One of the components in each basic module is a pre-module test, which allows students to check the prerequisites before starting the module, as well as pre-module materials that students can study if they need to top up their knowledge before starting the module (can be both materials created specifically for this, or pointers to relevant teaching material). The pre-module work is part of the individualised learning path, which allows students with different backgrounds to follow the same modules. However, it is still necessary to consider students´ backgrounds: Creating this pre-module material might be more suitable for students with similar backgrounds, where some might lack knowledge of specific skills or tools. If background knowledge corresponding to years of studying in a specific domain is required, providing this would be out of scope for pre-module studies. Another consideration refers to the workload estimation: For whom is the workload estimation intended? Does it include pre-module material? And is it possible to design the full course with similar workloads for all students, when their backgrounds are so diverse? While it is tempting to say that the workload depends on the background of the student, it has to be kept in mind that the workload of a 5 ECTS course should be 150 hours for every student.

The advanced modules differ from introductory and basic modules since they include interactions between the participants in terms of group work and/or peer review tasks. Based on the previous experiences, this is a more challenging part since it requires more scheduling between the students, in terms of either virtual

meetings or deadlines for submission/reviews. This became quite complex in the last year when it was included in many modules in both basic and advanced levels (each with different deadlines and different students). For this reason, it is now limited to the advanced modules, and the deadlines are synchronised between the modules. Figure 4 shows an example of the structure of an advanced module.

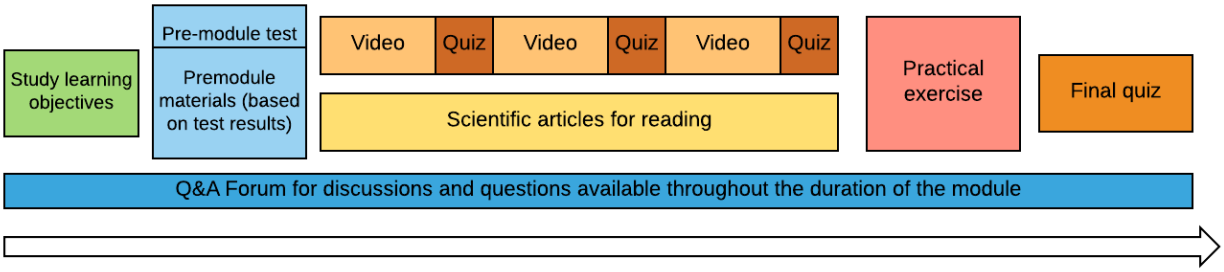

Figure 3: Example of a basic module.

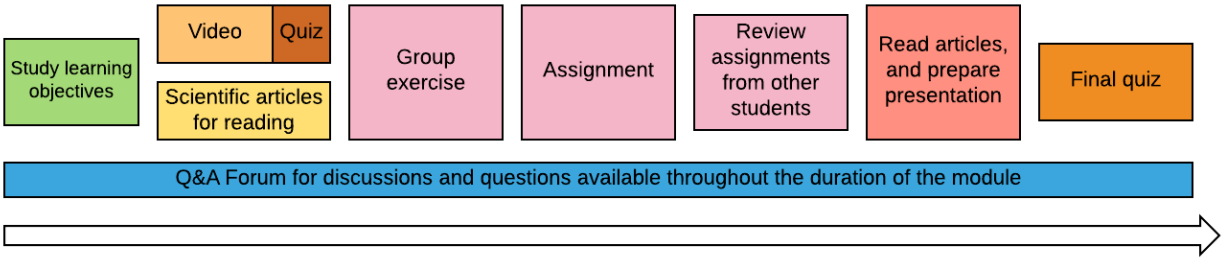

Figure 4: Example of an advanced module.

2.4 Midway seminar

Figure 5 provides a schematic overview of the seminars including the virtual collaboration phase. The idea behind the midway seminar is to synchronize the finalization of the course modules, and to start with the project work. During the first two days, time is allocated for a combination of introduction to group work and team building exercises. This boosts the social dynamics in the groups, which is important in order for the learning activities to work out well.

In the first year, the students followed a one-hour session for each basic and advanced module they took before, whereas in the second year the basic modules were more self-contained in Moodle, and with each student following fewer advanced modules it was decided to put more effort into finalising the advanced modules. Each student prepared a presentation of one of his/her advanced modules, and presented that for other students in a conference-like setting with two parallel tracks. This made it possible to finish the module's revision during the afternoon of the first day. Therefore, day 2 could already be devoted to focus more on group work, collaboration and project management – this was emphasized more than in year one, since the ability to work together as a group is an important foundation for the virtual collaboration that follows. This objective continued on day 3, where a workshop covered the topics of practical business development, to help the students to develop a business mind-set, and also to motivate and de-mystify the business aspects of the projects. This was set up in a way that would also bring the students closer together as a group.

With several different tasks and exercises, the question was whether to use the same groups for all activities (thus boosting their teamwork) or to vary the groups and to experiment with groups of different sizes to promote more social interaction processes across all the students, and let them experience different group dynamics.

During the last two days of the seminar the focus was on introducing the students to the projects, let them discuss with company representatives, and eventually come up with an initial problem analysis and a plan for the virtual collaboration phase. Compared to the previous year, the focus was more on structuring the forward work by providing the students with a description of the expected outcomes of the seminar (e.g. the initial problem analysis, time plan with mile stones and meeting plans), and to equip the students with relevant collaboration tools and templates for the virtual collaboration phase.

Throughout the seminar, there was a focus on training presentation techniques, both through a dedicated workshop and by video training sessions throughout the seminar. For example, each day ended with a "pitch talk" from each group, which was recorded and commented.

2.5 Virtual collaboration phase

During the virtual collaboration phase, the students worked on the real-world projects, receiving guidance mainly from their supervisors and company contacts. Examples of topics were: (1) how to develop a cloud-based Software-as-a-Service Threat Intelligence Solution, which could ensure that customers are protected from the volume and variety of cyber threats and (2) development of an easy-to-use bike-sharing platform for a German community, where the particular challenge was to make it more attractive to use the service compared to traveling by car, for example by developing an interconnected system easy to use (applications, interactive elements etc.).

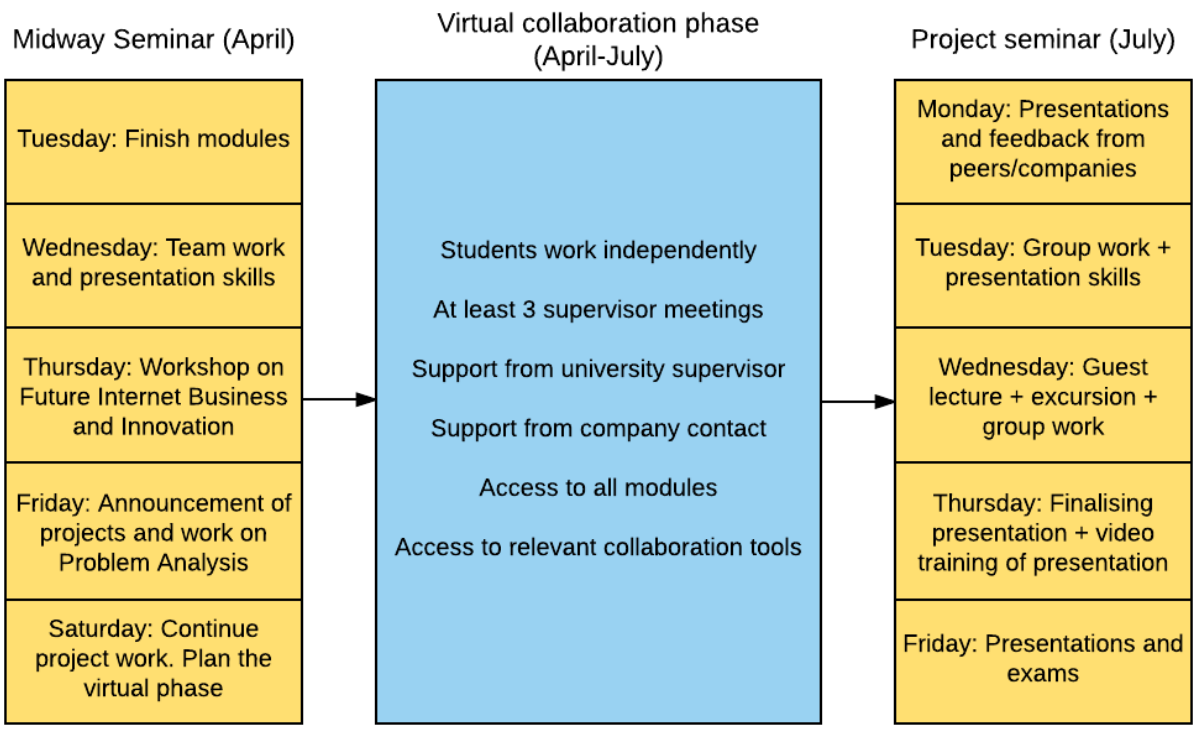

Figure 5: Schematic overview of seminars and virtual collaboration phase.

In the first year, this was a very student-driven process, but the experience was that for multiple reasons it was hard to get started: Students with different backgrounds have very different perceptions of what a project is and what roles supervisors and companies play. Working remotely can be challenging, and sometimes just coordinating a time to meet virtually can be difficult and delay the project – even more when organising meetings with relevant agendas and content. Letting the students decide on their own on the one hand, and steering the process through teaching/supervision on the other is another challenge. Last year at least 3 supervisor meetings were required, and students were asked to follow the time plan defined by themselves during the midway seminar for giving the course more structure. This also clarified the project and supervisor roles. Each group was required to send a report every second week to their supervisor to report on progress, and one student per university had to participate in virtual quality assurance meetings every third week and comment on the project progress. Moreover, the expected outcome of the virtual collaboration phase was clearly communicated to the students: A presentation of the project had to be uploaded at least one week before the project seminar, where they had to present it to a committee of company representatives, supervisors and fellow students.

2.6 Project seminar

The focus of the project seminar is to help the students finish the project work and conduct examinations. During the first day, a number of peer seminars are held as described above. These sessions take place in parallel each with participation of two student groups, their supervisors and company representatives, where the students present their work and receive questions, feedback and suggestions from a wider group than their own supervisor and company representative. Much of the work during the next days is organised within the groups with the help from supervisors and company representatives. However, each day has one or more different themes, often supported by joint learning activities. At the end of each day, the groups give a small presentation according to this topic. The themes of the different days are listed in Figure 5.

One consideration refers to guest lectures and excursions, something that has been part of the course in the previous years. On one hand, it is nice to use the opportunity for all students being together to offer interesting guest talks, and it can divide what is otherwise a full day of work alone in the groups. The same applies to the excursion, which provides an opportunity to explore a relevant company/setting in the location of the seminar. On the other hand, at this stage, it is rather late for providing useful inputs to the projects, and some of the students feel under pressure because of project deadlines and examinations. However, we decided to make use of lectures and excursions in the last years and will also make it part of the next seminar in order to make the seminars more diverse and less exhausting. Moreover, offering a variety of activities makes the learning experience much more well-balanced, motivating and effective.

3 Evaluations and future adjustments

The students were asked to evaluate all modules and projects through an electronic survey, both during and after the course, and to evaluate the overall course experience at the end. As the design of each module is different, it is hard to compare the different components between all the modules, but Table 1 summarises how many students of each module found the different activities to be either “Efficient” or “Very efficient” (the other alternatives were “Very inefficient”, “Inefficient”, “Neither efficient nor efficient”, and “Not used/applicable”). Full evaluations can be found in (Colibri, 2017). It is important to note that many of the low-scoring activities receive many (Not used/applicable).

It is clear from Table 1 that the students were generally happy with the overall modules of introductory, basic and advanced levels, and that components such as video lectures and questions/quiz material received quite good evaluations even with some room for improvements. The following comments reflect student's comments and observations by teachers to the other activities:

Table 1: Percentage of students of the 10 modules, who found that part to be "efficient" or "very efficient" for their learning experience.

Module number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Introductory level	89	97	72	80	86	89	73	92	73	89
Video lectures	62	82	72	65	72	79	73	96	55	79
Questions/quiz material	72	76	69	63	79	80	79	86	59	79
Q&A Forum	31	34	20	21	31	31	28	35	31	28
Self-study activities	55	55	52	45	58	51	58	76	45	75
Basic level	88	80	88	87	100	70	76	100	75	93
Peer learning activities (advanced level only)	13	84	14	43	57	25	25	0	38	78
Advanced level	40	84	86	72	85	50	80	100	88	78

Q&A and discussion forums have been launched for all basic and advanced modules, but only used to a very limited degree. At least two factors contribute to this: First, a technical issue, which makes it impossible to send out email notifications using the participants usual email addresses. This means that students are unaware of forum activity, unless they actively check for it – thus, the few topics posted received only little attention. Second, because discussions were not often actively initiated or encouraged by the teachers, e.g. by providing discussion topics or by building into exercises that the students should discuss certain topics. Those points are important to keep in mind for the next edition of the course. The self-study activities received a high number of "Neither effective nor ineffective". It was not always sufficiently clear defined what the students were supposed to do, and when an activity could be considered completed. For example, if students are asked to read a paper, but no follow-up in terms of assignments or exercises are submitted, it becomes easily confusing. The need for precise instructions is particularly important when most of the learning is online and without the possibility for discussions between teachers and students. For the peer learning activities (Boud et al., 2014), (Boud et al., 1999) the relatively low scores were surprising. Based on the comments received, and discussions with students after seeing the results, it became clear that many students were not aware of what peer learning is, and therefore rated as "Not used" or "Neither inefficient nor efficient". For the tasks where students need to work in groups, it is important to facilitate this (e.g. announce the groups well in advance, and explain exactly what they should do and how they should collaborate). With the relatively tight time constraints in the module phase, some students did not manage to coordinate even a meeting time. Again, the most important learning point is to be very clear about what the students are expected to do, and to make sure that the students know what the term "peer learning" covers. Generally, for the course part, it is important that it is very clear what the students are supposed to do, something which is supported also by the completion tracking. However, as discussed in the previous section, using completion tracking is not without challenges. After the course was completed, the technical platform in Moodle has been improved. One element is dependencies, so that

some activities cannot be accessed before previous parts have been completed. This is something that will be tested out during the coming year.

The projects were evaluated in a similar way, and the results can be seen in Figure 6. The most important point to work with is the virtual collaboration. Next year, even more focus will be on facilitating this, through better preparation of the students in the midway seminar, through providing a better platform for the collaboration, and through a more systematic support from supervisors during the phase.

