Active Teachers - Active Students

Proceedings of the 13th International Workshop Active Learning in Engineering

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ACTIVE TEACHERS
ACTIVE STUDENTS

Erik de Graaff, Montse Farreras,
Nestor A. Arexolaleiba (eds.)

13th International Workshop
Active Learning in Engineering

ALE

MONDRAGON
UNIBERTSITATEA

UNESCO
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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13th Active Learning in Engineering Education Workshop (ALE)

Mondragon University, 6-10 July 2015

Title: Active Teachers - Active Students

Organised by Mondragon University and initiated by the Aalborg Centre for PBL in Engineering Science and Sustainability under auspices of UNESCO, in collaboration with 5th International Research Symposium on PBL 2015, part of International Joint Conference on the Learner in Engineering Education (IJCLEE 2015) and International Symposium on Project Approaches in Engineering Education (PAEE)

PROJECT APPROACHES IN ENGINEERING EDUCATION

United Nations
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International Joint Conference on the Learner in Engineering Education (IJCLEE'2015)

Active Teachers Active Students

Proceedings of the 13th International Workshop Active Learning in Engineering

Foreword

Learning is active in nature. It is something you do, not something that is done to you. Engineering educators around the world recognize this basic truth and implement one or another form of active learning to enhance their teaching. Active learning in Engineering (ALE) was started as an initiative from the Polytechnic in Nantes, France and the University the Los Andes in Bogota, Colombia. The objective was to start a world wide collaboration allowing teachers in engineering to learn from each other about their experiences with active learning.

The ALE mission is "to bring active learning back into engineering education". The main activity of the ALE network is the annual organization of an ALE workshop in different parts of the world.

The first ALE workshop was organised in Venezuela in the year 2000. Since then ALE alternated between locations in the Americas and in Europe. Adapting to summer conditions, the time in the year varied from June-July in the Northern hemisphere to January in the Southern hemisphere this resulted in the following places and dates for past ALE workshops:

- **1st ALE Workshop (2001):** Organized by Universidad Simón Bolívar, Caracas, Venezuela
- **2nd ALE Workshop (2002):** Organized by DTU, Copenhagen, Denmark & Chalmers University of Technology, Gothenburg, Sweden
- **3rd ALE Workshop (2003):** Organized by Franklin W. Olin College of Engineering, Boston, USA
- **4th ALE Workshop (2004):** Organized by Ecole des Mines de Nantes, France
- **5th ALE Workshop (2005):** Organized by TU Delft, The Netherlands
- **6th ALE Workshop (2006):** Organized by Tecnológico de Monterrey, Mexico
- **7th ALE Workshop (2007):** Organized by INSA Toulouse, France
- **8th ALE Workshop (2008):** Organized by Universidad de los Andes, Bogotá, Colombia
- **9th ALE Workshop (2009):** Organized by Universitat Politècnica de Catalunya, Barcelona, Spain
- **10th ALE Workshop (2011):** Organized by Universidad de Chile, Santiago, Chile
- **11th ALE Workshop (2012):** Organized by DACIN and hosted at the Engineering University College of Copenhagen and Technical University of Denmark, Copenhagen, Denmark
- **12th ALE Workshop (2014)**: Organized by Universidade de Caxias do Sul, Caxias do Sul, Brazil.

In this thirteenth edition, ALE joins forces with the International Research Symposium on Problem Based Learning (IRSPB) and the International Symposium on Project Approaches in Engineering Education (PAEE) to organise the first International Joint Conference on the Learner in Engineering Education (IJCLEE 2015) hosted by Mondragon University, in San Sebastian, Spain.

ALE will take care of the opening day of IJCLEE with a total of 56 accepted papers and abstracts represented in these proceedings. ALE 13 has about the same number of contributions as we had the past years. However, this time we also expect participants who come from the communities of PAEE and IRSPBL, so the audience will be bigger than usual. We will do our best to maintain the high level of interaction and personal contact.

Twelve of the ALE 2015 contributions are presented as hands-on-sessions. This basic ALE format allows teachers in engineering to experience each other's classroom experiments. Nine papers will be presented in discussion sessions involving the audience actively. The remaining 35 contributions will be presented in one large active poster session

We hope you will enjoy active participation in San Sebastian.

Welcome to ALE'2015

Erik de Graaff, chairman ALE steering committee

Montse Farreras, member ALE steering committee

Nestor Arana Arexolaleiba, chair IJCLEE 2015

IJCLEE2015 Welcome

Imagination and initiative, which are catalytic elements for the learning process, are often constrained by classical tests. A manager of Velatia, a leading company of the energy sector, recently said to a group of students that they should be both curious and capable to find their own personal development path. The inherent curiosity, imagination and initiative of young people have to be directed through new educational methods. These methods should encourage a central role for the student in their learning process, taken profit of each mistake as an opportunity to foster both learning and personal growth. Active learning methods, such as problem and project based learning methods (PBL), acceptance is increasing at all levels of the educational community; from primary school to university. A PBL student faces a challenging problem which must be solved where imagination and initiative are essential to solve the problem.

We need to remind that our society is facing new dramatic global challenges, never seen before in human history, due to resource scarcity or environmental pollution among others. These new global challenges require new global tools to be confronted, tools such as the worldwide internet network. These new tools generate huge amounts of knowledge, which are increasingly more difficult to handle. In order to manage the vast amount of available knowledge, as mentioned by Steve Coll, future professionals will be forced to build their career by catalyzing thinking and self-learning in a sustainable way over a long period. A higher-level of thinking will be needed and students should be trained to fast and efficiently adapt to new scenarios and build the required new mental structures. PBL strategies provide an invaluable opportunity to achieve these higher-level of thinking.

Over the last 15 years, Mondragon University (MU) has been adapting its educational practice by giving more room to active learning methods. Nowadays, an interdisciplinary PBL approach is put into practice in all the studies offered by MU. By organizing the Joint Conference on the Learner in Engineering Education (IJCLEE 2015), our aim is to take our commitment to active methods one step further and to exchange experiences with universities around the globe.

We would like to express our sincere gratitude to the Active Learning in Engineering Education Network (ALE), the International Symposium on Project Approaches in Engineering Education (PAEE) and the International Research Symposium on Problem Based Learning (IRSPBL) for their collaboration and for giving us the opportunity to host the IJCLEE 2015.

We hope you will enjoy the conference and your stay in San Sebastian.

Welcome to IJCLEE'2015

Nestor Arana-Arexolaleiba, chair IJCLEE 2015

Contents

Keynote

An essay on the Active Learner in Engineering Education

Michael Christie and Erik de Graaff

Text to accompany the keynote interactive session for the International Joint Conference on the Learner in Engineering Education (IJCLEE 2015)

Engineering and Medical Education have made significant contributions in the area of pedagogical modelling. In both cases the emphasis has been on the active learner in medical or engineering education. One could argue that it is tautological to use a term such as ‘the active learner’. A person cannot learn unless the brain or body is active in some way or other. If learning is something we do which results in a discernible and fairly permanent change in what we know, or can do, or value, then a learner is by definition a doer, an active agent. From the moment we are born, and perhaps even in the womb, we are learning. Babies are practising scientists, experimenting, developing and testing hypotheses. ‘If I cry loud enough will someone change my nappy? If I say mamma I get cuddles and smiles from everyone but especially from her’. It will take time before this natural instinct becomes a more conscious and reflective activity, before we think and learn in a more deliberate and problem solving way.

All of us, no matter what our age, naturally pursue new knowledge, skills, and values, or busily reinforce or revise what we already know, do and feel. John Dewey’s timeless explanation of how we learn best by first doing and then reflecting on what we have done, was a starting point for our first ALE keynote in Copenhagen in 2012. At that conference we expanded on this theme and argued for a philosophical basis to ALE. Using Dewey we challenged an Engineering tradition that both of us have experienced. At Chalmers and Delft universities of technology we had experienced an unholy alliance between teachers and students. Higher Education is still characterised by written tests of students’ knowledge and skills and by sorting those students into graded categories. In such a system getting the best grade, or just getting through, depending on your educational ambitions, is what motivates students. In such a system political, economic or other pressures can lead some teachers and students to agree on an unwritten pact. The teachers, who really want to be researchers (since that is where the academic rewards are) say, in effect: ‘I’ll provide heavy hints to what will be in the closed-book, end-of-term exam in my lectures. Go through my old exam papers and make sure you can answer the questions there. I don’t have time to hand-feed you’. The questions that such lecturers set often test declarative knowledge and set ways of applying that knowledge. The students who want to simply get their meal ticket are content. The students who really want to deeply understand and apply the subject in new and different situations are frustrated. The Swedish expression for this is ‘korvstoppning’, which translated literally means ‘stuffing the sausage’. The English call it ‘cramming’. The teachers who push this approach reinforce their distaste for teaching but also free up time for research. They can publish more and unfortunately reap the rewards of a system that privileges research over teaching. Unfortunately in this educational approach the students become passive recipients of knowledge. The teacher is seen as the one who supplies content. All they need to do is learn it off by heart and repeat it in the end of course exams.

At Caixos du Sol in early 2014 we expanded on our argument for the importance of activating learning. We stressed again that we are all natural scientists and encouraged participants at our interactive keynote to devise and critique relevant research questions in their scholarly investigation of how to best encourage and implement active learning in Engineering Education. This year we concentrate on the theme of ‘the Active Learner in Engineering Education’, a theme that binds the PBL Symposium, the ALE Workshop and the Project Approach to Engineering Education Conference together. It is a fitting focus for what is a ground-breaking event in Engineering Education.

We described above how students can be put in fairly passive position when it comes to learning. We know from researchers like Hounsell, Entwhistle, Marton, and Biggs [1] that students will approach their learning differently depending on the pedagogical models that their lecturers use. We want to stress from the outset that although we favour a what Dewey’s calls a ‘progressive’ approach to education there are good and bad aspects in the practical application of both traditional and progressive models. Teachers in both approaches have a great deal of responsibility. They can influence students to take what the literature refers to as a surface approach to learning. If the lecturer tests mainly for declarative knowledge students can get away with not truly understanding and applying what they are taught. It takes skill for a teacher to design a course so that students are required to take a deep approach, in other words, to really understand the subject matter and prove that by applying it in new and different situations. Models such as Problem and Project Based Learning consciously strive to activate students and a well designed PBL course has inbuilt in it authentic assessment tasks.