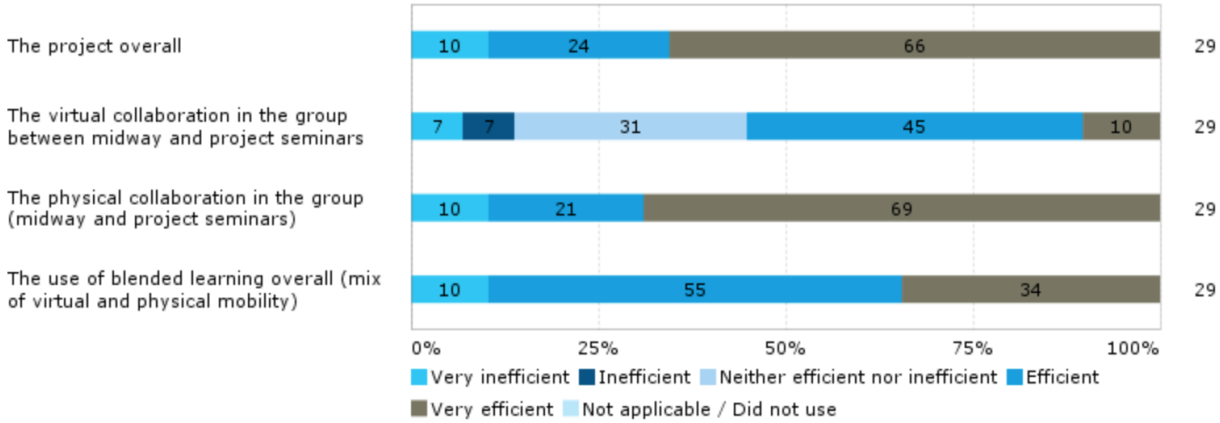

Figure 6: Students´ responses to the question: Please rate how efficient the following parts of the project have been for you with respect to learning.

The course was also evaluated as a whole. The students´ evaluation of the impact on them is shown in Figure 7. Overall, this supports the conclusion that the teaching methods tested out contribute to solve the issues listed in the introduction of the paper.

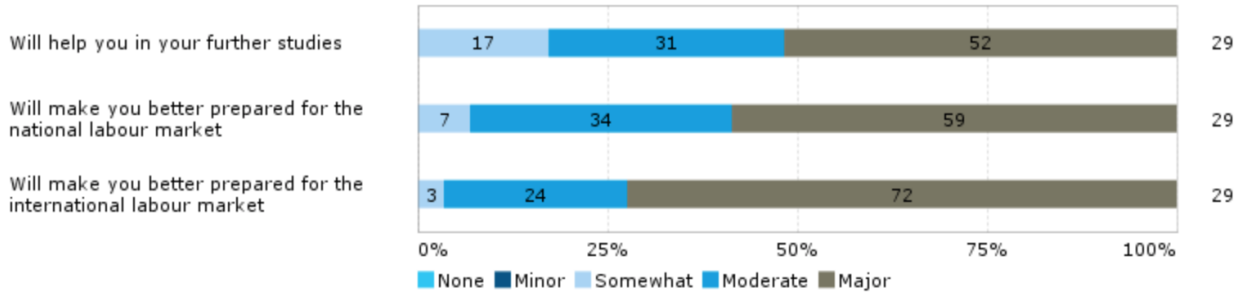

Figure 7: Students´ responses to the question: Based on your personal outcome from participating in Colibri, please assess to which extend the teaching methods used in Colibri impact the following.

4 Just-in-time resources for PBL

We observed that the online/interactive material from the modules was used during the project phase, and that this gave a good support for the project work. These observations led us to develop a model for just-in-time resources for PBL, which can be beneficial also in more traditional PBL teaching situations.

The initial project design was based on first studying the modules, then doing the project work. This is adapted from classical PBL models (e.g. the Aalborg model), where courses take place in a traditional manner that requires all students to take the course at the same time. With the online modules, it provides

much more flexibility as it makes it possible for students to follow relevant parts of the module when they need it, so that (1) the students are very motivated because they know what to use the knowledge for and (2) it allows for efficient learning because the students get to use the knowledge to solve a real problem.

Figure 8 shows the model we have developed. The first step is that the students need to analyse their problem, and obtain some initial knowledge. When students then work on the project, this initial knowledge can be used to identify which methods/tools could be relevant to use, of course also with the assistance of supervisors. The material is not limited to that of the modules, but could also come from many other sources. After having solved one problem in the project, the cycle continues with other problems.

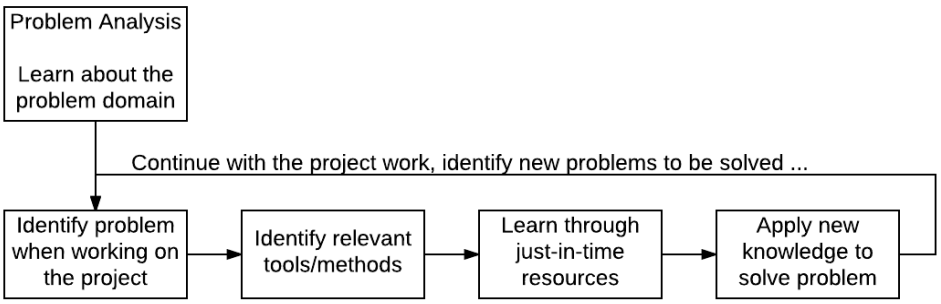

Figure 8: Just-in-time resources for PBL.

5 Conclusion

This paper presented how blended and problem based learning can be combined in a multidisciplinary and multinational setting, and we demonstrated how we handled the most important challenges in the course, i.e. the different technical backgrounds of the students, the diversity in educational culture/background, experiences with project work, and the challenges when most of the work was done remotely.

Based on the feedback from students, the course was successful and especially the work on real-world problems in diverse and international groups of students was highly appreciated. In the future, it would be an advantage to focus more on the group work and project management during the midway seminar, and also to have a more structured process during the virtual project work – something that could also be supported by using a more suitable collaboration platform, which is one of the changes we will do for the next run. The online module material was also evaluated positively, even if there is room for improvements especially when it comes to self-study activities, Q&A forums and peer learning. Especially the comments from the students regarding "peer learning" show that it is important to explicitly explain the students the learning activities and the thoughts behind them, especially when working with diverse groups of students who come from different educational cultures and habits. The paper also introduced the concept of just-in-time resources for PBL, where online material is made available for students to access during their project work: This provides students with knowledge and skills just when they need it, increasing their motivation as well as their learning process since their new knowledge is applied to a real case straight away. This also demonstrates the potential of combining problem based learning with virtual learning platforms. It is still a young movement and there is further investigation needed on how to implement it in the best possible way; especially when it is integrated in the project work.

Based on the results achieved, it is clear that there is a potential in working further with the methods proposed in the paper. When doing so in the future, we will address the points identified above and work further on implementing just-in-time resources for PBL.

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Using Fuzzy Analytic Hierarchy Process to Assign Weights to Project Based Learning Outcomes

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Abstract

Course learning outcomes should be the centre of attention when it comes to achieving the intended learning of a subject utilizing a PBL approach. The subject should have clear learning outcomes that the student should focus on throughout the project in order to allow students managing their learning effectively and facilitators assessing students' performance. However, consistent summative assessment has been identified as a challenge when the same subject is facilitated by more than one facilitator and with different perceptions on the importance of the intended learning outcomes. The purpose of this study is the collaborative identification of weights of learning outcomes, in order to improve grading quality by incorporating varying importance of learning outcomes. The case study research method will be used to show how the Fuzzy Analytic Hierarchy Process (Fuzzy AHP) can be used to prioritize and assign weights to the learning outcomes used in two different subjects by extracting and aggregating the perspectives of involved PBL facilitators. The identified weights of learning outcomes show that the most important learning outcome is twenty-two times more important than the least important learning outcome in one unit while the other unit shows that the most important learning outcome is nineteen times more important than the least important learning outcome. Two learning outcomes in each unit show similar importance. The weights are based on the accumulated experience of the involved PBL facilitators and derived in a collaborative manner. Furthermore, clarity on these weights improve grading transparency, allow students to allocate their learning effort accordingly, and enable facilitators to improve grading quality.

Keywords: Project based learning, analytic hierarchy process, learning outcomes, grading

Type of contribution: Research paper

1 Introduction

Two types of system attributes exist in decision-making which include objective and subjective attributes. Objective attributes, such as expenses, are defined and measured in numerical terms. Subjective attributes, such as consequences of disruption in a service, are considered as qualitative. Subjective attributes cannot be exactly and arithmetically measured by the decision maker. The analytical hierarchy process (AHP) is a multiple attribute decision method that uses structured pairwise comparisons with numerical judgments from an absolute scale of numbers. AHP has been applied in several areas, such as logistics, manufacturing, government, and education (Ho, 2008). Fundamental elements of AHP include a multi-level structure with pre-set goals, the estimation of the relative weights of the decision elements, and an aggregation method to obtain a final composite vector of priorities.

To compare several alternatives one can assign a number from a fundamental scale of absolute numbers to each one of them. This requires data or knowledge in the relevant area. One way to collect such data is by

interviewing the experts. This data can be accompanied with contingent valuation methods (Brugarolas *et al.*, 2010); or by the partaking of an expert panel (Reid & Keith, 2009); or by applying the Delphi technique which is a systematic and interactive forecasting method that depends on a panel of specialists for predicting (Elmer *et al.*, 2010). The person coordinating the Delphi method is known as a facilitator, and facilitates the responses of the panel of experts. Pairwise comparisons are measured using a scale. There are several approaches in developing such scales (Dong *et al.*, 2008).

A comparison matrix shows two basic properties, namely homogeneity and reciprocity. A third property (i.e., consistency) should hypothetically be needed for a comparison matrix. Consistency expresses the rationality that may exist between judgments about the elements of a set. Because preferences are stated in a subjective manner, it will be reasonable to see some incoherency to exist. Usually the judgments show some inconsistency unless they are forced in an artificial manner.

2 Assessment

The assessment of both courses considered here ("Project Planning" and "Project Implementation") is based on the following approach. Foundation for learning and assessment is a set of learning outcomes. As an example, the learning outcomes for the course "Project Implementation" are shown in Table 1. These learning outcomes were shown by the institution's curriculum committee to cover clearly specific program outcomes, and with that some of the stage 1 competency elements developed by Engineers Australia (EA, 2017), the institutions accrediting body.

Table 1: Learning outcomes of the course "Project Implementation"

1. Demonstrate a capability to apply to a substantial degree the Engineers Australia generic attributes for engineering technologists to an engineering project.
2. Implement the plan prepared for the project, monitor and review project progress, and take initiative to resolve problems, adjust project strategies and maintain work and reporting schedules.
3. Work and learn autonomously and in a professional manner and communicate effectively using formal and informal progress reports, professional presentations and project documentation.
4. Gather, evaluate and extract relevant information from key sources and relevant authorities and use information effectively to justify analysis, project choices and decisions.
5. Think critically, demonstrate sound analysis and make sound judgments in all stages of the project and articulate decisions and supporting thinking in project working documents for the project supervisor and in final reports and presentations.
6. Solve technical problems and issues that arise, explain judgments made based on technical knowledge and standard practice, and comply with safety, risk, sustainability and other professional requirements.
7. Identify and comply with relevant safety, risk, sustainability and other professional requirements
8. Evaluate project processes, technical outcomes of the project and the lessons learned from the project experiences.
9. Write a formal technical report and dissertation describing the project, the issues faced and the choices made in managing or implementing the project, the reasons for making choices, project evaluation and what was learned from the project experiences.

Each of these learning outcomes can be reached with different qualities as reflected by the continuum "unacceptable – acceptable – good – excellent". Performance criteria have been identified previously for each learning outcome, by faculty members involved in delivery of the this course, which reflect these qualities. An example is shown for learning outcome two (LO2) of the course "Project Implementation" in Table 2.

Table 2: Performance criteria for learning outcome two

LO	Unacceptable	Acceptable	Good	Excellent
2	Insufficient evidence of monitoring and review of progress; failure to manage project to meet deadlines.	Acceptable evidence monitoring and review of progress; managed project to deal resolve problems and meet deadlines.	Evidence of systematic monitoring and regular review of progress; managed and adjusted project plans to resolve problems and meet deadlines.	Evidence of systematic monitoring and regular review of progress using a range of project management tools; managed and adjusted project plans to resolve problems and/or enhance the project and meet deadlines.

In order to present how students covered these performance criteria, they are required to submit a portfolio at the end of the semester for summative assessment. Portfolio items include (but are not limited to) the following:

- Workbook, showing student's project work;
- Reflective Journal, presenting student's learning journey;
- Technical Drawings, as required by type of project;
- Technical Report, summarizing outcomes of student's group work;
- Peer Assessment, showing student's assessment of his team colleagues; and,
- Individual Grade Nomination, showing student's self-assessment based on the learning outcomes and performance criteria.

In addition, students undergo informal formative assessments throughout the semester as they present on a weekly basis their work and learning to their academic supervisor.

Finally, students present their project outcomes to an examination panel of at least three faculty members at the end of the semester. Each student of a team is presenting a part of the project which may be a certain aspect of a project (e.g. one student carries out the structural design, another student soil stability analysis, and a third student aspects related to construction management), or it may be a part of a bigger project (e.g. one student carries out the structural design of the main building, another student the structural design of wing A, and a third student the structural design of wing B).

Following student's presentation, questions are asked by the examination committee, addressing individual students, in order to probe into students' understanding of the work carried out. Students' answers may impact the previously carried out portfolio assessment, if it is found that a student did not understand the work they carried out. For example, if a student's work related to learning outcome two was found to reflect an "excellent" quality based on their portfolio, but they are not able to explain details of the used

project management tools (i.e. they did not understand their work), the overall quality of learning outcome two will be reduced to "good".

The final grade is calculated by multiplying the number of learning outcomes on each quality level with a score for the specific quality level (6 for acceptable, 8 for good, 10 for excellent). For example, if a student reflected five learning outcomes on an acceptable level and 3 learning outcomes on a good level, the resulting percentage grade would be

(5x6 + 3x8) / 8 * 100 = 67.5%

The following section describes the identified challenges of the approach described so far.

2.1 Challenges

The approach outlined in the previous section has led to the identification of the following challenges:

First, not all academic supervisors agreed with the fact that all nine learning outcomes have the same weight. From an engineering practitioner's perspective, some learning outcomes should have a larger weight. This means, a more collaborative process of deciding on weights of these learning outcomes should be aimed at. Secondly, the consistency in grading between different academic supervisors could not be ensured. Without clear weights of the learning outcomes, assessors of the same course may evaluate differently the performance of different students since different weights for different learning outcomes were given on a sub-conscious level. A clear risk of inconsistent grading is existing. Thirdly, the transparency of grading is limited. Based on the given learning outcomes, students would rightly assume that all learning outcomes have the same weight. This is especially true for students without work experience. However, if assessors, based on their experience as engineering practitioners, are giving more weight to some learning outcomes and less weight to other learning outcomes, learning outcomes would not have equal weights.

It is a rare approach that an institution would have a systematic and structured approach to assign the weights to PBL learning outcomes. The weights (if any) are usually determined by consensus (Wood, 2003) rather than an actual systematic approach that takes into consideration the prioritization of learning outcomes through a pair wise comparison. This carries the risk of assigning weights to the learning outcomes that are not aligned with the learning needs and industry requirements. Since this study focuses on PBL units that assess students learning based on one summative assessment item only (i.e. portfolio), the prioritization of learning outcomes becomes a very important matter to reflect the actual importance of these learning outcomes.

The following methodology section shows the application of the Fuzzy AHP approach in order to solve the shown challenges, followed by the results, discussion and conclusion section.

3 Methodology

The analytic hierarchy process (AHP) is a multi-criteria decision-making method for qualitatively evaluating various options through using different and independent criteria in the process (Saaty, 1990). AHP is a measurement method underpinning mathematical and psychological aspects (Bhushan & Rai, 2007). AHP does not require a huge sample for drawing conclusions. AHP is rather effective in the decision-making process that is fixated on a specific issue (Lam and Zhao, 1998). The utilization of AHP for ranking different criteria was pointed out as on the primal usages of the method (Saaty, 2003). Nonetheless, it is important to consider that conventional AHP process is considered inadequate in complex situations (Pang, 2006) where the vagueness of the human's choice would have a big effect on the decision-making process.

Therefore, it is more effective to utilize the fuzzy AHP approach in unclear situations where a decision needs to be made (Buckley, 1985). Since the learning outcomes of the courses under study are independent and the decision concerning their significance is vague and susceptible to the interpretation of the decision makers, the fuzzy AHP was found to be the most suitable methodology in the prioritization and ranking of these learning outcomes. This ranking will be generated by considering that the learning outcomes are the criteria that forms the AHP hierarchy for both courses as shown in Figure 1 and Figure 2. A questionnaire survey will be created and distributed amongst selected PBL facilitators that have experience in both courses and can contribute to the ranking of the learning outcomes based on their experience in these courses. The data collected from the questionnaire survey will be analysed through the utilization of a fuzzy AHP algorithm. The major steps of the multiple-criteria decision-making (MCDM) process utilized through fuzzy AHP were previewed by Bhushan & Rai (2007) and included:

- Understanding the set of circumstances;
- Structuring multiple criteria;
- Evaluating multiple criteria;
- Evaluating alternatives according to the criteria;
- Ranking the alternatives; and,
- Integrating the judgement of involved experts in the matter.

The data collection process starts with the participants setting their preferences by utilizing a qualitative scale known as the AHP scale (Bhushan & Rai, 2007) and indicate the preference of the compared elements' significance from the perspectives of the participants. A sample of nine facilitators who are experienced in PBL courses were selected to participate in filling in their preferences. These facilitators were selected based on having sufficient experience in the academic field, industry and are accustomed to the unit-level PBL model used. This questionnaire was administered on a face to face basis to explain the learning outcomes and ensure similar understanding amongst all the respondents. This method resulted in a 100 percent response rate for the questionnaire survey.

The fuzzy AHP is based on creating a pair-wise comparison illustrating the relative importance of N number of criteria. This comparison is organized into a square matrix where the diagonal elements of the matrix is naturally equal to 1 since the criterion's importance would be compared to itself. If the element value of element (i, j) is more than 1, this indicates that criterion in the ith row is more important than the criterion in the jth column. On the other hand, if the element value of element (i, j) is less than 1, this indicates that criterion in the ith row was less prioritized than the criterion in the jth column. The matrix is built in a way that the (j, i) element of the matrix is always the reciprocal of the (i, j) element as mentioned by Bhushan & Rai (2007). Then the eigen-vector of the matrix would be produced and normalized to indicate the relative importance of the criteria being compared. The consistency of the resulting weights is then tested to account for the subjectivity of the decision-making process. Establishing the decision-making consistency necessitates the calculation of the consistency index (CI) in addition to calculating the consistency ratio (CR) and ensuring that it does not exceed 10% to satisfy the consistency threshold set by Saaty (1980). In case the CR limit is exceeded, the subjective opinion is considered inconsistent and the decision will not be considered trustworthy.

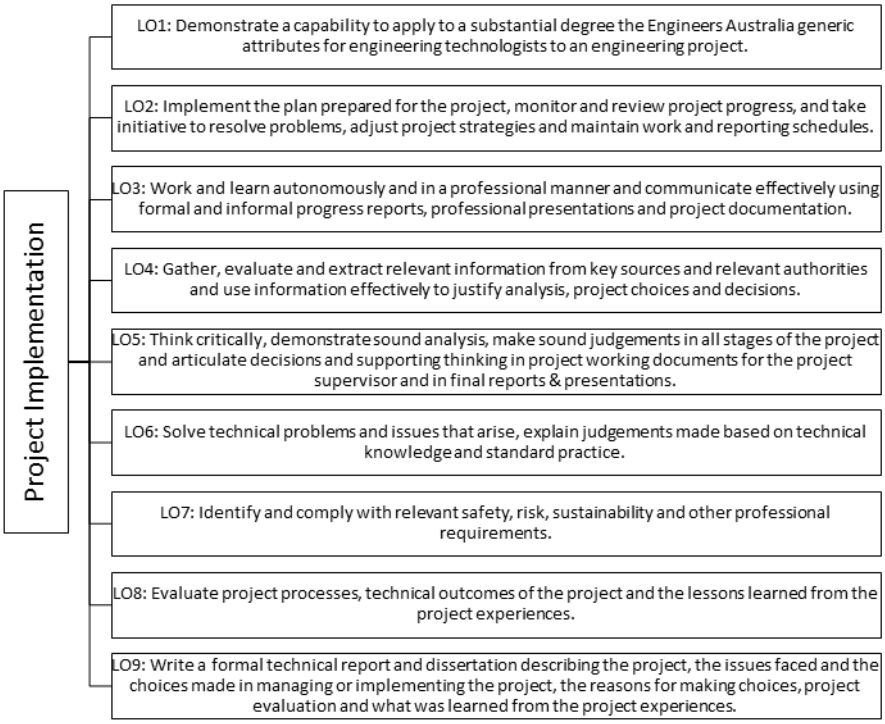

Figure 1: Hierarchy of "Project Implementation" Course Learning Outcomes

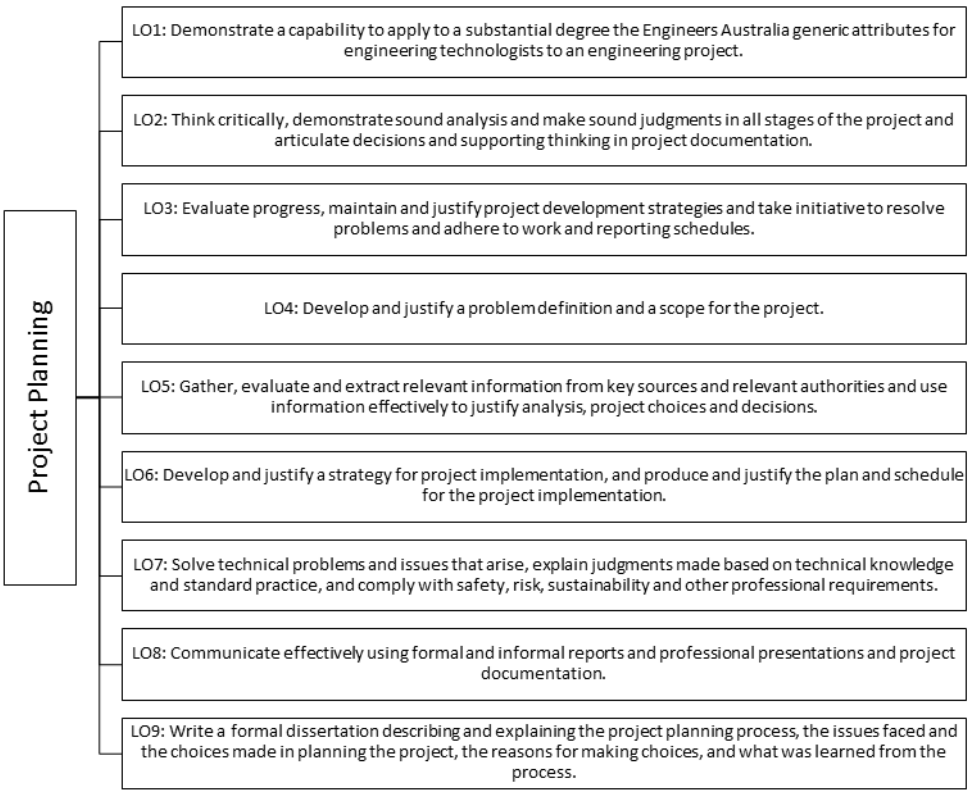

Figure 2: Hierarchy of "Project Planning" Course Learning Outcomes

After ensuring the consistency of the decisions made, the focus would be on aggregating the opinions of various individuals and creating a combined holistic ranking of the learning outcomes (Regan *et*

al., 2006). The most common and practical route to aggregating the group weighting is by using a summarized AHP weight across the group (Xu, 2000), the aggregate crisp judgment matrix. This method entails that all the weights extracted from the participants would be added and averaged to determine which weight has the highest average value and then rank the criteria accordingly.

4 Results

After collecting the data and organizing it in a matrix, the consistence index (CI) of the eigenvalues was calculated to measure the respondents' decisions consistency. A threshold of 10% was selected (Saaty, 1990) and resulted in eliminating the data collected from two respondents (in both courses) as they indicated inconsistent decision making (CI was above 10%). The remaining respondents provided responses with the consistency of these judgements being sufficient to answer the questions of this research and establish the ranking of the learning outcomes for both courses. Additionally, the resulting number of respondents (seven per course) is considered adequate for fuzzy AHP since it does not require a large sample (Lam and Zhao, 1998). The aggregate crisp judgement matrix for the respondents was calculated as shown in Table 3 and Table 4. The overall weight of each criteria (learning outcome) for both courses was determined through the calculation of eigenvector and their corresponding ranking is shown in Figure 3 and Figure 4. The ranking of the learning outcomes is then established and shown in Table 5.

Table 3: The aggregate crisp judgement matrix for the project implementation course

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C1	1.00	0.12	0.12	0.12	0.12	0.12	0.14	0.12	0.32
C2	8.68	1.00	2.52	3.54	2.52	3.54	0.40	3.54	3.00
C3	8.68	0.40	1.00	3.56	0.28	0.28	0.85	3.56	2.00
C4	8.68	0.28	0.28	1.00	0.50	0.50	0.50	1.00	3.00
C5	8.38	0.40	3.56	2.00	1.00	0.50	0.50	2.00	3.00
C6	8.68	0.28	3.56	2.00	2.00	1.00	1.00	2.00	2.00
C7	7.26	2.52	1.17	2.00	2.00	1.00	1.00	2.12	3.00
C8	8.68	0.28	0.28	1.00	0.50	0.50	0.47	1.00	2.00
C9	3.13	0.33	0.50	0.33	0.33	0.50	0.33	0.50	1.00

Table 4: The aggregate crisp judgement matrix for the project planning course

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C1	1.00	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.25
C2	9.00	1.00	3.00	1.00	3.00	1.81	0.55	1.81	3.00
C3	9.00	0.33	1.00	1.81	1.81	0.50	0.33	1.00	2.00
C4	9.00	1.00	0.55	1.00	0.50	0.50	0.50	1.00	2.00
C5	9.00	0.33	0.55	2.00	1.00	0.50	3.00	0.61	2.00
C6	9.00	0.55	2.00	2.00	2.00	1.00	0.61	2.00	3.00
C7	9.00	1.81	3.00	2.00	0.33	1.64	1.00	4.00	3.00
C8	9.00	0.55	1.00	1.00	1.64	0.50	0.25	1.00	3.00
C9	4.00	0.33	0.50	0.50	0.50	0.33	0.33	0.33	1.00

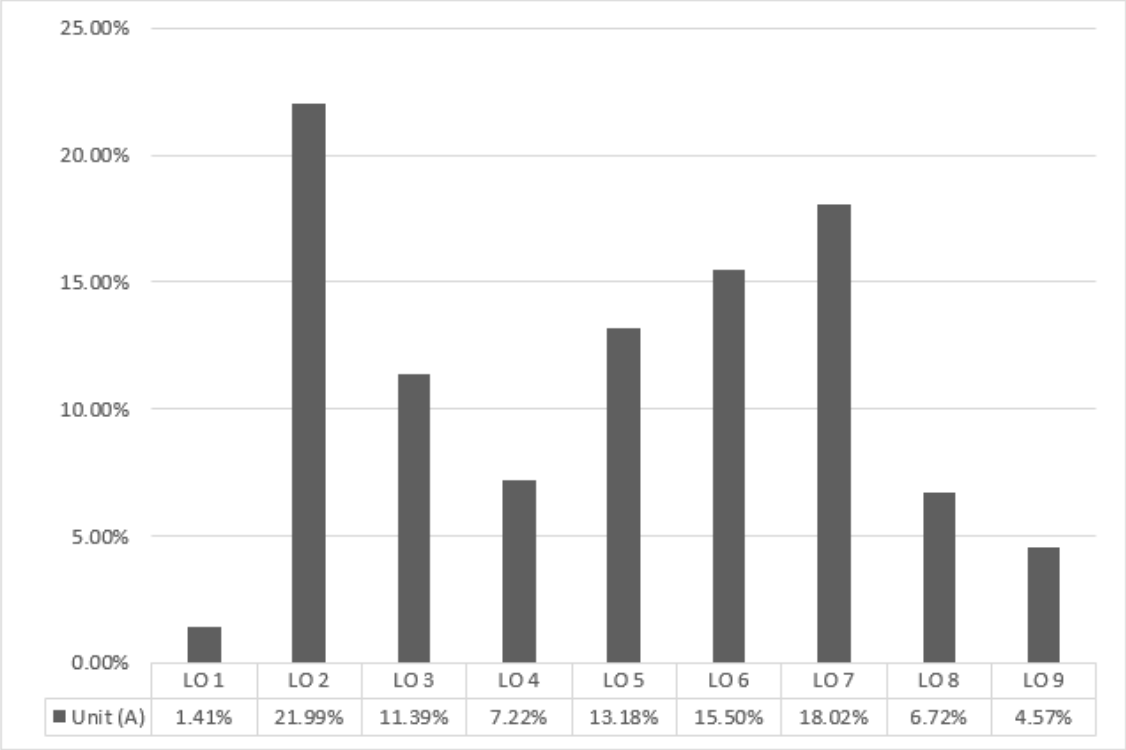

Figure 3: Eigenvector corresponding ranking for the "Project Implementation" course