Dewey used the word 'Progressive' to contrast his educational approach to the 'Traditional' model that he saw in contemporary American schooling in the early 1900s. The shortcomings in either model are most obvious when practitioners pervert the philosophical and pedagogical reasons for employing one or other of the models. Some disciplines, like Medicine and Engineering, have a large amount of content and technical language that must be learned in order to communicate key concepts or carry out correct procedures. For example you must know anatomical terms if you are going to discuss and diagnose a disorder or deal with a problem in a particular part of the body. The same is true for engineers who must know formulas and technical terms if they are going to design, build and test a product or determine the causes of problems with a product. The medical student who rote learns the Latin names for parts of the body is an active learner. The engineering student who remembers formulas by heart is also an active learner. The student debating in her mind the content of a lecture she is listening to is also actively learning. But if this is all the student does then we are short changing them. Social engagement with and the practical application of knowledge, skills and values are necessary to truly activate what has been learned as an individual, no matter what educational model is used.

Lecturers who love their subject and want to inspire others to learn about it tend to activate their learners even when they teach in a university that is still very traditional in terms of its values and educational architecture. However it is much easier to do that when one is working in a university like Aalborg, Denmark, that was purpose built to deliver PBL curricula. Inspiring teachers, even if they are locked into a format of lecture, tutorial, laboratory exercises and final, closed-book exam, can still devise ways of helping students to really understand and apply the content of their course. However it is easier to do that if the model has been constructed to promote understanding and application. Most of you here today fit the category of 'inspirational teacher'. The proceedings from earlier conferences, workshops and symposia are proof of the amazing creativity and versatility you use to activate your learners. The interactive part of this keynote will allow you to share some of those ideas, techniques, exercises and systems.

Engineering, Medicine and Economics are rather conservative disciplines so it comes as a surprise that progressive educators in these disciplines have been energetic advocates for two of the most influential pedagogical models to have emerged in Higher Education in the last half century. We refer to Problem Based and Project Based Learning (PBL). In essence these two pedagogical models have been around for thousands of years. Both Confucius and Socrates (c 500 and 400 BC) stimulated rather than transmitted learning. Socrates is famous for his dialogues that forced students to think, question and problem solve. Confucius knew the importance of intrinsic motivation and commented: 'I only instruct the eager and enlighten the fervent. If I hold up one corner and a student cannot come back to me with the other three, I do not go on with the lesson'. One of the earliest and best known varieties of PBL is the form that was introduced in the Faculty of Health Sciences at McMaster, a Canadian University, in 1969. It was soon adopted elsewhere including at the medical faculties of the University of Limburg in Maastricht, Holland, the University of Newcastle, Australia, and the University of New Mexico in the United States. Today it is a worldwide phenomenon.

As is too often the case, 'followers' of a new educational model can became more dogmatic about its practice than the founders [2]. In 1996, nearly thirty years after the PBL movement started, Gwendie Camp was concerned that 'true PBL' was being watered down [3]. She insisted that unless PBL was 'active, adult-oriented, problem-centred, student-centred, collaborative, integrated, interdisciplinary and utilized small groups operating in a clinical context' it should not be called PBL. She correctly pointed out that if a PBL program was ‘teacher-centred’ rather than ‘student-centred’, the heart of ‘pure’ PBL would be lost [4]. Although very few would cavil at her concluding sentence there were many who objected to Camp’s ‘purist’ approach. Ranald Macdonald was one [5]. Savin-Baden [6] also argued that PBL is an approach characterized by ‘flexibility and diversity in the sense that it can be implemented in a variety of ways in and across different subjects and disciplines and in diverse contexts’. Boud and Feletti [7] pointed out that ‘The principle behind PBL is that the starting point for learning should be a problem, a query or a puzzle that the learner wishes to solve’. We also argue that there can be a number of approaches and variations in the practice of PBL. Today a large number of disciplines use PBL, in different shapes and forms.

In Business and Economics many Faculties design their architectural space to allow for ‘syndicate rooms’ where students can work on problems either as one-off tasks or as a connected series of problems that make up a whole subject or curriculum. The table opposite, which provides a simple diagrammatic sketch of PBL is taken from the English Economics Network site that includes a handbook on PBL. The site details key features of PBL and reasons for using it. The link is http://www.economicsnetwork.ac.uk/handbook/pbl/21

In Engineering a particular form of Project Based Learning that has gathered momentum over the last 25 years is CDIO. The abbreviation stands for Conceive, Design, Implement and Operate and this model started as a curriculum project at Massachusetts Institute of Technology (MIT) in 1997. Since then it has grown into a worldwide movement in Engineering Education. CDIO and has just held its 10th international conference (Barcelona, 2014) and published a second edition of the CDIO book which outlines its principles and practice. It is now spread across a number of countries and is practised in 107 different Engineering Schools. The table below taken from the CDIO website provides a useful overview.

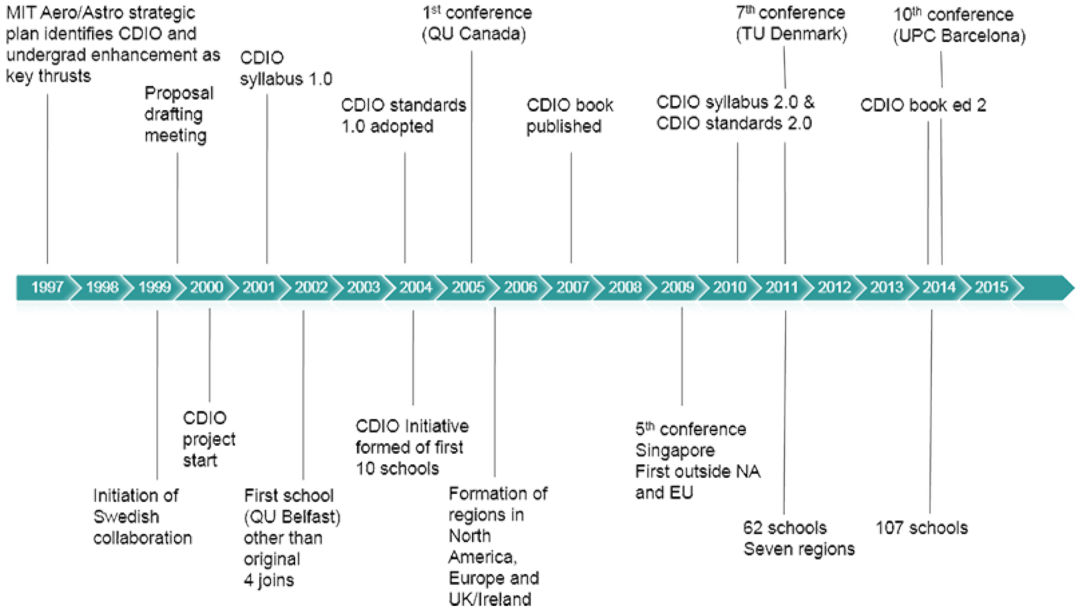

Table 1. CDIO history. Source: http://www.cdio.org/cdio-history

Engineering educators who promote this form of project based learning argue, as the McMaster staff did, that the pedagogical model emulates the way practitioners in their profession work. Doctors diagnose medical problems and try to find remedies. Engineers design, build and test products.

It is the nature of PBL to adapt to different settings, cultures, curricula and circumstances. Camp did everyone a favour by clearly showing that PBL has its theoretical origins in the conceptual work of adult educators like Malcolm Knowles [8], a constructivist epistemology [9] and in the psychological principles of learning [10]. Having a sound philosophical basis for PBL is important. However, none of those theories espouse a dogmatic approach. PBL should not become a straitjacket for educators. It is a practical, pedagogical paradigm robust enough to be adapted by a range of disciplines and for a variety of purposes. Both Problem and Project Based Learning enable educators to prepare their students for their future professional life as opposed to simply being able to pass exams. In the concluding part of our essay we encourage participants at this joint conference to reflect on their own practice and critically analyse what constitutes the key characteristics of an Active Learner in Engineering Education. More importantly we ask 'how can we, as educators, facilitate and encourage active learning?'.

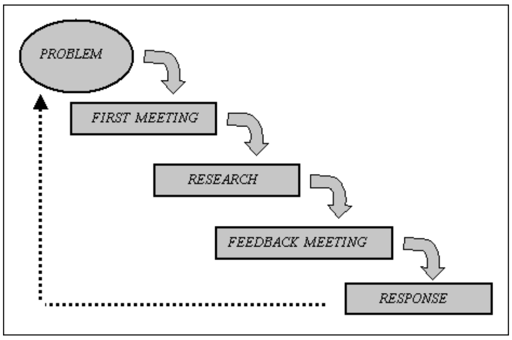

Table 2: A simple PBL model

Without getting bogged down in 'academic' detail it is worth comparing Project-Based and Problem-Based Learning in order to see how they can best serve the Active Learner in Engineering Education. In doing so we will answer, in a more general, theoretical way, the questions we have posed above. Are our two models the same or different? Both are concerned with engaging students in real world exercises to enhance their learning. Some tasks can be simulated, others require wider field experience in an actual workplace. We mentioned earlier that Higher Education tends to default to pen and paper exams. Both Project-Based and Problem-Based Learning emphasize performance based, authentic assessment.

We have already alluded to one of the more significant differences between the two models. Project-based learning usually has the creation of a product or an artefact as a goal. Although projects can differ widely students have to acquire the knowledge, skills and right values if they are to be successful in designing, building and testing their product. Problem-based learning, as the name suggests, begins with an issue or problem that the students need to solve or learn more about. Ill defined problems are often selected to ensure that the scenario or case study, if that is the format which is used, simulate real life complexities. In some instances the problems are actual problems that businesses want solved. Both forms of PBL can complement one another. Which is why it is fitting that the associations that represent research into PBL and Project Based Learning in Engineering Education should come together with ALE at this joint conference. Placing of the various keynotes at the intersection of the ALE workshop, the PBL Symposium and the Project Based Learning conference eloquently demonstrates how well all three support one another in their desire to activate learning in Engineering Education.

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Papers and extended abstracts from the Hands-on sessions

Is it possible to produce innovative graduates in your university? Basics of innovation pedagogy introduced!"