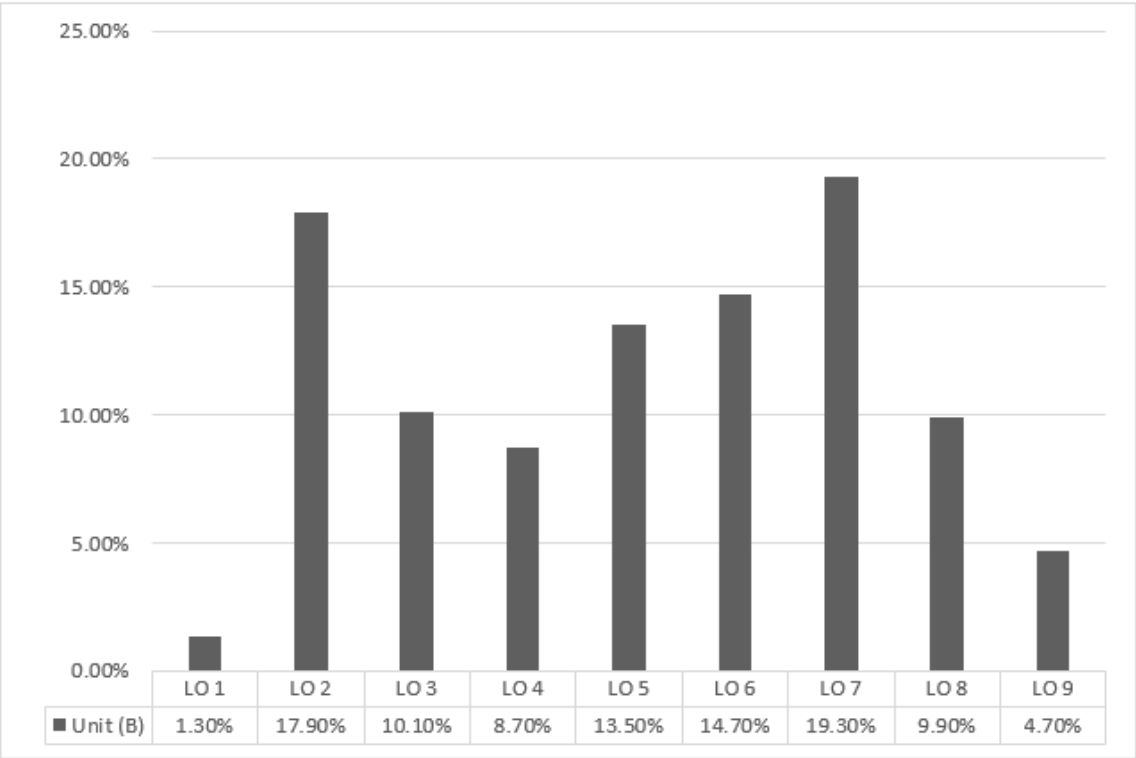

Figure 4: Eigenvector corresponding ranking for the "Project Planning" course

Table 5: The learning outcome rankings in the "Project Implementation" and "Project Planning" courses

Project Implementation Course		Project Planning Course	
Learning Outcomes	Ranking	Learning Outcomes	Ranking
LO1	9	LO1	9
LO2	1	LO2	2
LO3	5	LO3	5
LO4	6	LO4	7
LO5	4	LO5	4
LO6	3	LO6	3
LO7	2	LO7	1
LO8	7	LO8	6
LO9	8	LO9	8

5 Discussion

The rankings of both courses' learning outcomes were qualitatively generated through the fuzzy AHP process. This ranking represents the importance of each learning outcome which could be used within the grading scheme of the courses. The grade granted to the students by being competent in a learning outcome should be aligned with the importance of the learning outcome itself. For instance, LO2 in the project implementation course and LO7 in the project planning course should be assigned the biggest weight since these learning outcomes come in as the most important as per the ranking in their courses. When it comes to the exact percentages, the overall weight of each learning outcome in the eigenvector could be used as a guideline to develop the weights of learning outcomes of both courses as shown in Table 6. The table features the weights that are like the eigenvector weights that resulted from aggregating the respondents' opinions, but these weights are rounded to provide a whole number. The reason behind this rounding is to increase the ease of use in the grading process and having a clearer number. These weightings are set as an example of how a course's learning outcome weight can be generated based on the importance of its learning outcomes.

Table 6: The potential grading criteria of "Project Implementation" and "Project Planning" courses

Project Implementation Course		Project Planning Course	
Learning Outcomes	Weight for grading	Learning Outcomes	Weight for grading
LO1	1%	LO1	1%
LO2	22%	LO2	18%
LO3	11%	LO3	10%
LO4	7%	LO4	9%
LO5	13%	LO5	13%
LO6	16%	LO6	15%
LO7	18%	LO7	19%

LO8	7%	LO8	10%
LO9	5%	LO9	5%

The identified weights of learning outcomes show that the most important learning outcome is twenty-two times more important than the least important learning outcome in one course, while the other course shows that the most significant learning outcome is nineteen times more important than the least significant learning outcome.

It is clear from the rankings of both courses that LO1 came in as the least significant learning outcome. This may be a result of the redundancy of this learning outcome with the other learning outcomes. This means, LO1 is basically a summary of all other learning outcomes, and the need for such a summary learning outcome is not clear. Therefore, the institution may consider to remove LO1 from these courses.

6 Conclusions

Based on the fuzzy AHP approach, the ranking of the learning outcomes of two different PBL courses was carried out to comprehend the relative importance of these learning outcomes. When looking at the ranking of the learning outcomes, it turned out that a learning outcome can have up to twenty-two times more importance than another learning outcome in the same unit. This difference of importance can set the path for potentially creating weighted learning outcomes for PBL courses according to the concluded importance. It is apparent that the preference of the learning outcomes' importance was skewed towards what is actually specific and relevant learning within these courses.

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Problem-Based Learning – Best Practices for Freshman Engineers in Physics and Chemistry Classes

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Abstract

Since 2014 freshman engineering students at Instituto Mauá de Tecnologia have been working with a Problem-Based Learning (PBL) approach on Chemistry and Physics subjects. This paper analyses the activities developed and shows some reflexion about the introduction of PBL methodologies in those subjects, best practices and how to improve them.

Keywords: PBL, Chemistry, Physics

Type of contribution: best practice paper.

1 Introduction

In our institution, the subjects of Physics and Chemistry has theoretical classes (4 hours in Physics and 2 hours in Chemistry), and 2 hours a week in laboratory activities for each of these subjects. In laboratory classes, students must carry out experiments related to the contents covered in theory. This constitutes a demanding situation, because most of the students have some degree of difficulty in assimilating the concepts and in stablishing the right connections between practice and theory (Cutri *et al.*, 2015), (Cutri *et al.*, 2016).

Students motivation can be achieved through meaningful real situations that challenge their problem-solving abilities, their grasp of the concepts and their capacity of innovative thinking.

The adoption of active learning techniques, such as project development through problem-based learning (PBL), develops numerous skills like critical thinking, information processing, analysis and reflection (Prince, 2004), (Du, X.; De Graaff, E.; Kolmos, A., 2008), (Goodhew, 2010), (Ribeiro, 2011), (Fraser *et al.*, 2014), (Rossi, 2015).

In order to improve the academic skills of analysis and modelling, the following activities were proposed:

- scientific thinking and reflection using physical problems;
- application of real problems in open projects;
- setting a goal and providing the necessary tools but not a roadmap to reach it or proposing a task and providing the necessary tools but not a guide to its completion.

In Physics, each year, a universe of 1000 freshman students is divided in four membered teams that are given a problem for them to simulate, evaluate, compare and analyse mechanical concepts using software analysis. All problem based learning activities are done as extra class lab activities, the groups are supposed to solve open and closed problems using prior knowledge (previously seen in class) and new knowledge (acquired from their own research on the subject).

The subject of Physics in divided into 4 hours of theoretical classes and 2 hours of laboratory activities per week. The introduction of PBL activities in an out-of-class approach was held to allow greater involvement of the students in simulation and analysis situations. This methodology also allowed teachers to use face-to-face classes to show experimental demonstrations and presentation and to reinforce some Physics concepts.

The teacher works as a facilitator and moderator of such activities. Each semester, three procedures developed throughout the semester are applied using PhET (Physics Education Technology from Colorado University) activities, video analysis and conceptual questions. In a biannual assessment, students present their results in a seminar and there are also oral and written individual evaluation tests. Finally, an auto-evaluation survey is applied in order to make students evaluate their learning process.

At the same, In Chemistry, the lab students (around 1000) are divided in two or three-membered teams. Each group receives equipment and reagents to solve two challenges: build an electrochemical cell with the best output voltage possible and identify the electrolyte present in an aqueous electrolysis using inert electrodes.

2 Best practices for freshman engineers in physics classes

To pursuit PBL objectives, annual projects were proposed with the following common characteristics:

- working in groups (four-membered teams, resulting in six groups in each lab class);
- number of students undergoing activity: 1000 (65% enrolled in morning courses and 35% in evening courses) divided in laboratories with 24 students each;
- all the activities presume extra classroom work with supervision and evaluation by laboratory teachers;
- each team works on a script with open solution problems using software analysis, research and engineering problem analysis;
- also each team must do an Oral Examination test so the teacher can see if the physics concepts were correctly understood;
- the PBL activities compose 25% the laboratory semiannual grade. That relevant percentage motivates students to engage in the projects.

2.1 Designs characteristics

Scripts mix open and closed problems. An overview of the learning goals and related activities can be seen in the Appendix. In open-ended problems, there is not any procedure to be followed, but a goal to be achieved. In order to solve the problems, students must identify variables and use the scientific method, performing planned experiments, not random tests.

In this methodology, the teacher only works as a facilitator and moderator of such activities. Also, the teacher is allowed to clarify some aspects about the activities during regular theory/laboratory classes, although such interventions are not previously scheduled for the semester. The scripts and general guidelines for the activities are self-explanatory. Each semester, three procedures are applied. The proposed activities could be summarized by: pictures of practical situations and their analysis, simulations by using PhEt (PhEt, 2016) or Tracker softwares (Tracker, 2016), solving numerical problems, and analysis of videos and building prototypes. Two facts are worth mentioning: a) in first, second and sixth scripts, students have to solve numerical problems with their groups and b) in the sixth script, students have to

build a prototype of a planar truss and discuss the forces that act on it when loaded. All scripts are available at (MIT, 2017).

In the biannual assessment, students present their results in a seminar and there are also oral and written individual evaluation tests. Finally, an auto-evaluation survey is applied.

The quantitative and qualitative analysis of the survey's results, for each PBL edition (Cutri *et al.*, 2016), allows teachers to do a SWOT analysis. Table 1 shows the analysis based on the three PBL editions already held.

Table 1 – SWOT analysis – Teacher's perception

	Strengths	Weaknesses	Opportunities	Threats
PBL projects	Active and meaningful learning through open-ended problems and simulations	Resistance (students sometimes prefer attending lectures and traditional classes)	Engage students in situations that promote better learning of the concepts involved	New problems need to be proposed every year

The quantitative analysis of the last three editions shows that around 80% of the students support the project and consider it encouraging. In general, most students perform very well during the semester, getting excellent grades (above 85 out of 100).

Positive and negative aspects:

Working in groups, students engaged in the project listed the following positive aspects:

- putting in practice concepts learned during theory class motivated students;
- using real and actual problems is a better approach to get compromise from students;
- the understanding of Physics concepts is very important to improve knowledge.

And negative:

- scripts are not same length, sometimes they're too long;
- the project runs simultaneously with other demanding activities, turning its execution a hard work;
- teachers should give more information about how to solve the problems.

According to the survey conducted with both day and night classes students, 70% of the students said that the approach was successful in making them improve their knowledge, while 20% were indifferent and 10% claimed the proposed model had no effect. This result has remained almost unaltered throughout the years.

2.2 PBL methodology in traditional classes

Grades comparison between students is hard to carry out since students vary as do problems. It was observed, however, that they seem to achieve higher positions of Bloom's Taxonomy, which means a qualitative improvement on students' cognitive skills.

From interviews conducted with teachers, it was noticed that conceptual gains are more robust than those obtained employing only written tests as tools of trade. Students showed more motivation, but a better understanding of concepts is needed (the use of a Tracker video analysis software demanded a deep explanation about it). Moreover, they also improved their communication skills and teamwork, which are key to the practice of engineering (teachers noticed a great improvement from first to second semester presentation). Oral evaluation, despite less homogeneous (due to the need to diversify questions for each group) allows teachers to better analyse the students' performance and involvement by demanding active participation.

3 Best practices for freshman engineers in chemistry classes

In Chemistry laboratory classes, the students had two goals to achieve in this PBL activity:

1: Build an electrochemical cell with the highest output voltage possible, comparing the experimental result with the projected one;

2: Identify the components of an unknown given electrolyte, after verifying experimental evidences generated in its electrolysis.

To achieve such PBL objectives, the experiments are proposed under the following conditions:

- working in teams (two or three students per team), with a maximum of eight groups in each laboratory (around 24 students total);
- based on previous concepts and knowledge, the team must finish the task without teacher's interference;
- each team should not employ material and resources allotted for another team;
- only the equipment and reagents available in the laboratory could be used;
- each team had a different set of reagents and electrolytes. This setup is defined by a "raffle" among all the teams in the laboratory;
- the experimental results must be analysed in a written report, evaluated later by the teacher;
- the reports must show the setup and conditions. The data collected must follow the standard units and the expected precision of the instruments available. This knowledge was presented in previous classes and activities;
- the experimental work of the students is also graded to ensure that proper procedures are followed.

3.1 Designs characteristics

The challenges were proposed as open problems; even if the results are more or less expected, the strategy that each team follows has a reasonable degree of freedom.

The task of identifying variables and how to cope with them is demanding and sparks a good measure of planning, reflection and scientific thought.

The teacher acts only as an observer, with minimum interference only to avoid potential hazardous situations.

The students could peruse the written content of previous experiments to draw examples and insights applicable to the task at hand.

The grades attributed encompass not only the numerical results but also evaluate the efficiency, organization of the students and their capacity to work in a common environment without interfering (willing or not) with the progress of the others teams. Foul play, lack of cooperation, hazardous behaviour, lackadaisical attitudes and wrong procedures result in lower grades even when the proposed goals are achieved. Special attention is focused on the proper disposal of the residues.

4 General lessons learned from the past three years

The experience suggests that:

• students become inspired and feel connected to the problems. There must be a sense of purpose and meaning. A good PBL approach must make learning meaningful.

• in order to avoid students to stray too far from their set goals, teachers should be prepared to show the boundary conditions for each problem. As facilitators, teachers should only lead the way encouraging students to solve the problems themselves.

• assessment results become more clear (both process and final result are verified). In active learning approach, the final results are sometimes less important than steps taken to get there. The oral examination allows the teacher to check if the student has either used a scientific methodology to solve the problem or if it was simply trial and error. Students must know what they are doing as they complete the task. This approach allows students to prevent and correct their mistakes and also leads them to an improved performance in future challenges.

• all activities must be in accordance with the available digital and material resources (internet, computer, softwares, textbooks, report guidelines...) that students have access to.

• rewarding students for achieving set goals with grade increments, certificates or symbolic prizes like medals or trophies motivates students. By promoting certain competition among the teams through open-ended problems, students tend to take up the challenge in order to stand out. Creativity must be encouraged and rewarded.

5 Final considerations and future perspectives

The use of active learning methodologies like problem-based learning was very positive. Students showed a better understanding of the relationships between physics and chemistry concepts and practical applications on engineering. In general, students showed a greater commitment to the idea.

One of the future perspectives for this research it to assess the medium-term impact of the activities carried out, by questions like: "What perceptions do sophomore/junior/senior students have regarding the contributions of such activities? How can we define the relationship among time employed, concepts addressed and competence development? What activities could be jointly held by Physics and Chemistry subjects in order to promote greater integration between them and develop desired competences?"

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Appendix

In following, Table 2 present a summary of the scripts to be developed by the students.

Script	Objectives	Simulations	Analyzing Videos/ Reading texts
1st	Identifying forces on mechanical systems (building free body diagrams from pictures of objects); Studying vectors and their properties	Practicing vectors and their properties (addition, obtaining components and so on) with Phet software [a]	Watching and commenting video "engineering an effective team"[b]
2nd	Studying equilibrium of paralell forces and momentum of force	Studying equilibrium of parallel forces: a) to obtain the equilibrium of three body with known masses, discovering the position of one of them and b) to discover the mass of one of the objects with software Phet [c]	_____
3rd	Studying movement: launching projectiles in a plane	Studying parameters of launching projectile in a plane. Software used Phet [d]; Understanding that the launch of projectile in a plane. Software used Phet [d] Analyzing an experiment using tracker [e]	Watching and commenting one of the videos of engineering challenges. [f] Reading a text about the history of launching projectiles [g]
4th	Studying balance of energy in conservative and non-conservative systems	Simulating the changes of energy enrolled in a skate track without friction; Simulating the changes of energy enrolled in a skate track with friction; Studying chans of energy when the type of track is also changed. Phet Software used [h]	Analyzing the Water Park and the paper of water in these equipment's.
5th	Studying collisions, analyzing vectorial representation before and after collisions and identifying the several types of collisions	Simulation of collision in a plane and studying the linear momentum conservation. Phet Software used [i]	Correlating the movie "The Fast and the furious". Studying historical evolution of the concepts of energy/ linear momentum [j] Studying enviromental impact during the project of packages and the collisions during their

			transport [k] Watching video about collisions and giving two examples of each type [l]
6th	Learning tension and compression forces in equilibrium systems by using examples of application. [m] ; Learning about trusses and their applications		Watching video about truss bridges and discussing about the importance of trusses [n]

Web site activities references

[a] https://phet.colorado.edu/pt/simulation/vector-addition
[b] Engineering An Effective Team, YouTube video, https://youtu.be/JkWlKstUl_s
[c] https://phet.colorado.edu/sims/html/balancing-act/latest/balancing-act_en.html
[d] https://phet.colorado.edu/pt_BR/simulation/projectile-motion
[e] http://physlets.org/tracker/
[f] http:// www.engineeringchallenges.org/
[g] http://repositorium.sdum.uminho.pt/bitstream/1822/23542/1/Lancamento%20de%20 Projeteis.pdf
[h] https://phet.colorado.edu/pt/simulation/energy-skate-park
[i] https://phet.colorado.edu/pt/simulation/collision-lab
[j] http://dfis.uefs.br/caderno/vol9n12/PatrickPonczek.pdf
[k] Packaging test - http://www.intertek.com/packaging/testing/
[l] Collisions, YouTube video, - https://youtu.be/LUXvU34HASI
[m] http://www.pbs.org/wgbh/buildingbig/lab/forces.html
[n] http://www.pbslearningmedia.org/asset/phy03_vid_bbtrussanim/

TABLE 2 - A summary of the scripts to be developed by the students.

Table 3 presents a summary of the proposed activities with their correspondent goals of learning practice. The scripts were elaborated aiming first that students acquire a practical view about what was taught in theory classes and latter, giving the opportunity to them to develop the several skills that are necessary to build up a good professional, such as comparing theory to practice by using soft wares, working in group, training oral presentations, developing skills of projecting (learning the limitation between cost and benefits).

Table 3: Types of proposed activities on the scripts and learning practice goals.

Types of proposed activities on the scripts	Learning practice goals
Pictures and analysis	Opportunity of identify the concepts learned in classroom in day by day activities
Simulations (Phet and Tracker softwares)	Predicting behavior of practical situations and evaluating the results according the learned theory
Numerical solution problems	Practicing in another environment the solution of problems as a group activity
Watching videos and analysis/ Reading texts	Illustrating practical situations of the learned concepts and evaluating their capacity of identify the concepts in those situations.
Building prototypes	Developing skill of projecting.

Experiencia significativa de cambio e innovación a través del PBL aplicado al diseño digital

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Abstract

La desmotivación los bajos resultados académicos, la dificultad para poner en práctica lo aprendido y la descontextualización del conocimiento, fueron algunos de los elementos que llevaron a la necesidad de cambio en el modelo de enseñanza aprendizaje en el área de electrónica digital en la Universidad Nacional de Colombia.

Este proceso sistemático, inició con la revisión y el re-diseño curricular basado en la iniciativa CDIO que implementó el Departamento de Ingeniería Eléctrica y Electrónica de la Universidad Nacional de Colombia sede Bogotá, en el cual se da un mayor énfasis a la concepción, diseño e implementación. Sin embargo, trasladar este currículo al aula de clase requiere un modelo pedagógico adecuado. El modelo de pedagogías activas Aprendizaje Basado en Proyectos (ABPr) está compuesto por 5 fases que se adaptan al flujo de diseño de sistemas digitales (Identificación y definición del problema, Diseño y planificación, Implementación, Evaluación y Socialización), al tiempo que permiten el desarrollo de habilidades relacionadas con el emprendimiento, el trabajo en equipo y la auto-dirección del aprendizaje. El trabajo aquí presentado resume los resultados de la aplicación del ABPr a un currículo basado en CDIO para el área de electrónica digital.

Dentro de este proceso, la re significación de roles docente - estudiante ha jugado un papel fundamental en el éxito del modelo, entregando el protagonismo de la construcción del conocimiento al estudiante a través de la orientación de su conducta a metas claras y definidas, las cuales están basadas en necesidades del contexto (social, cultural, afectivo, económico, etc.) que son atendidas desde el área a través de la creación de proyectos, los que el docente guía, brinda herramientas y acompaña.

Finalmente, se implementa un método de evaluación enfocado en un modelo de realimentación basado en el agente y que toma el feed up, el feed back y el feed forward como estructura fundamental para la mejora continua del proceso, del docente y del estudiante. Durante esta experiencia se ha podido evidenciar una mejora considerable en la autodirección del aprendizaje, interés en el emprendimiento dado por la oportunidad de vender ideas a través de los productos diseñados y se ha generado inquietud en docentes y estudiantes de otras áreas, sobre formas innovadoras de construir conocimiento.

Keywords: Re-diseño – Autodirección – Innovación – Emprendimiento – Ingeniería.
Type of contribution: Mejores prácticas educativas

1. Introducción

El enfoque de competencias implica cambios y transformaciones profundas en los diferentes niveles educativos, y seguirlo es comprometerse con una docencia de calidad, buscando asegurar el aprendizaje de los estudiantes (Tobón, 2006).

Aprendizaje, que necesariamente debe ser logrado a través de la experiencia, del descubrimiento, de poner en contexto el conocimiento y de reconocer la necesidad de cambio en la estructura del pensamiento del

docente, del imaginario del estudiante y de la organización interna del aula y de las áreas que se imparten en el marco de un programa de formación en educación superior.

La iniciativa CDIO nace de la necesidad de devolverle a la enseñanza práctica (en ingeniería) el lugar que había perdido en los últimos años, empresas como Boeing y el Instituto Politécnico de Rensselaer, con el ánimo de hacer que las Universidades fijen sus metas en las necesidades del mundo real y modifiquen sus métodos de enseñanza, generan una lista de habilidades que buscan en sus ingenieros: "Conocimientos fundamentales en ciencia, conocimientos profundos en procesos de diseño y manufactura, perspectiva multidisciplinaria y sistémica, comprensión básica del contexto económico y habilidades de comunicación, estándares éticos, habilidades críticas y creativas, flexibilidad y trabajo en equipo"; Ron (2015) fundamentándose en éstas, en las nociones del Massachusetts Institute of Technology, el aporte de académicos, industriales, ingenieros y estudiantes crea la iniciativa CDIO. Esta, se basa en la suposición de que los egresados de los centros de formación en ingeniería deben ser capaces de: Concebir, Diseñar, Implementar y Operar sistemas funcionales en el mundo real. En Colombia, una parte importante de las universidades enfocan sus programas al análisis y operación de sistemas digitales, descuidando la concepción, diseño e implementación, lo que impide que se generen habilidades necesarias para crear productos innovadores que satisfagan necesidades del mundo real (empresas o público en general). La frase del mundo real resalta la importancia de trabajar en la solución de problemas que pueden encontrarse en el ejercicio profesional, lo que es muy difícil de determinar cuando los docentes no tienen un contacto frecuente con él. Actualmente la iniciativa CDIO está siendo adoptado por un número creciente de instituciones de educación en ingeniería de todo el mundo (Ron y Malmqvist, 2015). Sin embargo, la estructura del CDIO no propone una estrategia pedagógica en el aula que permita crear o reforzar las habilidades deseadas, y se centra en la estructura del currículo y como este debe modificarse para alcanzar los resultados deseados del programa.

El Departamento de Ingeniería Eléctrica y Electrónica (DIEE) de la Universidad Nacional de Colombia ha implementado la iniciativa CDIO en sus programas de pregrado, el trabajo aquí presentado habla específicamente de la implementación en el área de Electrónica Digital, la cual, está compuesta por tres asignaturas para la carrera de Ingeniería Electrónica: Electrónica Digital 1, Electrónica Digital 2 y Sistemas Embebidos y por electrónica Digital 1 para Ingeniería Eléctrica.

Para Concebir, Diseñar, Implementar y Operar sistemas funcionales en el mundo real, es necesario dar soluciones tangibles a los problemas, es aquí donde la estrategia pedagógica Aprendizaje Basado en Proyectos (ABPr) ayuda a definir las fases que deben tenerse en cuenta para definir el problema a resolver y llegar a la implementación física.

En este proceso, es importante tener claridad sobre las bases teóricas del ABPr con el fin de comprender el camino que se recorrió desde una metodología tradicional hasta la pedagogía por proyectos.

Partiendo del constructivismo como corriente pedagógica que muestra cómo llegar al conocimiento de una forma activa, participativa y experiencial, tal y como lo expone el Aprendizaje significativo propuesto en los años 60 por David Ausbel quien establece relaciones funcionales entre lo que se conoce, con lo que está por conocerse dando cuenta de los mecanismos a través de los cuales se lleva a cabo la adquisición y retención de los conceptos, teorías y temáticas que en general se imparten en las instituciones educativas. Estos cuerpos de conocimiento han sido transmitidos a los estudiantes a lo largo del tiempo usando métodos de memorización de datos sin contexto, donde es el docente quien determina qué, cómo y en qué tiempos deben aprender cierta disciplina, dificultando al aprendiz la importante tarea de llevar a la práctica lo aprendido, de desarrollar habilidades y competencias necesarias para el mundo del trabajo y en general para la vida.

Esta realidad educativa, acompañada de bajos resultados de aprendizaje efectivo, desmotivación y absentismo se evidencia en las aulas de la Universidad, esto, junto con el análisis, la adaptación y adopción del modelo CDIO, llevó a explorar diferentes formas de construir conocimiento que permitiera tener al estudiante como el centro del proceso educativo y poner en contexto los conocimientos a través de una pedagogía por proyectos como el ABPr.

Esta estrategia pedagógica representa una riqueza funcional y estructural para docentes y estudiantes que participan en ella, funcional, ya que parte de atender factores motivacionales en el proceso de aprendizaje (elemento olvidado en el modelo tradicional); al permitir al estudiante involucrarse en su proceso de aprendizaje se aumenta de forma significativa la motivación, incrementando su autoestima, autoconfianza, valía personal y sentido del "yo". Estructural, ya que involucra a la comunidad educativa (directivos, docentes, estudiantes, padres de familia) en el proceso de identificar las necesidades del contexto para trabajar sobre la realidad circundante del estudiante y del docente, a partir de la cual se "Identifica y Define un problema (Fase 1 del ABP - Planteamiento "Concebir" del CDIO)" qué será abordado, atendido y trabajado a lo largo del proceso.

El ABPr como estrategia pedagógica representa una oportunidad para construir mucho más que conocimientos sobre áreas específicas, ya que permite desarrollar en los jóvenes competencias transversales como la autodirección del aprendizaje, haciéndolos capaces de orientar su conducta a metas, monitorear sus avances y retrocesos en un proceso de mejora continua, realizar trabajo colaborativo potenciando habilidades comunicativas, pensamiento crítico, creativo y analítico; todo en el marco del "Diseño y la Planificación (Fase 2 del ABP - Planteamiento "Diseñar" del CDIO)".

Todo lo que implica el proceso de diseñar y planificar la forma más apropiada para dar solución a un problema, permite al estudiante establecer sus necesidades de aprendizaje, identificar con qué habilidades cuenta, qué conocimientos requiere, cuáles de ellos tiene y cuales debe consultar, comprender y construir a través de la práctica en el desarrollo del proyecto; articular las diferentes áreas del conocimiento propias de la disciplina yendo más allá de las temáticas establecidas en un plan de estudios, convirtiendo esta estructura curricular en un esquema de tipo circular en el que es posible abordar de forma "desordenada" los contenidos propios del área, tomándolos a demanda del problema identificado y de las necesidades de los estudiantes. Bondades claras de la estrategia que permiten comprender el porqué de su adopción para los cursos del área de electrónica digital.