- Extended abstract for a Hands-on session for the International ALE workshop 2015

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Abstract

The topic of this hands on session is innovation pedagogy which is a *learning approach interested in the development of innovation competence of individuals and groups. It examines the uptake, production and use of knowledge in such a way that will bring innovations*. Innovations are a hot topic in the whole European Union and all measures to help the creation of them are needed. This is the case especially in engineering education as engineers are the ones conceiving, designing, implementing and operating new products. Production of added value produced is bigger if these products are based on innovations. Universities have a great responsibility in helping their graduates, especially engineers, to become the future innovative actors in the market. It must be understood in the universities what is needed to reach this aim.

The core business of any university is in producing educational services. In the production process there are several shareholders who define whether the results are good or not. The learning process requires active participation by the student. The teacher is the interpreter and inventor of the means needed to help the student develop and reach innovation competences. There are several meta-innovations helping to generate the aim of this approach. One of the tasks of these meta-innovations is to activate students and this way facilitate and increase learning. These meta-innovations are the topic of the workshop.

As the meta-innovations leading to innovation competencies can be very versatile, expertize of the audience is being used when carrying on the discussion. The ways to produce innovation competencies found during the discussion can be very valuable to every participant.

1. Introduction to innovation pedagogy

The workshop starts by introducing the concept of innovation pedagogy. Innovation pedagogy *learning approach interested in the development of innovation competence of individuals and groups. It examines the uptake, production and use of knowledge in such a way that will bring innovations*. It aims to produce innovation competencies which can be divided into individual, interpersonal and networking competencies.

The core idea in innovation pedagogy is to bridge the gap between the educational context and working life. Learning and teaching processes are developed so that they provide improved competences for the students and enable personal and professional growth. Learning is deeper when the previously gained knowledge is continuously applied in practical contexts. (Penttilä, Kairisto-Mertanen, Putkonen, 2011.)

In accordance to this its conceptual core can be divided, as figure 1 describes, into three different spheres in parallel to the three major actor groups benefiting from innovation pedagogy: (Penttilä, Kairisto-Mertanen & Putkonen, 2011.)

- Final learning outcomes are connected to the students and measured by their success in future working life. The student must gain ability to participate in the innovation processes and be able to create actual innovations in their future working life. To reach this they also must possess substance knowledge (f.ex. engineering) needed for the creation of innovations.
- Learning of innovation competences alongside with study programme specific substance knowledge, skills and attitudes is mostly connected with working life, which provides students with ideal surroundings to acquire the competences needed in innovation processes and in future working life in general
- Meta-innovations refer to methods of learning and teaching utilized in the learning processes by the faculty members together with the students enhancing both the creation of innovations and innovation competence.

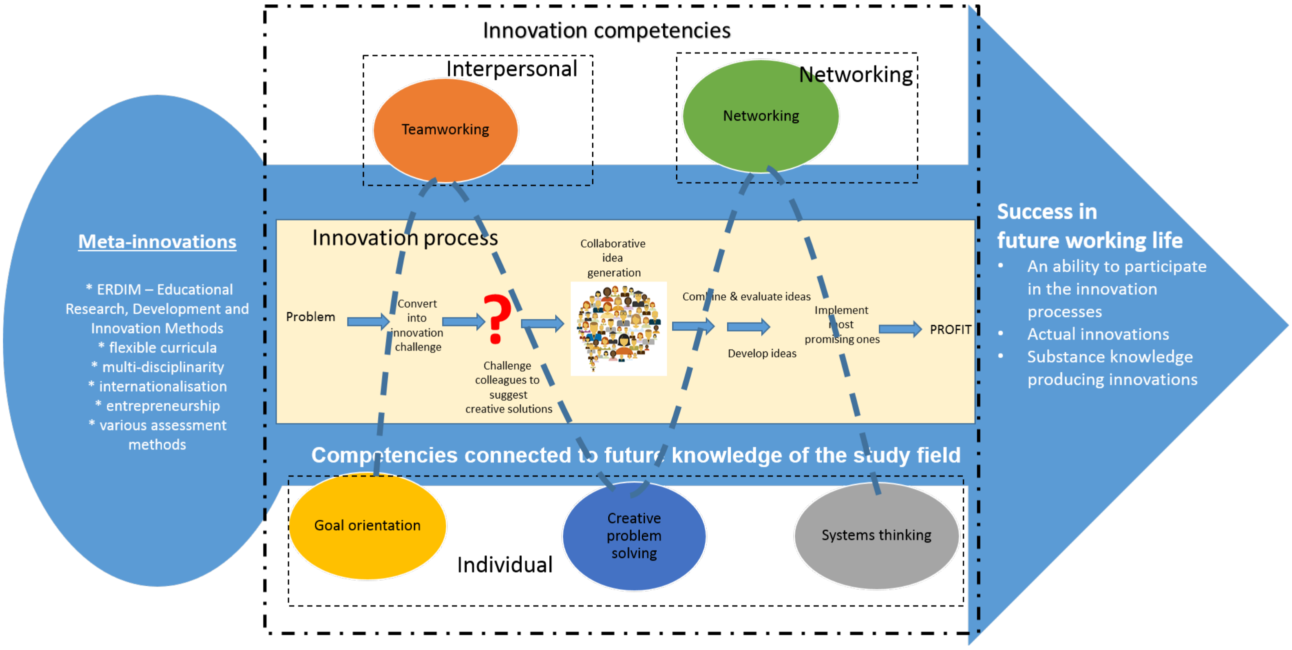

Figure 1. The final learning outcomes according to innovation pedagogy

Learning outcomes are statements which are used to describe specifically what is expected from a learner in form of understanding, knowledge and know-how at the end of a certain period of learning. They are broad statements of what is achieved and assessed at the end of the course of study (Harden 2002; Buss 2008). The outcomes cover both cognitive and practical skills (Davies 2002). They can be called knowledge or understanding, skills and attitudes, feelings and motivation accordingly.

Innovation competency as a learning outcome consists of knowledge, skills and attitudes. They enable students to participate in innovation activities in different phases of the innovation process and contribute to creating innovations. According to Ritter & Gemunden (2004, 548) innovation researchers can be roughly divided into two categories. One group is looking into the internal success factors of innovations and the other group into the boundary of the organizations, and in its network. The theoretical framework of innovation competencies includes these both perspectives. Individual competences such as creative problem solving skills, goal orientation and systems thinking are included, but also competences especially emphasized by the working life nowadays; interpersonal competencies such as team working and communication skills, and networking competencies such as ability to create and maintain networks. Individual innovation competencies of individual entail more than just clever ideas it includes also putting them into practice and spreading them more widely in cooperation with groups of people. Innovation competencies are generic by nature and expected in all study fields in higher education as well as in all industrial fields in businesses and organizations.

Innovation competencies are learned gradually as new information is added to our knowledge structures. Knowledge acquisition and application are critical components in this process. Thus, creating new services, products and organizational or social innovations – new added value – requires both knowledge and skills, which are applied in an innovation process. (Gibbons et al., 1994; Kairisto-Mertanen, Penttilä, & Putkonen, 2010; Nonaka & Takeuchi, 1995; Nowotny et al., 2001, 2003.)

Innovation can be defined in many ways. For example, Schumpeter speaks about innovative entrepreneurship. It is an Idea, practice or object which is considered new by the people (Rogers, 2006) or a solution which brings economic benefits knowledge or other practices applicable in working life. (Kairisto-Mertanen, Penttilä & Nuotio, 2011.) In the context of innovation pedagogy innovation has been defined as the process of constantly improving knowledge, which leads to new sustainable, ideas, products, further knowledge or other practices applicable in working life. This is a very broad definition of innovation and means that innovation can also be something else than a tangible new product or a service connected to that product. It can also be a new process or a new way of doing things or even a new pattern of thought – always depending on the industry where it is being applied.

Innovation pedagogy contributes to the development of new generation of professionals whose conceptions of producing; adopting and utilizing knowledge make innovative thinking and creating added value possible. (Kairisto-Mertanen, 2011; Putkonen, Kairisto-Mertanen & Penttilä, 2010.) This is an important target, which integrates applied research and development, entrepreneurship and flexible curricula to meet the multi-field customer needs in regional and international networks (Kettunen, 2011). The core idea in the application of innovation pedagogy is to bridge the gap between the educational context and working life. Learning and teaching processes are developed so that they provide improved competences for the students and enable personal and professional growth. Learning is deeper when the previously gained knowledge is continuously applied in practical contexts. (Penttilä, Kairisto-Mertanen & Putkonen, 2011, Kairisto-Mertanen & Mertanen 2012.)

2. The meta-innovations in Innovation pedagogy including the different educational research, development and innovation methods

Innovation pedagogy is a learning approach but it is also a strategic decision to reform existing pedagogical structures and curricula in higher education. Both faculty members and students are in a key position when developing the ways how innovation pedagogy can best be applied in its corresponding context. A joint vision and strong engagement of the management are essential factors when aiming to ensure the sustainability and coherence of the educational services.

How to make the reform possible? We trust on a step by step approach and on the power of positive experiences. There are several practical and concrete examples of delivering the education according to the principles of innovation pedagogy in several fields of education. (For examples see: Kairisto-Mertanen al. 2012). According to the aims of innovation pedagogy different educational research development and innovation methods must be developed so that the meta-innovations, cornerstones of innovation pedagogy can be found in the learning environment as presented in figure 1. The meta-innovations contribute especially to the development or student's interpersonal and networking competencies. They include gross disciplinary environment, research and development activities executed by a big amount of students, flexible curricula, concentration of acknowledging the importance of entrepreneurship and service production and internationalization in the level of research, development and student engagement.

One of the new ideas for applying and carrying out education according to the principles of innovation pedagogy is a method called hatchery work. This method combines real life assignments, peer counselling and working in gross disciplinary groups including the international aspect in all work. It is a teaching and learning method which includes different types of hatcheries. The principle of carrying out the work in the hatcheries is approximately the same but the expertise level of student varies in the different hatchery types. A first year student is capable of handling less complicated assignments requiring not so much expertise whereas a third year student has much more content, often individual, knowledge to be used when participating in the hatchery work.