En todo este proceso de construcción del conocimiento la parte que desde la perspectiva de los ingenieros docentes y de quienes han aplicado el modelo de pedagogía por proyectos representa el mayor reto y a su vez el mayor valor de aprendizaje, es la "Implementación (Fase 3 del ABPr - planteamiento "Implementar" del CDIO)" dado que es justamente en ésta fase en la que el estudiante pone en juego todas sus destrezas cognitivas, funcionales, y estructurales que lo llevarán a construir la solución tangible de su proyecto, tal y como lo plantea el CDIO cuando menciona que "los ingenieros deben construir sistemas y productos para el mejoramiento de la humanidad" lo que implica un alto nivel de exigencia, con estándares de calidad y efectividad que garanticen la solución al problema. Tener las capacidades y competencias suficientes para lograr dicho reto, requiere de una preparación profunda que necesariamente debe darse durante la formación universitaria.

Desde la iniciativa CDIO, Operar atiende a la utilización del producto o proceso implementado para entregar el resultado esperado, incluyendo el mantenimiento y el perfeccionamiento, lo que desde la estrategia ABPr se encuentra en las "Fases 4 y 5 Evaluación y socialización" en las que se presenta el producto o servicio a la sociedad (grupo objetivo para el que fue pensado y/o creado el proyecto) con el fin de que sea evaluado y mejorado si es el caso, atendiendo siempre al proceso que llevó al resultado final. Para ello, la fase de evaluación es fundamental y debe hacerse de forma diferencial en cuanto a procesos se refiere, por ello para la experiencia que comparte este trabajo se implementó un modelo de retroalimentación centrada en

el agente (auto, hetero y co evaluación) que a través del feed up, feedback y feedforward permite hacer un proceso de seguimiento continuo a la construcción del conocimiento del estudiante, a la forma de orientar del docente y a la estrategia misma como herramienta pedagógica de aprendizaje activo.

De esta forma el proceso de evaluación manejado de manera transversal lleva a los estudiantes y docentes a un proceso de reestructuración cognitiva a través del cual comprenden que los resultados obtenidos en cuanto a calificación y aprendizaje dependen de las acciones que emprendan durante todo el proceso y de la orientación de su conducta a metas establecidas con antelación, lo que finalmente se ve reflejado en interés y compromiso con un aprendizaje de calidad.

Los requerimientos que la sociedad tiene para un ingeniero, obliga a que la academia ofrezca una formación sólida en competencias específicas y transversales y que se desarrollen durante todo su proceso en educación superior de manera integral. El CDIO plantea la construcción de bloques de conocimientos, habilidades y actitudes necesarias para Concebir, Diseñar, Implementar y Operar Sistemas en la Empresa y la Sociedad: Conocimientos técnicos y razonamiento (conocimiento científico - Fundamentos de ingeniería - Fundamentos avanzados de ingeniería), habilidades personales y profesionales (Resolución de problemas - creatividad - sistemas de pensamiento) y habilidades interpersonales (Trabajo en equipo y comunicación). Desafortunadamente, el perfil académico que prima en la mayoría de los docentes de las facultades de Ingeniería unido a su poca o nula experiencia en desarrollo de proyectos tangibles ha reducido a niveles críticos la experimentación con sistemas reales lo que impide el desarrollo de habilidades necesarias para el entorno laboral colombiano. Estas competencias son ampliamente trabajadas en la experiencia significativa que se presenta en este artículo, cada una de ellas abordada a través de las temáticas propias de las áreas de Electrónica Digital y Sistemas Embebidos y de las fases que contempla el ABP como estrategia pedagógica innovadora para construir conocimiento.

Por otro lado, estudios como el realizado por Surif, Ibrahimb y Mokhtarc (2013) sobre la implementación del Aprendizaje Basado en Problemas en la Educación Superior y su impacto en el aprendizaje de los estudiantes, muestran qué el ABP tiene un impacto positivo en el aumento de la motivación de los estudiantes, el autoaprendizaje y las habilidades específicas y transversales, dado que éste utiliza problemas de aprendizaje como herramienta para alentarlos a pensar críticamente. Así mismo las actividades de aprendizaje grupal y los roles de liderazgo ayudan a desarrollar las habilidades de comunicación y colaboración.

El estudio adelantado por Aliane y Bemposta (2008) sobre la experiencia de introducción del ABP en una asignatura de la facultad de Ingeniería en informática de la Universidad Europea de Madrid, (España), indica que el carácter multidisciplinar de la ingeniería hace que sea flexible para la implementación de la metodología ABP, el aspecto lúdico del proyecto permitió mantener un nivel de motivación muy alto, y no solamente, desarrollar las competencias específicas relacionadas con el manejo de las tecnologías afines a la robótica y en sí la ingeniería, sino también desarrollar competencias transversales como el trabajo en equipo, la planificación y la autodirección.

Finalmente Camargo (2011) en su Tesis doctoral sobre Transferencia tecnológica y de conocimientos, demostró cómo el diseño y uso de plataformas didácticas (tarjetas de desarrollo junto a una metodología de diseño), aporta a la difusión del conocimiento y a la solución de problemas locales, orientando la construcción del conocimiento de sus estudiantes de pregrado en Ingeniería Eléctrica y Electrónica de la Universidad Nacional de Colombia a través del modelo ABPr, brindándoles las herramientas tecnológicas, personales (competencias genéricas: pensamiento analítico, lógico, trabajo colaborativo y autorregulación) e intelectuales necesarias para generar ideas, productos y proyectos en pro de la sociedad colombiana.

2. Inicios

En las asignaturas del área de Electrónica digital del Departamento de Ingeniería Eléctrica y Electrónica de la Universidad Nacional de Colombia no se habían introducido grandes cambios desde hace más de 20 años. Esto desde el punto de vista tecnológico es injustificado ya que la industria de los semiconductores ha realizado avances muy grandes reduciendo el costo de los componentes electrónicos, aumentando el número de componentes en los circuitos integrados y facilitando su programación y pruebas; del mismo modo, la industria del software ha creado entornos de desarrollo abiertos que permiten diseñar placas de circuito impreso y programar los dispositivos semiconductores, esto con la ayuda de los fabricantes quienes aportan librerías para usar fácilmente sus productos.

Por otro lado, la literatura disponible no es adecuada para sacarle provecho a los avances mencionados anteriormente, esto, debido a que las nuevas versiones de los textos más usados no realizan cambios metodológicos sino que se centran en actualizar las herramientas utilizadas, es así como pasan de explicar las familias lógicas TTL y CMOS al uso de lenguajes de descripción de Hardware (VHDL, Verilog) dejando intacta la metodología de diseño, que en su mayoría es la conocida como Botom-up la cual se centra en la experiencia del diseñador, lo que no es adecuado para estudiantes que se inician en el diseño.

Lo anterior unido a métodos tradicionales de enseñanza desactualizados que centran sus esfuerzos en tareas que pueden ser realizadas por computadores (minimización, simulación) y métodos de evaluación tradicionales (quiz, parcial) que miden conocimientos enciclopédicos o ejercicios que pueden ser resueltos con ayuda de herramientas CAD (Computer-Aided Design) han generado un retraso en la industria electrónica nacional, condenando al país a ser un consumidor de tecnología extranjera con muy poca producción local.

Este panorama se oscurece aún más al reducir el componente práctico al uso de plataformas comerciales, y no permitir que el estudiante realice el proceso completo de concepción, diseño y fabricación de placas de circuito impreso, algunas facultades menosprecian estas actividades tildándolas de aptas para técnicos o tecnólogos. La fabricación de placas de circuito impreso involucra conceptos como capacidad de corriente de un conductor, frecuencia de operación, comportamiento en frecuencia, emisiones electromagnéticas y son el medio perfecto para entenderlos.

Por otro lado, el montaje de las placas de circuito impreso muestra al estudiante la importancia de seleccionar de forma adecuada los componentes del circuito (tolerancias y niveles de funcionamiento) ya que su costo puede aumentar si se selecciona de forma inadecuada, aumentando el costo final del dispositivo fabricado.

Todo lo anterior acerca más al estudiante al mundo de la fabricación de dispositivos digitales, siendo este el primer paso para la generación de productos innovadores.

Para contribuir a la solución de este problema Camargo (2011) propone un programa académico para las asignaturas Electrónica Digital I y 2 y Sistemas Embebidos siguiendo los lineamientos del CDIO adoptados por el DIEE. Sin embargo, estos lineamientos no eran suficientes para lograr que los estudiantes desarrollaran habilidades necesarias para el diseño y el emprendimiento, lo que confirma lo mencionado anteriormente sobre el fuerte perfil académico de la mayoría de los docentes. Es así como el primer paso en el proceso fue complementar los lineamientos del DIEE con las siguientes competencias:

Tabla 1: Habilidades CDIO específicas para los cursos del área de electrónica digital del DIEE de Electrónica Digital

HABILIDADES CDIO	Nivel 1		
	E. Dig 1	E. Dig 2	Sist. Emb.
Contexto Externo, Social, Económico y Ambiental		IEU	
22 Rol y responsabilidad de los Ingenieros		IEU	
23 Impacto sobre la sociedad y el medio ambiente		IEU	
24 Cuestiones y valores actuales		IEU	
44 Sostenibilidad y necesidad de un desarrollo sostenible	IE	IE	IE
Empresa y contexto empresarial		EU	
25 Interesados en la empresa, metas y objetivos		I	
26 Espíritu empresarial técnico		I	
27 Trabajo exitoso en organizaciones		I	
45 Finanzas y Economía de los proyectos de ingeniería	IE	IE	IE
Concepción y administración de sistemas en ingeniería		IEU	
28 Entender las necesidades y establecer las metas	IEU	EU	U
29 Definir la función, concepto y arquitectura	IEU	EU	U
Diseño		IEU	
30 Proceso de diseño	IEU	EU	U
31 Fases del proceso de diseño y enfoques	IEU	EU	U
32 Utilización de conocimiento científico en el diseño	IEU	EU	U
33 Diseño específico	IEU	EU	U
34 Diseño multi-disciplinario	I	E	U
Implementación		EU	
35 Proceso de fabricación Hardware	IEU	EU	U
36 Proceso de implementación de Software	I	EU	U
37 Integración Software-Hardware	I	EU	U
38 Pruebas, verificación, validación y verificación	IE	EU	U

Los niveles de competencia seleccionados para indicar el grado en que debe ser apropiada una determinada habilidad son:

Introducir (I): Introduce, pero no evalúa.

Enseñar (E): Enseña y evalúa.

Utilizar (U): Utiliza, puede ser evaluado o no.

Estas competencias permiten que los estudiantes cuestionen su rol dentro de la sociedad y piensen en la posibilidad de crear nuevos productos contribuyendo de esta forma en el desarrollo de la industria electrónica del país. Pero para ser esto posible es necesario modificar las estrategias en el aula y re-pensar la forma de evaluación.

El primer grupo de habilidades: *Contexto externo, social, económico y ambiental*, apunta a que el estudiante entienda que el rol de un ingeniero es crear soluciones a problemas de la sociedad y que estas soluciones deben estar enmarcadas dentro de un contexto económico social y cultural respetando las normas establecidas.

Las habilidades relacionadas con *empresa y contexto empresarial,* motivan al estudiante a la creación de empresa, el docente aquí muestra las ventajas de ser "su propio jefe" y habla de experiencias exitosas de egresados del programa y muestra cómo es posible financiar proyectos innovadores en la actualidad (por ejemplo, con portales como Kickstarter, crowdsupply o Indiegogo).

Las habilidades desarrolladas para la *Concepción y administración de problemas en ingeniería* buscan que el estudiante pueda identificar una necesidad y pueda generar una lista de funcionalidades que resuelven dicha funcionalidad para luego modelarla usando arquitecturas compuestas por componentes hardware y software.

Las habilidades relacionadas con el *diseño*, muestran al estudiante las diferentes etapas del flujo de diseño de sistemas digitales con el fin de identificar que profesionales son necesarios para diseñar, fabricar y comercializar un dispositivo. Al tiempo que aplica sus conocimientos para aplicarlos en la implementación de la funcionalidad requerida.

La *implementación* busca desarrollar habilidades relacionadas con la materialización de los modelos creados en los pasos anteriores, así como el entendimiento de las diferencias entre la implementación software (SW) y el hardware (HW) que determina la combinación (HW-SW) más adecuada para la funcionalidad requerida dadas las restricciones del proyecto.

Primera aproximación: enfoque OBA (Basado en resultados).

El objetivo principal de este proceso es lograr que los estudiantes desarrollen habilidades en diseño de sistemas digitales, y es claro que esto no se puede lograr realizando quices o parciales y realizando prácticas de laboratorio en algunos casos desconectadas de la teoría y que no muestran el flujo completo desde la concepción hasta la comercialización.

Para esto, se plantea un proyecto que deben realizar los estudiantes por grupos de trabajo, el docente imparte los contenidos teóricos y prácticos de la asignatura y efectúa 4 revisiones para establecer el avance de cada grupo. El problema del enfoque OBA es que no toma en cuenta el proceso del estudiante ni los estados inicial y final de las habilidades a desarrollar. Adicionalmente, los estudiantes al no tener experiencia en el desarrollo de proyectos no pueden por sí solos completar con la tarea, lo que genera frustración.

De esta experiencia se concluye que trabajar en un proyecto durante todo el semestre es la mejor forma de evidenciar el desarrollo de las habilidades en diseño de los estudiantes, pero que es necesario guiar el proceso debido a que ellos no cuentan con experiencia previa y es necesaria una realimentación constante para solucionar problemas de forma inmediata durante el proceso. Adicionalmente, se observó que el componente teórico no es utilizado de forma eficiente ya que no se presenta cuando va a ser utilizado y es olvidado, lo que hace necesario repetir ciertos conceptos varias veces.

Para dar solución a estos inconvenientes se adaptó el Aprendizaje Basado en Proyectos como metodología de aprendizaje. Sus seis fases se adaptan perfectamente al flujo de diseño de sistemas digitales y abarcan todas las habilidades CDIO que se desean desarrollar.

Fase Inicial

Contextualiza sobre modelo pedagógico. Roles - Metodología.
Habilidades – Conformación de equipos de trabajo colaborativo.