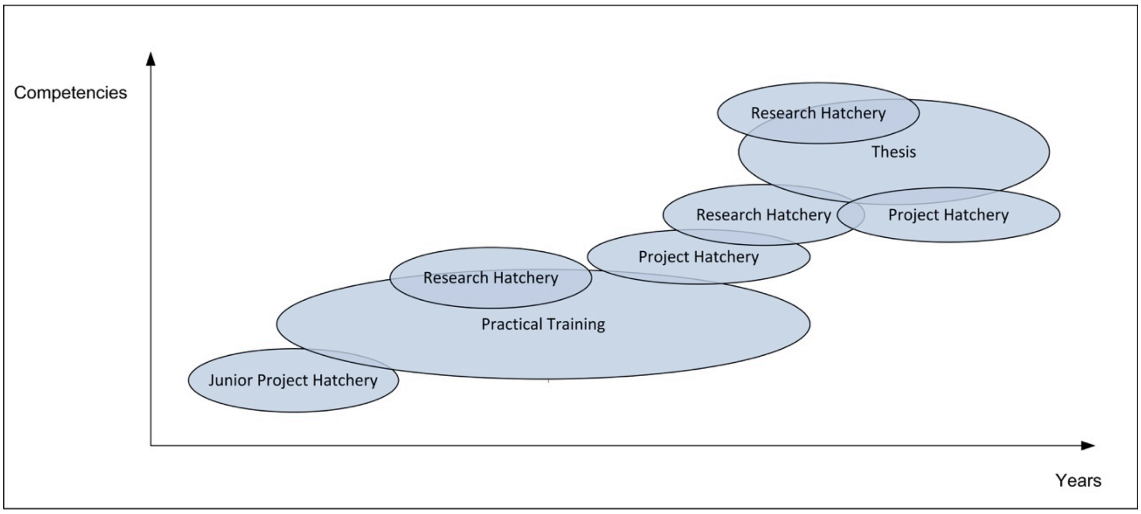

Figure 2. The different hatcheries in the student's path

The first step is to create a multidisciplinary learning environment. One successful example designed in Turku University of Applied Sciences is project hatchery. It puts new students together working in multidisciplinary teams during the first semester of their studies. By implementing it we have been able to create a tolerant and supportive learning environment where students in one discipline do not feel themselves better or worse than students in another discipline. Parallel to project hatchery the student-tutors coaching the project hatchery groups take part in a study unit "leading a group". They get practical experience about leading a group when they perform their coaching work.

When applying new pedagogical methods according to innovation pedagogy it seems to be critical to put a lot of emphasis in mentoring the students. (Lappalainen 2012.) Using these methods seems to require cooperation and careful planning of how the division of tasks is done among university personnel.

When innovation pedagogy is applied it is essential, as can be seen from figure 2, to give the students several opportunities to engage themselves in different kinds of hatcheries during their studies. Junior project hatchery forms the base and introduces the capabilities needed for this type of studying and working. After that it is up to the student to choose between different available options.

The research hatchery is meant for the students in the beginning of their studies who have completed their basic studies and, as a result, are familiar with the basic methods of the field and have thus reached an appropriate level of general knowledge on the topics of the more advanced hatchery. The students may also have experience of project activities when they get involved with the research hatchery.

Both the research hatchery and the advanced Project hatchery are essentially content-orientated. In other words, the target learning outcome of them relate to the subject matter itself. The difference between the research hatchery/advanced Project hatchery and the junior project hatchery is at its greatest in this context, in junior project hatcheries the orientation is towards methods rather than contents when compared to junior Project hatcheries. Working within the conceptual sphere of the project hatchery and gaining methodological skills precedes the production of content which happens in the research hatchery.

Practical training is a compulsory part of the education in a university of applied sciences and it always takes place out at the workplace where contacts to real working life are natural. Thesis work is another compulsory part of a university degree; it is preferably accomplished in close co-operation with working life. Research hatcheries bring the research done at the university to the proximity of every student. A student can participate in a research hatchery several times during the studies and move from less complicated tasks to more complicated ones as the studies progress. Advanced Project hatcheries bring the working life problems to the university to be solved by the students. They offer a great and easy access point to the surrounding environment and make it possible for the students to start building networks with working life partners already during their studies.

3. Design for the hands on session

Introduction 10 minutes

The hands on session will start with an introduction about innovation pedagogy and innovation competencies. The introduction will also include a brief overview of the ERDIM methods applied in Turku university of applied sciences. Time reserved for the introduction is 10 minutes.

First hands on 40 minutes

For the hands on session the participants will be divided into six groups. The groups are given a task to first discuss and share their ideas concerning innovation pedagogy. Each group will also be given role according to the method of six hats. The groups are supposed to share ideas among themselves according to their corresponding role defined by the hat they get. The overall topic for the discussion is innovation pedagogy and the possibility of applying it in the University of the Participator. They should prepare their opinion on Innovation pedagogy according to the role they are given. In a group discussion one member of the group represents the given opinion of their group.

Second hands on 40 min

The original groups gather together for a second round of discussion. Now the task is to explore methods used in their universities and choose one method to be discussed more in detail by the group. The group writes a poster about the method they have chosen and later presents it to the whole audience.

The results will be shared among all the participants in a form of a learning cafe. The groups will send their representative to express the ideas born in the group to the whole audience.

Result

It is expected that many new ideas are born through this sharing of results and the participants can start applying these ideas in their universities.

The participants will also gain basic understanding of what innovation pedagogy is all about and a vision of how they could join the movement and what would it require to adopt it in their own university.

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LSP workshop: applicating Lego Serious Play® to concept's shared understanding

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Abstract

The evolution of thought on change has moved in the last two decades from the "visionary on top", to an "experts improve whole systems" to the "everyone improves whole systems" approach (Sykes, 2008). Based on this belief a strong methodology was developed in 2007, the Lego Serious Play. The methodology believes in the potential of people, and also that everyone within an organization can contribute to the discussion, solutions, and outcomes to enhance business performance (Ariely, Kamenica, & Prelec, 2008; LegoSeriousPlay; Pike, 2002). Besides this application to business, Lego Serious Play methodology helps most of us realize that our brains contain a lot more than we are consciously aware.

This article aims to show an innovative pedagogical application of the Lego Serious Play method held in Mondragon University's Engineering School. The practical experience was developed through a workshop in the classroom with engineering students, and the main objective was the development of shared knowledge. In this case, the challenge was to learn about Quality Management using an active innovating methodology, usually used in business environments. At first glance students perceived it as a game and they remember those times when they used to build and play with the lego bricks. At this time they had to play, but it was a oriented play where the teacher, in the facilitator role, had to make students go through a learning process. The conclusions of the experience showed that building with others is key to unlocking new knowledge and that applying the Lego Serious Play was a very different and interesting way of learning for students. The students themselves and their perspectives were included on the learning process from the very beginning, and the process ended with a shared vision.

Once the common understanding of a concept was achieved, students were ready to move on and learn about the application of this concept to different scenarios, or even to learn more complex topics based on the previous one.

1. Introduction

The evolution of thought on change has moved in the last two decades from the "visionary on top", to an "experts improve whole systems" to the "everyone improves whole systems" approach (Sykes, 2008). Based on this belief a strong methodology was developed in 2007, the Lego Serious Play. The methodology believes in the potential of people, and also that everyone within an organization can contribute to the discussion, solutions, and outcomes to enhance business performance (LegoSeriousPlay).

Based on research which shows that this kind of hands-on, minds-on learning produces a deeper, more meaningful understanding of the world and its possibilities, the LEGO® SERIOUS PLAY® methodology deepens the reflection process and supports an effective dialogue – for everyone in the organization. The LEGO® SERIOUS PLAY® methodology is an innovative, experimental process designed to enhance innovation and business performance (LEGO®SERIOUSPLAY®). Up to date, the potential for exploration and experimentation using the medium of LEGO materials with adults in areas such as therapy, experiential learning, and organizational processes would seem to be significant (Said, Roos, & Statler, 2001). The methodology, as it is considered in its name, is based on playing, understanding that play is a mode of human activity that increases adaptive variability through the imaginative creation of meaning (Jacobs & Statler, 2004).

Although the methodology is established and has shown to have value within the commercial environment, particularly when focused on business strategies, there is also evidence that the LSP process can be effective in educational contexts, where individual goals are examined and synthesised to identify ways of meeting the learning needs of a group of individuals with separate but common aspirations (Mccusker, 2014)

Taking the previous into account this article aims to show an innovative pedagogical application of the Lego Serious Play method held in Mondragon University's Engineering School. The practical experience was developed through a workshop in the classroom with engineering students.

The article is divided into four main sections. We start with the introduction section where the core ideas of the article are introduced. The second section makes reference to the LSP method itself, the origins and the core process that is the source code of it. Then, we jump into the development of the application of the LSP method as a learning method used in class. This third section describes the phases of the workshop held at university and its most important elements. Finally, we close the article with some conclusions with reference to the application of the method and to the feelings of both the students and teachers, together with a suggestion of further applications of the method.

2. LEGO Serious Play ® Method (LSP)

The idea of using Lego bricks with a different purpose of playing came about in 1994 in a cooperation between Johan Roos and Bart Victor from IMD and Kjeld Kirk Kristiansen from LEGO. They formed a small company called Executive Discovery LTD. (ED). Later on, Robert Rasmussen took on the task of Director for Educational R&D in LEGO and from 1999 – 2003 developed the idea into the robust methodology it is today. In 2007 Robert Rasmussen further refined the methodology by introducing the seven application techniques. This is today fully integrated in method and in the facilitator training programs.

The LSP method is based on the belief that there is vast untapped potential in the people in organizations and those people have the imagination to resolve most serious issues. So, it is necessary to open ways to extract people's potential, making them contribute to the discussion, solutions, and outcomes to enhance business performance (Lego Serious Play, 2012). This way, the solutions achieved will be quicker, more sustainable and more efficient.

The LSP method seeks the participation of every team member tapping into the unconscious knowledge that each individual possesses. Everyone speaks and expresses his or her feelings, opinions or thoughts, and no one discusses them. Instead of having a typical meeting where 20% of the people take up 80% of the time, the LSP method ensures that the 100% of the time is divided among all participants equally, so that everyone participates in order.

Even if the solution or the milestones are not obvious when starting the process, point A in Figure 1, the limits and barriers throughout the process are quite clear for everyone in the team. It's like following the blue road.

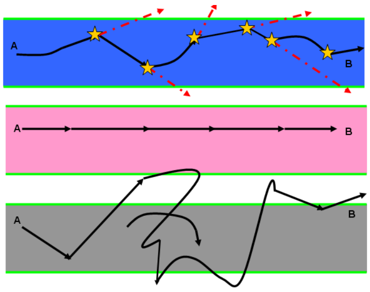

Figure 1 Possible roads to follow when solving problems or team-working.

The basic tenet of LSP is that Lego bricks are simple to use and provide ready-made, powerful and multi-purpose symbolic pieces, known to most people and used in different cultures.

The core process is at the center of the method, it is the source code that in essence defines that something follows the LSP method. It has four essential steps that are consecutively executed. These four steps can be repeated as many times as considered or necessary.

The four steps are as follows:

- Step 1: Pose the question. The challenge is posed and the facilitator has the objective of ensuring that everyone understands the question and the corresponding challenge. Therefore the framing of the challenge has to be clear and concise
- Step 2: Construction. The participants make sense of what they know and what they can imagine. They do this by constructing a model using the Lego bricks in an established period of time. The model must be a kind of metaphor of the answer.
- Step 3: Sharing. Everyone, in turn, shares the story of the model. The story must answer the question posed in step 1.
- Step 4: Reflection. As a way of internalizing and grounding the story, reflection upon what was heard or seen in the model, is encouraged. If anyone has any doubt or comment referring to the shared story or to the model itself, he or she can ask the model.

At the centre of the answer to the question of why to use the LSP method, is the notion that we know much more than we think we know, and the belief that we live in a world that is not linear and predictable. Only articulating what we know, and what we can imagine, can we intentionally work towards changing the world the way we would like to.

3. LSP in the classroom

The situation was the following: 25 students from the second course of the engineering degree starting to have lessons related to quality management. The teacher had to introduce the subject and wanted to reach a deep understanding based on students' experiences and previous knowledge.

When designing the session, the teacher thought it could be a good idea to work with the Lego bricks during the class. It was good for two reasons: the first one that using Lego bricks itself was an innovative way of teaching, and also learning; and, secondly, in this way, students would gain the dual benefit of learning about quality management and, at the same time, learning an innovative methodology that they could use in their professional or personal future.

Taking all these into account, the idea became a reality and a four step session was designed:

- Introduction or warming-up phase
- Understanding and building the beast

- Writing down the manifesto (a kind of resume or conclusions)
- Closing

Finally, it was needed a three hours session to go through the four phases.

a. Introduction or warming-up phase

The introduction or warming-up, is where the participants get used to the Lego bricks, they remember how to use them, and learn how to tell stories about the models they built. It is very important that everyone in the room takes part, as this is one of the characteristics of the method, so that, for facilitators, this is one of the most difficult tasks in inviting and encouraging everyone to take part. As it was quite a big group of people, we divided the class into three smaller groups. Each person was provided with an exploration bag, a bag where a selection of Lego bricks is contained (see Figure 2). These bags are usually used for initiating sessions, lasting no more than 4-5 hours.

Figure 2 Exploration bags and the Lego bricks contained in it

Before explaining the first challenge, it is important to refer to the core process of the LSP method and to explain in so that everyone keeps it in mind:

- The facilitator asks the question you have to answer by building a metaphorical story
- Everyone builds individually and gives it meaning while building
- Everyone tells the rest of the group the story in the model
- There is a chance to make questions, reflections, identification of patterns, …

And also the ground rules that are at the base of the methodology:

- DON'T have a meeting with yourself. Just START building
- TRUST your hands. Let them pick the bricks they want
- When you tell your story the meaning will emerge
- DON'T get bogged down in the design

During the warming-up phase, the facilitator posed three challenges to the group.

- Challenge one: Starting with the black base plate build a tower. Build it exactly as you want, but finish the tower with the pink flower. Build individually. You have about 4 minutes.

The main objective of the first challenge is to show the group that everyone is able to build a model, and that also everyone can tell a story, even a simple one, about the built model. In this case, there are not many indications or even limitations when building.

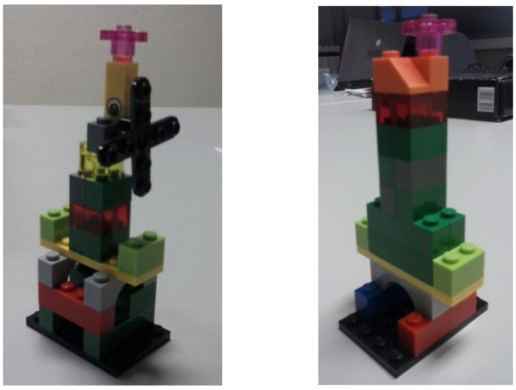

Figure 3 Examples of the response to the first challenge. A tower starting with the black base and finishing with the pink flower.

- Challenge two: It was developed in two steps.
    - First; Select one of these models (Figure 4) and try to build it using the bricks you have. Build it individually. You have about 5 minutes.
    - Second; Modify your model so you can use it to tell a story about what makes you feel good or motivates you about the engineering degree you are studying at the moment.

The second challenge had a double objective: to show that it is possible to build a model by copying, and to show that we are able to adapt a reality (in this case the model) and give it meaning. Therefore, that everyone is creative.

Figure 4 The models used for the first step of the 2nd challenge.

- Challenge 3: Build a model telling the story about the worst nightmare about a no quality item or experience? What's the worst thing that can happen when referring to the quality of an item? Build it individually. You have about 3 minutes.

The objective, in this case, is to open the creative process, without references or restrictions, to start building while answering the question. The third challenge is related to the main topic of the session. At this point the group is getting closed to the core of the session.

After the warming-up phase, it is time to jump into the main question of the session. Therefore one more challenge is posed to the group.

b. Understanding and building the beast

At this phase the group works on the core issue and the right performance of the session is very much dependent on the good work developed at the previous phase. It means that it is necessary to spend enough time working on the warming up phase if we want to achieve the global objective of the session. To this end, a fourth challenge was posed.

- Challenge 4: What is something of quality? When do you say something has quality? Which are the specifications of an item if it's a quality item? Build it as you understand it right now. Build it individually. You have about 5 minutes.

Once again, the facilitator has to encourage everyone in the group build the model with his or her own vision of the answer to the question. It is important to insist that no matter how different, opposite or similar the models and the stories are and the important thing is that everyone has the chance to talk about the self-built model (see Figure 5).

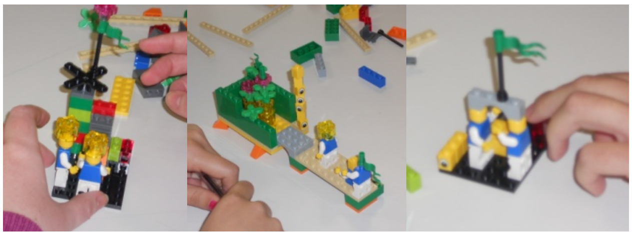

Figure 5 Examples of the models built for answering the fourth challenge.

For learning it is important to share (Sutton, 2012), but it is not enough. Once knowledge is shared, it can be combined and rebuilt, with shared knowledge or even new knowledge.

To put this into practice, the following step is to build a shared model. The shared model construction is used when you want a group to agree on one deeply shared answer to a question or challenge. The models and, what is really important, the stories about what individuals understand about innovation management and the main elements/factors/stakeholders are mixed to build a reinforced, common and shared understanding of the beast (Figure 6).

To go through this step, each of the team members has identified the most important part of his or her model using a small red plate. After sharing with the group the reasons for selecting that part, it is the group's work to build a shared model where all the selected parts make a final outcome, where it is more than the sum of individual pieces. The shared model is made from bigger or smaller sections of individual models. So there now follows a negotiation phase. The shared model has a coherent story that encompasses the essential meanings from each of the individual models and, of course, all the participants are happy with and commit to it.

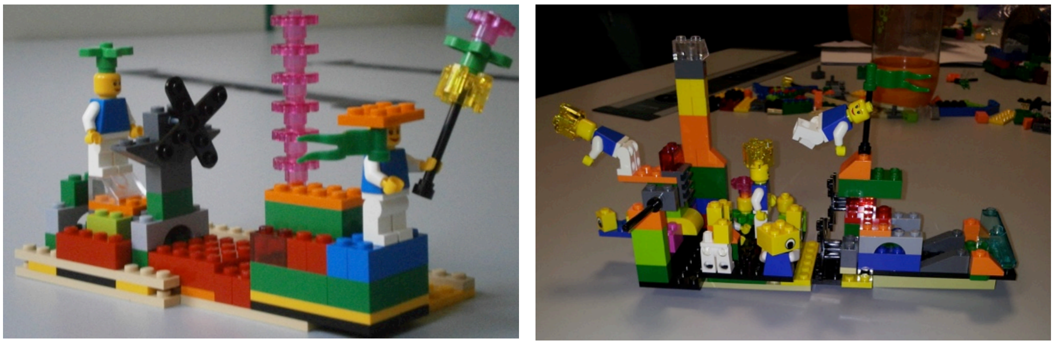

Figure 6 Examples of the shared models.

c. *Writing down the manifesto*

Once the shared model is built, and the shared story is agreed by the participants, it is time to write it down. It is an exercise of storing the insights and lessons learned from the process. The manifesto reflects the wisdom gained through the shared experience and can be composed of simple sentences that are easily remembered.

d. *Closing*

The last phase of the session is the closing, in which the facilitator makes a summary of what has happened in the last hours. It is important to keep the same creative, open and positive spirit as in the beginning.

What the facilitator says during these five to ten minutes will remain in the participants' mind for a long time, so it is important to do it properly.

4. Results and conclusions

Using LSP method as a learning methodology has been a really positive experience, both for the students and the teacher-facilitator.

As the session goes ahead, simple conclusions appear. The reflection phase corresponding to each posed challenge leads the participants to those conclusions. These are some obtained conclusions in the session:

- Everyone can build
- Everyone can tell a story
- While someone is sharing his or her story, the participants are looking at the model, and not the person speaking
- Those that touch the model while speaking, reach more powerful, creative and realistic stories than the ones that don't
- Following a model while building (challenge 2) is easier than having simple instructions (challenge 1) or having none (challenge 3 and 4)
- When building a shared model, it is about negotiation
- The manifesto, helps reflecting the wisdom gained through the shared experience into a document

The general conclusions of applying the LSP method as a learning method are as follows:

- It is a very interesting method for students
- The students feel themselves appreciated and that their opinion is taken into account.
- The student and its insight is included in the learning process, and from the beginning
- The process is closed with a shared vision, therefore it is easier to continue working.
- The facilitator has an extremely important role within the process;
- Has to know the method
- Has to be very careful
- Does not have to provide judgments, and must limit themself to the facts
- The model belongs to that person who has built it, so they must be handled respectfully

And… everyone is able to construct or build a model, and everyone is able to tell stories.