Fase Identificación y definición del problema

En el ABPr se crea un ambiente de aprendizaje en el que el problema dirige el aprendizaje. Con tal propósito, aquel debe presentarse de tal manera que el estudiante entienda que debe profundizar ciertos temas antes de poder resolver el problema en cuestión (ChemengMcMaster, 2000). Los problemas simulados que se utilizan para promover el aprendizaje deben ser progresivamente abiertos, no estructurados, para que el estudiante agudice su habilidad de búsqueda.
Escoger y plantear un problema relevante y complejo es acción definitiva en la estrategia ABPr, ya que la solución de la mayoría de los problemas toma un tiempo generalmente largo. El problema debe mantener la motivación de los estudiantes y llevarlos a indagar áreas básicas de la profesión que estudian, para lo cual es necesario que el problema cumpla con determinadas características que la investigación sobre ABPr ha ido señalando (Chemeng- McMaster, 2000). Bernardo Restrepo Gómez (s.f) Recuperado de: www.universidad.edu.uy/renderResource/index/resourceId/34093/ siteId/12

Diseño y Planificación

Una vez definido el problema tan ampliamente como sea posible se tratará de evocar toda clase de ideas y asunciones. Esas ideas sobre cómo el problema está estructurado se basará en los conocimientos previos o puede ser un resultado de pensar lógicamente sobre el problema. El análisis del grupo sobre el problema consiste ahora en averiguar qué miembros del grupo piensan o saben (o creen saber) los procesos y mecanismos subyacentes sobre el problema. En este punto el grupo no se limitará únicamente a discutir la información factual, sino que también intentará formular posibles explicaciones sobre la base del sentido común. En este proceso, es esencial que cada miembro del grupo tenga la oportunidad de hacer una breve contribución antes de continuar con el examen de las ideas y preconcepciones más críticamente. Esto es más fácil de decir que de hacer. Lo que sucede con frecuencia cuando alguien presenta una idea es que los otros interrumpan, señalan aspectos adicionales o simplemente critiquen la idea.
Giménez Jesús. (2013). Introducción al aprendizaje basado en problemas. Recuperado de: https://uvadoc.uva.es/bitstream/10324/1524/1/ABP.pdf

Fase Implementación

En esta fase los estudiantes tendrán que aplicar lo aprendido a la realización de un producto que dé respuesta a la cuestión planteada al principio. Dar rienda suelta a su creatividad.
Recuperado de http://www.aulaplaneta.com/2015/02/04/recursos-tic/como-aplicar-el-aprendizaje-basado-en-proyectos-en-diez-pasos/

Fase Evaluación y socialización

Las evaluaciones del ABPr, deberán ser auténticas, por lo tanto, se estructurará de tal modo que los alumnos puedan desplegar su comprensión de los problemas y las soluciones en formas contextualmente significativas (Gallagher, 1997).

El propósito de las evaluaciones es proveer al alumno de retroalimentación específica sobre sus fortalezas y debilidades, de tal modo que pueda aprovechar posibilidades y rectificar las deficiencias identificadas. La retroalimentación no debe tener un sentido positivo o negativo, más bien tiene un propósito descriptivo, identificando y aprovechando todas las áreas de mejora posibles.

Así, la retroalimentación juega un papel fundamental dentro del desarrollo del ABPr, la cual se recomienda hacerse de manera regular y es una responsabilidad del tutor llevarla a cabo. Unidad de Formación Académica de Profesores. (s.f). Recuperado http://www.uaa.mx/direcciones/dgdp/defaa/descargas/abp_aprendizaje.pdf

3. ABP en la UNAL

El modelo APBr implementado en las asignaturas del área de electrónica digital ha sufrido una serie de ajustes con miras a facilitar su implementación. Un aspecto importante a tener en cuenta es el número de proyectos a trabajar durante el período académico, inicialmente, cada grupo de trabajo realizaba un proyecto, sin embargo, esto aumenta la carga del docente y reduce las interacciones entre los estudiantes al tiempo que dificulta las revisiones ya que se pierde interés por los otros proyectos. Para solucionar esto, se genera una lluvia de ideas de las cuales se elegirá el proyecto a realizar por toda la clase. La tarea del docente en esta etapa es delimitar el problema para que sea adecuado para el nivel de los estudiantes y el número de grupos. En esta etapa se trabajan habilidades relacionadas con el emprendimiento y la comunicación, ya que el o los que proponen una idea deben convencer al grupo de que es la más indicada y de esta forma la pueden hacer realidad. Por otro lado, las ideas de los estudiantes en estos años han sido muy innovadoras y pertinentes a tal punto que posteriormente han sido ofrecidas (por personas externas a la clase) en el portal Kickstarter.

Esta lluvia de ideas inicial se realiza con el objetivo adicional de mostrar a los estudiantes que en las primeras etapas de la concepción de sistemas digitales se debe pensar en funcionalidades y no en arquitecturas o componentes, lo que lo hace ideal para cursos iniciales.

Una vez definido el problema a solucionar se deben definir las especificaciones del proyecto, se les hace ver a los estudiantes que para lograr un producto comercializable es necesaria la participación de una gran variedad de disciplinas y en estas asignaturas se centrará únicamente en las especificaciones funcionales, eléctricas y físicas. Para esto, se realiza una revisión de productos o proyectos similares, foros especializados, y portales de financiamiento como Kickstarter e Indiegogo para buscar productos similares, al finalizar esta tarea se deben definir tantas funciones como grupos de trabajo. Esto hace que todo un grupo de cerca de 30 estudiantes trabajen de forma conjunta en la búsqueda y justificación de funcionalidades con miras a cumplir las exigencias de los futuros clientes.

Estas funcionalidades deben interactuar entre sí para cumplir con las especificaciones, por lo que es necesario establecer un modelo del sistema que refleje la operación a alto nivel del mismo. Este primer modelo del sistema es obtenido de manera consensuada entre todos los estudiantes y representa la guía para las implementaciones de cada grupo. Los grupos de trabajo son creados de forma autónoma y normalmente son grupos creados con anterioridad.

Una vez definida la funcionalidad global cada grupo procede a repetir el proceso de especificación y modelamiento de cada subsistema, lo que obliga a todo el curso a repetir las etapas de especificación y modelamiento en el interior de cada grupo de trabajo. Es importante que los modelos, diagramas de flujo, de bloques y especificaciones se realicen usando un lenguaje de alto nivel y que sean independientes de la tecnología a utilizar en la implementación física, esto para no atar el contenido de las asignaturas a las herramientas disponibles en el momento y para que las primeras fases del flujo de diseño no sean restringidas por limitaciones tecnológicas.

En este momento inicia la labor tradicional del docente al presentar los contenidos del curso, los cuales deben estar sincronizados con la etapa de diseño para que los estudiantes puedan aplicarlos en sus proyectos y de esta forma lograr un aprendizaje significativo; esta información debe verse como un recurso más con los que cuentan los estudiantes para cumplir con el objetivo.

<u>Del diagrama de flujo a una arquitectura procesador - periférico</u>

A diferencia de los cursos tradicionales de electrónica digital en los que se comienza con el componente más pequeño (compuertas lógicas), en esta propuesta se inicia con una descripción a nivel de sistema, esto permite al estudiante entender cómo se implementarán las funciones identificadas en la etapa de especificación y modelamiento.

En versiones anteriores de estos cursos cuando se dividían tareas se asignaba un grupo para implementar el control del sistema, este módulo debía coordinar las tareas de los demás grupos para cumplir las especificaciones. La arquitectura resultante era un sistema en estrella cuyo centro era la unidad de control y existían conexiones entre los módulos, y era normal que se modificaran los componentes del sistema para incluir señales de comunicación, dando como resultado una sobrecarga de señales y una máquina de estados muy grande (más de 100 estados) que coordinaba las tareas. Lo cual, dañaba la planeación inicial y dejaba la sensación de que los primeros pasos no eran necesarios.

Por lo anterior, se propuso una arquitectura de implementación para Electrónica Digital 1 (Figura 1), basada en un procesador y varios periféricos (lo que se utiliza normalmente en las aplicaciones del mundo real). Esta arquitectura permite focalizar los esfuerzos de cada grupo en un periférico que implemente la funcionalidad deseada y deja el control de todo el proceso a una unidad de procesamiento central (CPU), esta propuesta tiene como inspiración la metodología de diseño de los programadores los cuales definen inicialmente bloques funcionales, la conexión entre ellos y al final realizan la implementación de la funcionalidad de cada bloque. Esto da una idea más general del proceso a los estudiantes y permite trasladar el modelo inicial de forma directa.

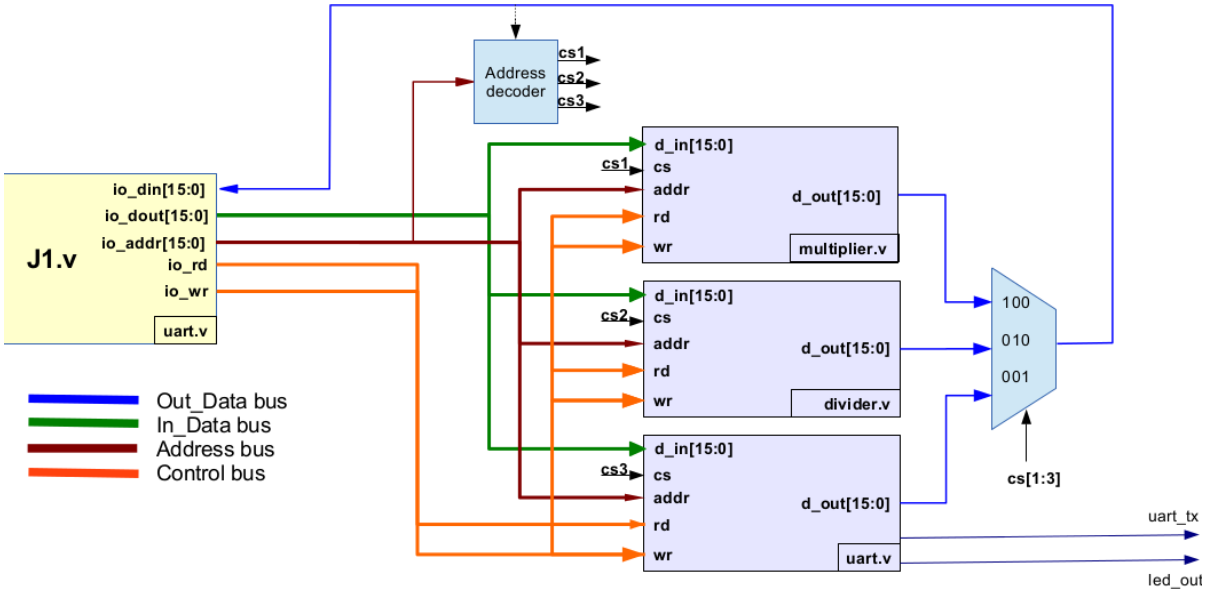


Figura 1: Arquitectura de implementación del curso de Electrónica Digital 1

Esta visión de alto nivel del sistema introduce a los estudiantes en conceptos de arquitectura de computadores (buses de datos, mapa de memoria, memoria de programa, interrupciones) y les muestra una forma real de implementar la funcionalidad global del sistema digital.

Una vez definido el mapa de memoria de los periféricos y la información relevante de cada periférico se procede a implementar la funcionalidad de cada grupo, para esto se utiliza una metodología que parte del diagrama de flujo que describe la funcionalidad y llega a una implementación formada por un camino de datos y una máquina de control (Ver Figura 2).

Esta metodología permite que un estudiante sin experiencia en el área pueda implementar un sistema digital, partiendo de un proceso de pensamiento y no del ensayo y error o de la experiencia como se hacía en la forma tradicional; adicionalmente, es claro el proceso de diseño partiendo de una descripción global a una particular mirando siempre el problema desde el plano funcional, esto es, a pesar que el estudiante no sepa cómo se implementan los bloques si sabe que deben hacer.

Una vez creados los diagramas de alto nivel de cada una de las funciones, el docente procede a presentar el componente teórico de los sistemas combinatorios y secuenciales y como se implementan usando lenguajes de descripción de hardware como VHDL y Verilog, esta explicación será más significativa ya que el estudiante conoce el problema global y conoce exactamente donde utilizar los temas que se le están presentando.

En este punto los estudiantes proceden a la implementación de las diferentes funcionalidades en periféricos adaptándolos a periféricos del procesador y creando código para la transferencia de información. Este proceso es apoyado de forma permanente por el docente a demanda de los estudiantes.

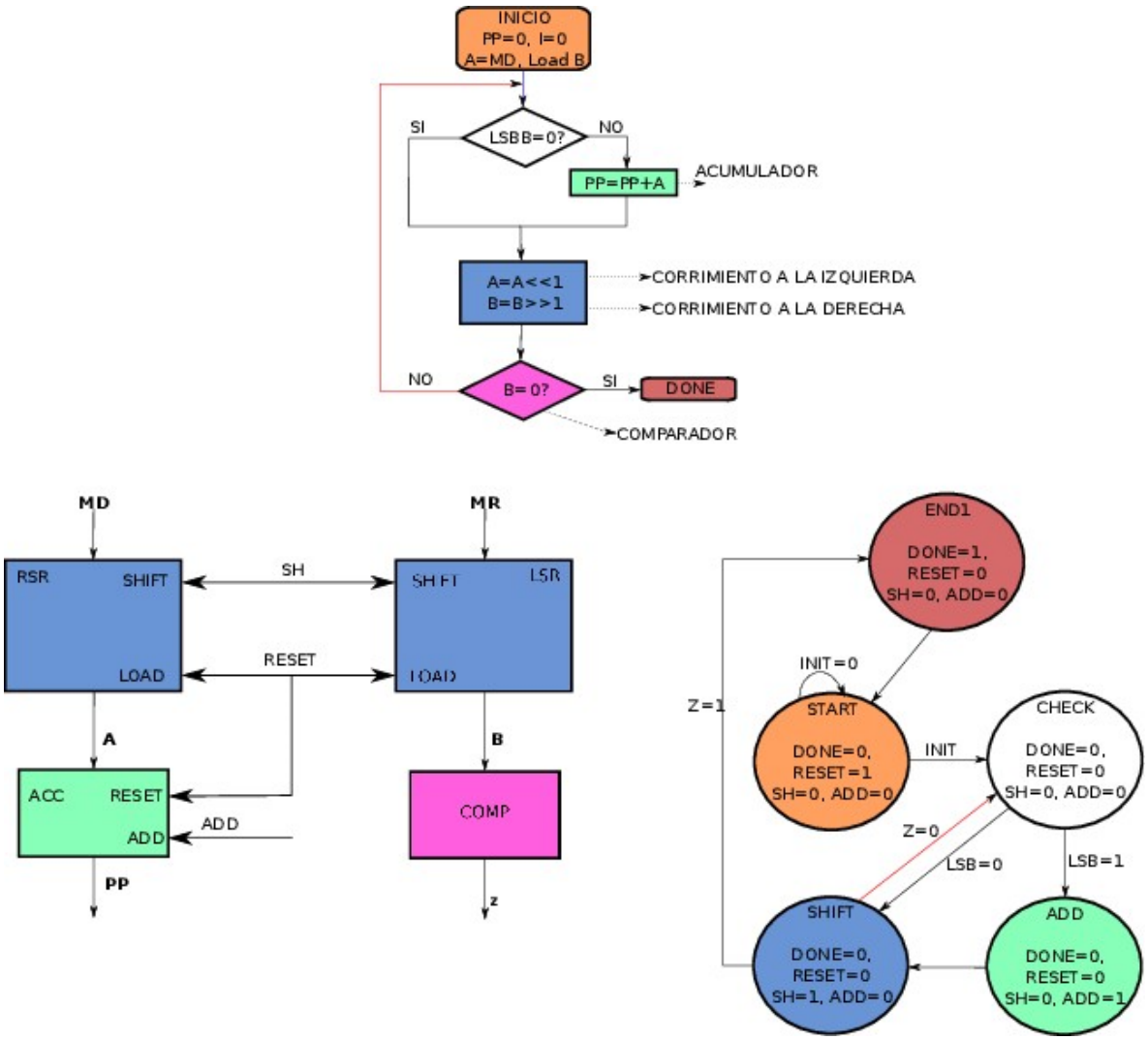


Figura 2: Implementación de una funcionalidad usando camino de datos y máquina de control.