5. Workshop activities

The proposed ALE hands-on workshop session will provide an experiential immersion in this methodology, focusing on the Active Learning concept development. Specifically, participants (and likewise students in our classes) will use LSP methodology during the session to get knowledge related to the application of new learning methodologies.

The workshop will have two main purposes. On the one hand to share, learn and understand what Active Learning means, and on the other hand to make an approach to how Active Learning acquisition can be assessed.

According to the objectives, the working session has been planned dividing it into five main phases:

- Introduction (10')

- What gives us energy? (40’)
- Understanding and building the beast (45’)
- Our beast conquering manifesto (15’)
- Discussion and Closing (10’)

The following chart (

Table 1) shows the proposed workshop flow according to the LSP methodology.

Table 1 Workshop flow

App Time	**Purpose**	**Main Challenge**	**Essential Outcomes**
10’	Introduction; give overview of the program and introduce LSP process.		
40’	To familiarize the participants with the LSP process.	CH1. Build a tower. CH2. Build a model representing what makes you feel good/motivates about teaching CH3. What is your worst nightmare about teaching a lesson?	CH3 will be kept in the fun and humorous spirit and is not intended to be about complaining. Indirectly the challenge is also to indicate that we all realize that not all teaching sessions are perfect.
45’	The team’s aspiration. This part will end up with ONE shared model. This model will tell the story about what the TEAM as a whole understands as Active Learning and furthermore, about Active Learning Assessment.	CH4. What does Active Learning mean? Step 1. Build individually Step 2. Identify the core of your model. (red brick) Step 3. Negotiate your individual models in to one shared model that you all can commit to. Step 4. Share the story with other groups CH5. Taking the previous definition as the starting point, how can we manage to assess the degree of achievement of Active Learning?	CH4’s goal is to get the team to identify some of the specifications of Active Learning. Sharing the story will be important in terms of the team getting a sense of how aligned they are. CH5 tries to go a step further and makes an approach to the way Active Learning can be assessed.
15’	Writing down the manifesto	Using the shared model, list the main guiding principles that will configure Active Learning.	This step has the objective of writing down the simple guiding principles (manifesto) that all team members shouldn’t forget.

10’	Discussion and Closing		

6. Further applications

This experience has shown that it is possible to work in the classroom using different teaching methods to those we are used to. In this case, some simple Lego bricks have been used and the potential they have has been tested.

Nowadays, further applications of the LSP method are being designed, in concrete for working with creativity and for building and developing knowledge related to innovation management.

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A role playing game for improving linear programming concepts: the case of an emergency ambulance system

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Abstract

This paper aims to present and reflect upon an active learning process on linear programming modelling in high school or first year Industrial Engineering students. In doing so, we develop a role playing game to compare the learning process among students that play the game to the ones that do not do it. This comparison supports the idea of enhancing students' modelling skills by the implementation of active learning initiatives. The design consists of groups composed of four students to discuss and decide about the assignations of a fixed number of ambulances in a city, as a real emergency system. The city is represented as a Cartesian model, and each ambulance could be assigned to one point in the map. The game involves several rounds. In each round an incident (e.g. car accident, people with heart attack, etc.) is randomly generated. Each incident is characterized by one point of the map and a number of patients to be served. The group must decide which ambulance will serve it, taking into account some constraints and with the objective of minimizing distance. They also have to choose which hospital will attend the patients, considering hospital's capacity and its location. The winner is the group that achieve the shortest distance to serve all incidents. The active learning model that underpins this game is one that considers three levels of recursive understandings: first, to experience and observe (i.e. to play the game); second, to question and distinguish (i.e. to explain what happen in the game and to relate it to real contexts); and third, to analyse the problem (i.e. to model the problem mathematically). The article includes the active learning conceptual framework, the description of the game designed, and final reflections.

Key words: linear programming, active learning activity, ambulance service, location problem, role-playing game

1. Introduction

The purpose of this paper is to present a role playing game to introduce the linear programming world to first year engineering students or high school students interested in studying engineering. Section one presents the learning model. Section two describes the real world application and the mathematical model used. The activity and the game are described in section three. Finally, section four presents final conclusions and future extension of this active learning activity.

2. The learning model

Active learning (AL) is an umbrella term to different models of teaching (e.g. collaborative learning, experiential learning, problem-based learning, etc.). AL implies the design of pedagogical strategies to work a concept into participants' personal knowledge and experience to learn. It also involves students' reflection and monitoring of both, process and results of their own learning (Barkley, 2010).

One of the core elements of AL is the transformation of experience as creator of knowledge (Kolb, 1984). The transformation of the experience is possible by reflexive observation, abstract conceptualization and active experimentation. This experiential approach to learn involves participating in hands-on activities *(level i in the proposed active learning model: living the problem – see figure 1)*. This reflective observation can be supported by a process of questioning about a phenomenon (e.g. a problem situation), comparing it to previous experiences, and distinguishing some concepts within the learning process (Kolb, 1984; Duque, 2006) *(level ii in the model: explaining the problem)*. To support abstract conceptualization, a discussion about formal theories or models to approach the phenomenon is required *(level iii in the model: modelling the problem)*. This leads to take a step forward for participants actively experience new levels of understandings and feelings about the problem situation learned (Barros et al., 2009) *(level iv in the model: solving the problem)*. Consequently, a learning cycle is generated.

Throughout the whole learning process cognitive as well as metacognitive skills (the self-awareness of the cognitive process) should be promoted (Barkley, 2010). Furthermore, within the AL approach, learning is considering a social process (Laverie, 2006), where interaction helps individuals to generate a common language to performance a task as well as to build understandings between them (Salkind, 2004). This social interaction can promote deep learning (Dillenbourg, 1999). Therefore, the activities proposed within an AL perspective should include the social dimension.

The learning cycle of social interactions should be held by a clear vision of the learning purpose, which has to integrate activities, feedback, and assessment (Barkley, 2010). Another basic aspect to promote learning in AL approach is motivation (the level of enthusiasm and the degree to which students invest attention and effort in learning). Accordingly, an AL approach should bear in mind the promotion of autonomy, competences, meaningful experiences, and sensitivity for the learning incentives to increase participants' motivation (Illeris, 2003; Barkley, 2010).

Finally, two other aspects to consider in the design of an AL model of instruction are the socio-cultural context and the support tools. The former refers to the cultural and social meaning that learning activities might have (Salkind, 2004). The latter refers to the set of supporting technologies that can be used to enhance learning (Barros-Castro et al., 2013).

With previous elements in mind, the possible emerging result is engagement (active involvement). An engaged student actively examines, questions, and relates new ideas to old, thereby achieving the kind of deep learning that lasts (Barkley, 2010; Barros-Castro et al., 2013). Figure 1 presents a proposal of active learning model, considering previous proposal by Barros et al., (2008, 2009) and the aforementioned aspects of the AL process.

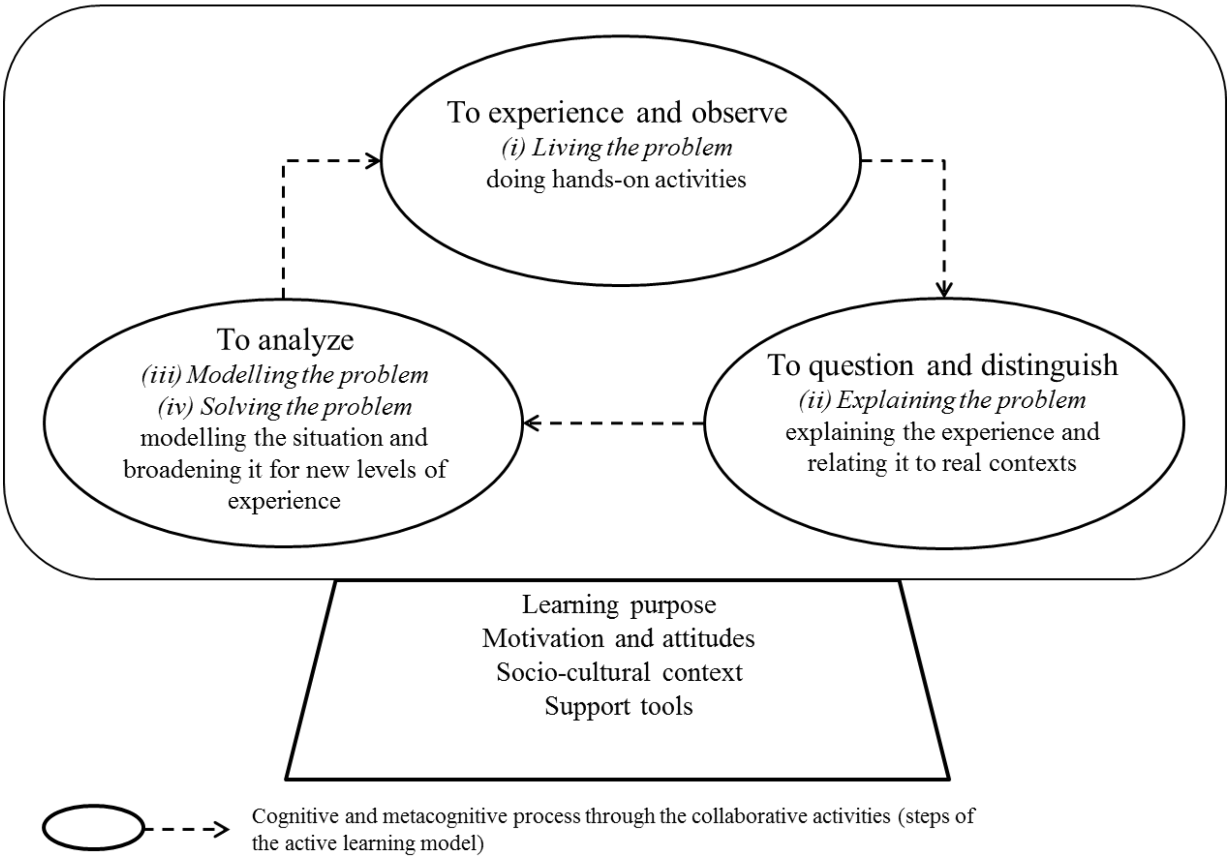

Figure 1. Proposed Active Learning Model.

3. Using the model

The former model is used to introduce general concepts of linear programming. The main objective is that at the end of the activity the students acquire a comprehension level that allow them to understand concept as decision variables, objective function and constraints, all of them important to define a linear programming model.

To accomplish this goal, first of all a real and daily world problem is presented. Then this problem is presented as a role playing game where the student should take several decisions, as in the real case occurs. Finally the round table is made in order to identify the linear programming components and a mathematical model is then generated.

a. The real world application

The Ambulance Service (AS) is the system responsible for answering and responding to medical emergencies in big cities. The biggest service is the London Ambulance Service (LAS) that serve more than 7 million people that live in work London (McGrath, 2001).

The process is as follows: once an emergency call number (usually 999) is received by Operations Centre, the AS will either resolve the call over the telephone or dispatch an ambulance. In some cities there are different kinds of vehicle that are dispatched depending on the nature of service.

If one ambulance is required the Operation Centre should dispatch the one that arrives in the shortest time to the incident. To do that, it is necessary to deploy the set of ambulances, allowing cover all city. Usually the ambulances are scarce resources, and this is why to select where to locate one is a very important issue for the system. In the present case we consider the system where ambulances must be affected to specific discreet points in the city. The location is made considering that all population must be cover at least once guarantying an average response time.

In this situation there are two problems: where to locate an ambulance and which ambulance will serve an emergency call. The first problem is the traditional location problem, the second is an extension of the first one and it is known as location – relocation problem (Brotcorne et al, 2003).

b. The mathematical model

Let I and J be the sets of discrete points that represent emergency calls and the feasible location points, respectively. Each demand point has a number of patients to be served $(h_i | i \in I)$. Consider d_{ij} represents the distance between the demand point $i \in I$ and the location point $j \in J$. If one ambulance is located on the position $j \in J$, the decision variable x_j take the value of one, zero otherwise. Additionally, it is necessary to define which ambulance will serve one demand, the decision variable y_{ij} will take the value of one if the ambulance located on position $j \in J$ will serve the demand $i \in I$, and the decision variable z_i will take the value of one if the demand $i \in I$ is satisfied.

The model is represented by equations 1-4. Equation (1) looks for minimize the distance to serve the most of demand. Equation (2) is the set of constraints that limits the number of ambulances to be located. The fact that only one demand must be satisfied by one ambulance is described by equation (3) and finally one demand must be satisfied by one ambulance that is effectively located is described on equation (4).

$$Min \sum_{j \in J} \sum_{i \in I} h_i d_{ij} Z_i \text{ Eq. (1)}$$

Subject to:

$$\sum_{j \in J} x_j = P, \text{ Eq. (2)}$$

$$\sum_{j \in J} y_{ij} = 1 \quad \forall i \in I, \text{ Eq. (3)}$$

$$y_{ij} - x_j \leq 0 \quad \forall i \in I; \forall j \in J, \text{ Eq. (4)}$$

4. Hands-on activity

Session format: Hands-on activity

Topic: Active learning to attract students to engineering courses

Activity outline:

- Recreate the role-playing game during the workshop.
- Make a discussion around the workshop with the participants. The goal is to measure the impact of the role-playing game on participants' learning process and motivation.
- Targeted issues for discussion: Role-playing game, motivation, and effectiveness to learning process.

Hands-on session Schedule: 90 minutes

- Presentation: 10 minutes
- Activity: 60 minutes
    a. 5 minutes first iteration
    b. 40 minutes (8 iterations)
    c. 15 minutes (evaluation and discussion)
- Discussion and conclusions: 20 minutes

Materials:

1 laptop

1 video beam

1 room for workshops

a. *Role-playing game description*

Contents:

- 1 board game for groups of 4 or more people
- 44 Random cards
- 1 dice
- 1 admissions and discharges of patient format
- Lego pieces representing patients (blue, green and yellow colours, depending on the round) and 10 ambulances with capacity of one patient (white colour lego pieces)

The board game corresponds to a city map characterized by grids (XY coordinate), each one identified by a number and a letter (see figure 2). Some of those grids denote hospitals (H), which have a capacity of two patients. Around the board, there is a set of grids that allows the players to move along the board game. These grids have different random situations; indicate by the random cards, which can happen in a real context (e.g. an earthquake, the acquisition of new ambulances or the damage of the current ones, among others). One corner represents the start of the game and the other three are reserved to extraordinary good events as for example, new investments.

The game involves several rounds. At the beginning, the players must decide where, in the city map, to locate the ten ambulances. After that, one player rolls the dice and moves along the board game. He/she takes the corresponding random card in order to identify the situation occurring in the particular round. In each round an incident (e.g. car accident, people with heart attack, etc.) is randomly generated. Each incident is characterized by one XY coordinate of the map, a number of patients to be served, and a colour (green, yellow or blue). The group must decide which ambulance will serve it, with the objective of minimizing distance. They also have to choose which hospital will attend the patients, considering hospital capacity and its location. In order to evaluate the objective function, the distance is measured as the number of squares between the ambulance and the incident, and between the incident and the hospital. All movements must be in a rectilinear way. If it is not possible to serve one or more patients, a penalty of ten units in the distance must be charged to the total displacement.

At the same time, another player should register the number of patients served, the colour and the total displacement executed. The patients will be in the hospital during two rounds. Once one ambulance is used, it must be out by two rounds (representing the sanitation process). When one round finishes, the used ambulances must be placed in the “waiting two rounds” area. Those ambulances placed in this area in a previous round must be moved to the “waiting for one round” area and those placed in this area must be relocated in the city map. The winner is the group that achieve the shortest distance to serve all incidents.

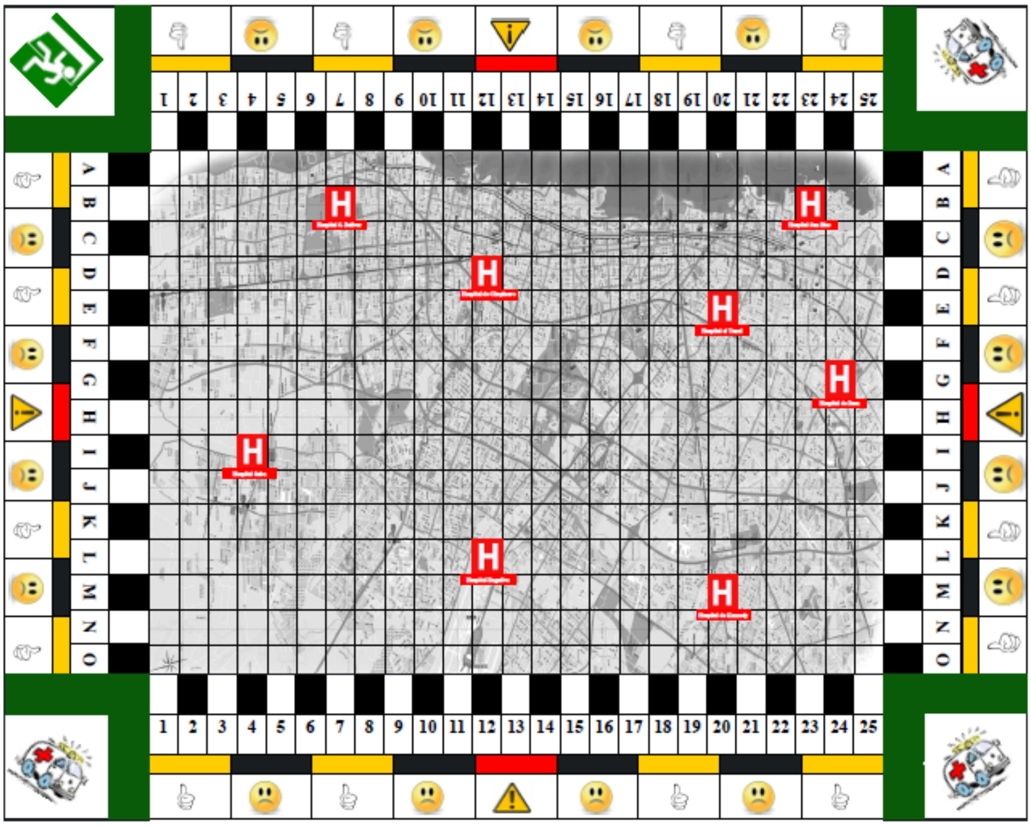

Figure 2. Board game.

Concerning the hospital, the group need to check if there are some discharged patients and release the hospital capacity.

5. Considerations

The game was played with last year high school students in order to motivate them to pursuit Industrial Engineering studies. Nevertheless those activities were useful to assess the game.

Furthermore, it is important to highlight the possible mechanisms to evaluate the effectiveness of this role playing game in learning performance and participants' motivations. In this regard, considering the model (figure 1) as a learning cycle with different levels of comprehension, some caveats are needed:

a. The role playing game can be used to make participants aware of this kind of situations and how engineering (in particular, linear programming concepts) can help to overcome *them (levels i and ii in the proposed active learning model)*. Here, the pertinence of the game is measured by how the students can explain the problem and the possible results (i.e. to relate the game with some notions about the linear programming concepts, but not necessarily to formulate the problem as a mathematical formal model).

b. The role playing game can also be used as a way to guide the formulation of mathematical formal model, taking into account the linear programming concepts and the reflections about the problem situation *(levels iii and iv in the proposed active learning model)*. Here, the pertinence of the game is measured by how the students can formulate the mathematical formal model and relate this formulation to the problem situation.

c. In addition, the role playing game can take advantage of the two previous uses to question whether the combination of the levels *i* to *iv* fosters an engagement and deep learning in comparison to traditional methods of instruction (i.e. to compare the learning process among students that play the game to the ones that do not do it).

d. In relation to the promotion of engagement, the role playing game can also be used to test participants' motivation. Issues that ask about whether the activity promotes autonomy, a meaningful experience, and a positive perception toward the learning process can help to measure the level of enthusiasm, effort and attention in learning.

Taking the aforementioned aspects into account, we expect to extend this activity using the learning model to evaluate different learning levels, that we have defined as (i) living the problem, (ii) explain the problem and its implications, (iii) model the problem, and (iv) solve it. In particular, we want to focus on (iii) and (iv) as so far the activity have been used mainly in the first two levels. Hence, we want to evaluate the different degrees of learning within each level. Additionally, in this part of the role-playing design we only consider the location problem, but it is possible to include the assignation problem and the relocation problem.