Una vez finalizada la implementación de la funcionalidad de cada grupo, se procede a su unión, cada periférico posee una dirección de memoria única y cada grupo crea las funciones en el procesador que permiten el uso de su periférico. El paso final es la construcción colectiva de la funcionalidad global del dispositivo.

Durante esta construcción se realizarán reuniones en las que cada grupo presentará sus avances teniendo en cuenta los lineamientos dados por unas rúbricas creadas para el área de digitales, las cuales tienen la siguiente estructura:

Tabla 2: Lineamientos dados por las rúbricas creadas para las asignaturas de Electrónica Digital

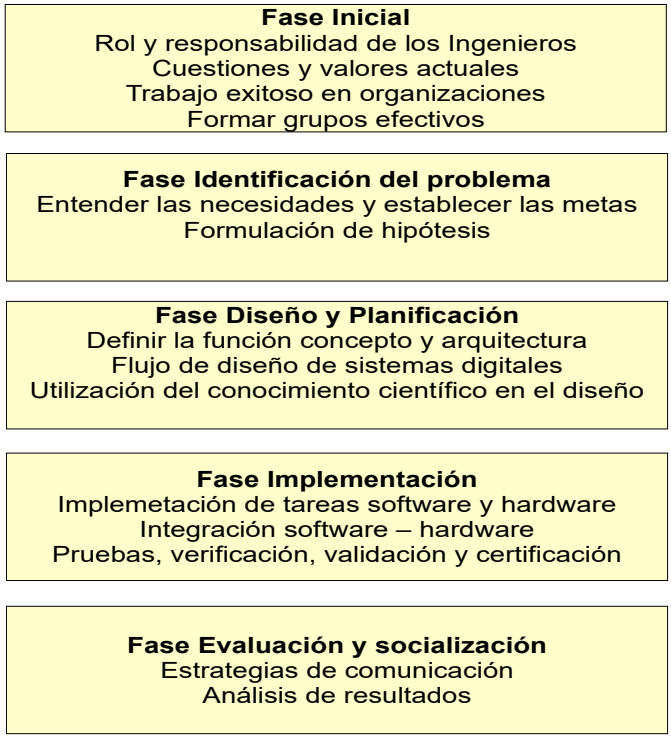
CRITERIO	
Aplicación 70%	Especificación del sistema
	Modelamiento
	Arquitectura del sistema
	Prototipado y pruebas
	Documentación
Evaluación 20%	Especificación
	Modelado
	Arquitectura
	Prototipado y pruebas
	Documentación

El componente de aplicación determina el proceso realizado por el estudiante, si entiende los conceptos presentados en el aula y si realiza de forma adecuada las actividades. Mientras el componente de evaluación determina si el estudiante realiza juicios sobre los resultados obtenidos por él y por sus compañeros, analiza la información obtenida y si realiza cambios a sus ideas originales después de evaluar el desempeño del sistema.

Estas rúbricas son genéricas para los tres cursos del área de electrónica digital, y debe ser así para que al final de la línea se obtengan los resultados deseados, y no se tenga la impresión por parte del estudiante que son tres asignaturas diferentes, con diferentes metodologías y alcances, sino que es la misma asignatura presentada en tres partes.

4. Discusión

El aporte del trabajo presentado se puede resumir como una integración del modelo ABPr con la iniciativa CDIO, en la cual el ABPr proporciona el medio para que se puedan desarrollar las habilidades contempladas en el currículo CDIO, en la siguiente figura se muestra las habilidades CDIO que se desean desarrollar en cada fase del ABP.



Adicionalmente, se presenta una forma novedosa de abordar la línea de electrónica digital, la cual tiene como referencia la ingeniería de software en la que se va de lo genérico a lo particular disminuyendo el nivel de abstracción en cada etapa hasta llegar a un nivel de compuertas, lo que contrasta fuertemente con el método tradicional de enseñanza de estas asignaturas en donde se inicia con componentes básicos y se trata de llegar a sistemas complejos. El problema radica en que el camino tradicional requiere cierto nivel de experiencia mientras que nuestra propuesta no, lo que la hace adecuada para cualquier nivel. Por otro lado, permite que el estudiante tenga una visión global del problema y comprenda desde el comienzo a donde se quiere llegar, lo que no es fácil de obtener con el método tradicional.

4.1 El docente ingeniero en el proceso

Este método propone un cambio radical en el rol del docente, ya que pasa de ser el centro del proceso de enseñanza a ser un acompañante y colaborador del mismo, guiando al estudiante en su búsqueda personal del conocimiento. Adicionalmente, en su acompañamiento identifica el avance del estudiante durante el período académico, lo que permite una mejor evaluación del desarrollo o creación de las habilidades que se desean trabajar.

Este acompañamiento reduce de forma considerable la barrera que existe entre el estudiante y el profesor en una metodología clásica y permite la creación de lazos que benefician al estudiante en su búsqueda de conocimiento. Al tiempo que permite tener en cuenta aspectos personales que afectan el desempeño del estudiante y deben tenerse en cuenta al momento de la evaluación.

Por otro lado, el docente pasa de ser el centro del conocimiento a un ser que aún puede aprender y que puede mostrar a sus estudiantes como enfrenta el proceso de aprendizaje de un nuevo tema, esta forma de educar con el ejemplo muestra a estudiantes como mejorar sus métodos de aprendizaje.

4.2 El estudiante de ingeniería en proceso

La metodología tradicional de enseñanza ha creado en el estudiante una serie de hábitos que no benefician el proceso de auto-dirección, ya que desde temprana edad han sido moldeados para responder ante la calificación. La calificación es lo más importante para un estudiante y el aprendizaje real pasa a un segundo plano.

Uno de los inconvenientes más notorios a la hora de implementar esta propuesta ha sido la ausencia de tareas, quices, talleres, laboratorios con calificación, ya que el estudiante está acostumbrado a realizar estas labores únicamente si le representan una calificación y no porque entienda que ayudan al proceso de adquisición de conocimiento.

Adicionalmente, un gran número de estudiantes revisan los temas tratados en clase solo cuando son evaluados, lo que se traduce en 4 semanas de trabajo real en la asignatura (antes de los parciales o quices), este fenómeno es llamado por los autores de este trabajo como “apaga-incendios” apagan el incendio que representa un parcial y dedican todo su esfuerzo en hacerlo y después se desentienden de la asignatura para concentrar sus esfuerzos al siguiente incendio (parcial o quiz). Cuando el proyecto es el centro de actividades se elimina esta mala costumbre ya que el estudiante debe realizar un trabajo continuo de forma independiente dentro y fuera del aula para cumplir con las especificaciones del problema. Esto no es bien recibido por algunos estudiantes ya que es más cómodo para ellos estudiar una semana para un parcial que dedicar grandes períodos de tiempo a un mismo problema.

Otro aspecto que incomoda a los estudiantes es la necesidad de revisión bibliográfica y búsqueda de información autónoma ya que están acostumbrados a que algunos docentes realizan esta tarea por ellos y la labor del estudiante se limita a hacer unos buenos apuntes.

Por lo anterior, es necesario hacer ver a los estudiantes que este proceso les va a formar habilidades necesarias para su oficio profesional donde no existirán docentes que les resuelvan sus dudas y sus problemas.

4.3 El currículo

La metodología propuesta permite una forma diferente de abordar el currículo al pasar de una estructura lineal a una circular donde el estudiante puede volver a tratar un tema para aclarar dudas (y realmente entenderlo y comprenderlo). Esto contrasta fuertemente con el método tradicional en donde se trata un tema en un instante de tiempo y el estudiante debe sincronizarse con ese instante y no importa si al final del proceso presenta dudas porque la rigidez y extensión del currículo algunas veces dificulta volver a tratar temas previos.

4.4 La evaluación

La evaluación ha sufrido grandes cambios desde que inició este proceso, inicialmente se conservó la forma tradicional (parciales, quices, tareas, talleres) dando resultados desastrosos, lo que creo un bloqueo generacional hacia la asignatura por un gran número de estudiantes, lo que se evidenció en el poco número de trabajos de grado relacionados con el área. Esto en parte se originó por que los métodos tradicionales (exámenes de dos horas) no permiten determinar si el estudiante puede resolver un problema de ingeniería usando el flujo de diseño de sistemas digitales.

En esta forma de evaluar, el proyecto era un porcentaje de la calificación final y no logró el efecto deseado ya que los estudiantes no se interesaban en él y dedicaban sus esfuerzos a los parciales y a las prácticas de laboratorio que tenían más peso en la calificación final, adicionalmente, requiere menos tiempo estudiar para un parcial que dedicar todo el semestre en un proyecto. Esto es el resultado del método de evaluación tradicional que hace de los estudiantes unos expertos en obtener buenas notas y no necesariamente en adquirir conocimientos.

Por lo anterior se llegó a un sistema de evaluación centrado en el proyecto. Inicialmente, lo único que se tenía en cuenta era el correcto funcionamiento, esto llevó a que en algunas ocasiones los estudiantes pagaban por el diseño, y a "ayudar" a los compañeros que no trabajaron. Esto de nuevo evidencia los efectos negativos de la evaluación tradicional en los hábitos de los estudiantes.

Finalmente, se desarrolló un sistema de evaluación centrada en el agente, generando rúbricas de hetero (docente) co (pares) y auto-evaluación. Con esto se busca que el estudiante sea consciente de su aprendizaje y no de la nota, que coloque por encima de la nota la ética y los conocimientos. Adicionalmente, hacerlo entender que los resultados del proceso obedecen a su comportamiento y son el resultado de sus decisiones y no del profesor.

El uso de rúbricas posibilita que el estudiante conozca cómo se le va a evaluar, que aspectos son importantes para que adquiera las habilidades necesarias para aprobar el curso, para que con esta información tome las acciones necesarias para obtener los resultados que el desee.

4.5 Los resultados

Después de aplicar esta metodología por cerca de cuatro años se percibe un cambio de mentalidad en los estudiantes, un ambiente donde la mayoría de ellos no se preocupa por la nota, sino por el proceso, esto lo

evidencian las auto-evaluaciones finales en las que algunos de ellos expresan que no consideran que han alcanzado el nivel deseado de conocimientos y habilidades y optan por repetir la asignatura. Así mismo, muestran una actitud crítica frente al compromiso de sus pares y realizan evaluaciones objetivas y éticas.

Por otro lado, la realización de proyectos que buscan dar solución a problemas reales muestran a los estudiantes la forma de materializar ideas en productos comercializables, al tiempo que se les muestra la forma de dirigirse a públicos diferentes: posibles usuarios e inversionistas, y a pares académicos. Esto les muestra el panorama general y el papel que juegan dentro del proceso de creación de nuevos productos, y la necesidad de otras disciplinas para completar el proceso.

El avance más notorio en este proceso se dio en la auto-dirección y el trabajo autónomo, los estudiantes no esperan a que el docente resuelva sus dudas, sino que trabajan de forma colaborativa para resolverlas, así mismo, mejoran sus métodos de aprendizaje dedicando más tiempo a la asignatura sin la necesidad de una calificación. Adicionalmente, el trabajo colaborativo ha aumentado y se evidencia más el compromiso en ayudar a que sus compañeros de clase adquieran los conocimientos y habilidades.

Desde que se está implementando esta metodología han aumentado el número de estudiantes que realizan proyectos de grado en temas relacionados con la electrónica digital, muchos de ellos utilizan los proyectos realizados en los cursos del área como base para su trabajo final.

Otro aspecto que ha mejorado es la percepción de los estudiantes con relación a la labor docente, esto se evidencia en la evaluación que ellos hacen del curso y del docente, la cual, ha ido aumentando de forma constante a lo largo de estos años.

4.6 Qué sigue - recomendaciones

Aunque esta metodología ha demostrado ser muy útil en estas asignaturas, es el único espacio que tienen los estudiantes de simular un entorno de desarrollo similar al trabajo profesional y es uno de los pocos donde se usan metodologías activas, por un lado, porque otras asignaturas no permiten hacerlo debido a la naturaleza de los temas allí tratados o porque los docentes usan metodologías de enseñanza tradicionales y no están interesados en hacer cambios.

Es recomendable utilizar métodos similares para eliminar la forma de evaluación tradicional que no refleja el avance del estudiante y crea malos hábitos en los estudiantes haciéndolos perder el foco de lo que realmente importa: el aprendizaje.

Es necesario sincronizar el contenido teórico de las asignaturas para que sean utilizados en la implementación del proyecto para que sea más significativo el aprendizaje.

Un panorama ideal utilizaría proyectos transversales en los que diferentes áreas atacan diferentes componentes de un mismo problema, de forma tal que el estudiante pueda entender la relación de todos los conceptos aplicados en un mismo sitio y no como se hace ahora con diferentes actividades que sobrecargan al estudiante y no le permiten entender cómo pueden utilizarse conocimientos de diferentes asignaturas para resolver un problema real. Para esto solo se requiere una coordinación de los docentes para que cada uno diseñe estrategias para que los conceptos y habilidades requeridas en sus asignaturas puedan ser tratados y desarrollados en un proyecto transversal.

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