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Teacher in a PBL Environment – Jack of All Trades?

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Abstract

Problem Based Learning is one among several approaches to active learning. Being a teacher in a problem based learning environment can, however, be an educational challenge because of the need to support student learning within a broad 'landscape of learning'. This landscape of learning may be mapped using the Study Activity Model developed by the Danish University Colleges. In this paper we will explore the outcome of applying this Study Activity Model in the context of the Faculty of Engineering and Science, Aalborg University, a university well known for its problem based learning approach to teaching and learning, with the aim of investigating to which extent this may lead to explication and clarification concerning the challenges faced by teachers in a problem based learning environment. This paper will present the Study Activity Model, the use of this model in a semester at Aalborg University and reflections upon the suitability of the model in a university setting where the problem based learning approach to teaching and learning is dominant.

1 Introduction

The benefits of active learning (AL), i.e. a teaching and learning approach where students are actively and often collectively engaged in collecting and processing information within their field of study and where the responsibility for learning is placed with the learners, is well supported, not only by generally accepted learning theories, such as social constructivism (Piaget, 1950; Vygotsky, 1978), experiential learning (Kolb, 1984) and situated learning (Lave and Wenger, 1991) but also by empirical studies (Freeman et. al., 2014). Yet, active learning is not implemented in many institutions of higher education in engineering. In this introduction reasons for this lack of implementation will be discussed, the research questions will be presented and an overview of the paper given.

a. Active learning

One of the reasons for the lack of implementation of AL may be that a transformation to AL would involve a transformation of the role of the teacher from a lecturer relying on information transmission to a facilitator responsible for *"the purposeful creation of situations from which motivated learners should not be able to escape without learning or developing"* (Cowan, 2006, p. 100), or, in other words, a transformation from 'the sage at the stage' to 'the guide at the side'. This role transformation may meet with external resistance from public opinion formers, incl. politicians who might consider that teachers are not doing their job if not lecturing. This political discourse will not be pursued further in this paper. The role shift may, however, also meet with internal resistance from the teachers themselves, caused by a mix of reasons, such as, for example, a universal human resistance towards change; a perception of losing authority in relation to the students; a self-perception closely connected with being the active lecturer; related to that a belief in the psychological misunderstanding of *"pretending that there is correspondence between what is taught and what is learned"* (Illeris, 2007, p. 237) and therefore a belief that teaching cum lecturing is the best way of securing students' learning. The extent to which these different reasons for resistance to change are at play in a situation of educational change will depend upon the dominant culture in which the change takes place.

Closely connected with the role shift of teachers is the role shift of students. Students need to change from being passive recipients of transmitted information to becoming active collaborators and constructors of knowledge based on information inputs from many different sources, incl. the lecture(r). This role shift may also in certain situations meet with resistance – being an active student requires more work than being a passive recipient – but it is the experience of the authors that this barrier to change normally is quickly overcome, once students start realizing that they learn more and deeper from active learning.

Thus, for whatever reason, an apparent schism may arise between the students' active learning on the one hand and the teacher's active teaching on the other hand. This schism may be solved by visualizing that the learning processes of students can be supported by a diversity of activities, apart from the traditional lecturing situation where students are passive listeners to an active lecturer. A model for visualizing the diversity of study activities in a higher education programme is the so-called Study Activity Model (SAM), developed by University Colleges, Denmark (UC-DK, 2015). The model has been developed specifically for use in connection with the Professional Bachelor programmes offered at the Danish university colleges.

b. Research questions

Our intention here is to apply the model to the problem based learning environment at Aalborg University (AAU), a university that is well known for its problem oriented and project organized group work, ie. an AL approach to teaching and learning. Our main aim is to explore to which extent it is possible to explicate and clarify the role of the teacher in a PBL environment through a visualization of the diversity of study activities taking place in this environment. A secondary aim is to explore to which extent the introduction of a new model for planning and explicating study activities in the problem based learning (PBL) environment may assist in continued development of the so-called Aalborg PBL model. Thus, the paper aims to explore the following three research questions:

1) *To which extent can the study activity model SAM be used to visualize the diversity of study activities in a problem based learning environment in engineering at Aalborg University?*
2) *To which extent can the study activity model SAM be used to explicate and clarify the role of the teacher in relation to different study activities?*
3) *To which extent can the use of the study activity model SAM lead to enhanced understanding and clarification of the study activities involved in the Aalborg Problem Based Learning model?*

These questions will be answered by applying the SAM model to a case study taken from first semester engineering at the Faculty of Engineering and Science, AAU. The reason for choosing a first semester for the case study is that the first semester in any university programme is crucial in the personal development of students transiting from being high school pupils to becoming university students. The case study will highlight the transition process. This delimitation defines the context of the paper and neither political nor cultural issues will be further addressed in the paper.

c. Overview of paper

The paper contains five sections of which this introduction is the first section. In the following section the SAM model is described and arguments for developing and introducing the model in the Danish University

Colleges are presented. The third section is the case study, i.e. the description of the first semester of the BSc in Electronics and Information Technology (EIT) engineering study programme at AAU, including the quantified categorization, according to the four categories of the SAM model, of the study activities involved in this semester.

The fourth section contains a discussion of the extent to which the experiment of applying SAM ’out of context’ has been fruitful in the sense that the diversity of study activities in the PBL environment can indeed be represented via the SAM model and that SAM thus may be useful in a PBL environment in visualizing the diversity, both in respect to types of study activities that students carry out during the semester and in respect to the role of the teacher in connection with the different types of activities.

The fifth and last section contains the overall conclusion in the form of answers to the three research questions above. Furthermore, possible future use of SAM at Aalborg University will be put in perspective.

2 The Study Activity Model SAM

Studying to become a professional in any programme of higher education involves taking part in a number of different study activities. By ‘study activity’ we will understand both ‘teaching activity’, i.e. an activity where the teacher is the main actor while students participate more or less actively, and ‘learning activity’, i.e. an activity where the student(s) is/are the main actor(s) and the teacher may or may not participate in person. In this section the study activity model (SAM) developed by University Colleges Denmark will be presented. The following presentation of the model is based on Mølgaard (2014) and UC-DK (2015). The description of the model is followed by a short presentation of the different purposes and uses that the model is intended to serve within the UC-DK context, as well as a short discussion of our intentions of introducing the model in AAU.

2.1 Description

The SAM model is a model illustrating the variety of different teaching and learning activities that any student of higher education will have to participate in to be a successful student. The model is focused on students’ notional study time, i.e. the time that an average student will have to spend on achieving a certain amount of credits.

The model is basically a coordinate system with two axes: The horizontal axis is labeled ‘Participation’ and the vertical axis is labeled ‘Initiation’. The two axes span four quadrants: C1, C2, C3 and C4, as illustrated in figure 1.

Category 1 (C1) contains all types of study activities that are initiated by the teacher and where students and the teacher participate, whether in person or online. The study activities in category 2 (C2) are also initiated by the teacher but only the students participate actively and directly in the activities. Category 3 (C3) which includes study activities initiated by students and with only students as participants may be the most controversial type of study activities seen from a traditional teaching cum lecturing perspective. The last category 4 (C4) includes student-initiated study activities in which both teacher and students participate.

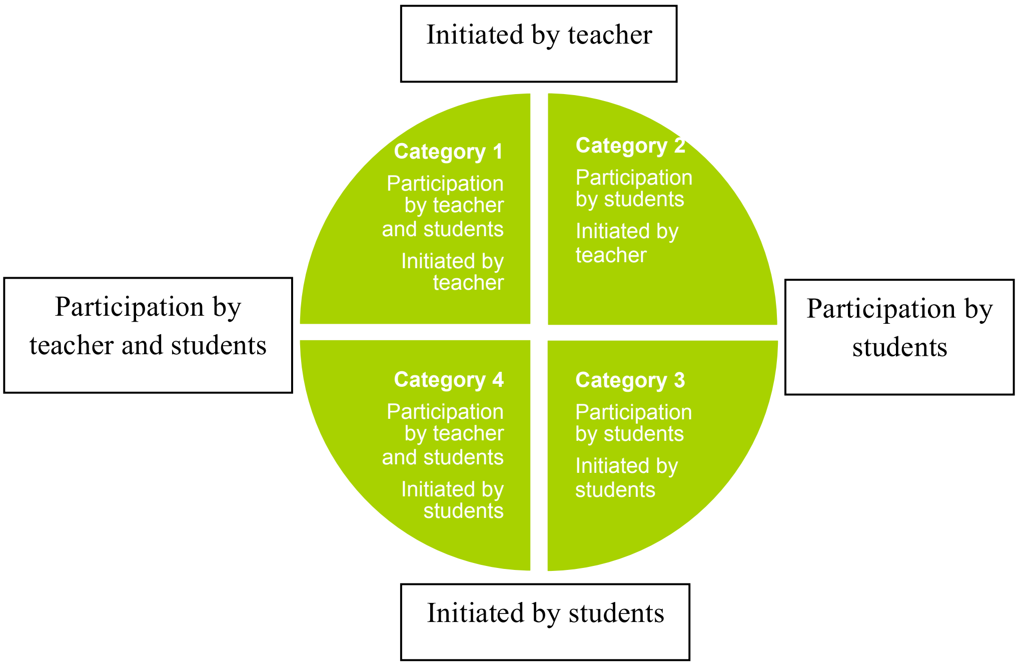

Figure 1. The Study Activity Model SAM (Mølgaard, 2014, page 9)

The SAM model is not based on any specific learning theory, although it may be assumed that the type of learning that happens in, say, C1 is likely to be different from the type of learning that happens in C3. Where learning in the upper two categories may be assumed to be more assimilative, the learning that happens in the lower two categories may tend to be more accommodative (Illeris, 2007). The relationship between learning theories and the SAM model will not be further pursued in this paper.

2.2 Purpose and use

The SAM model serves a number of different purposes. Initially, the model was developed in 2012 as UC-DK's response to a political demand for strengthening the study intensity of students in the primary school teacher educations in Denmark, with the intention of making visible the fact that studying to acquire a Professional Bachelor's degree as a primary school teacher includes taking part in a range of different study activities, not all of which requires the presence of a teacher. This educational policy discussion is not within the scope of this paper and will not be further pursued here.

Within the educational sector an important purpose of the model is to present a nuanced perception of what constitutes legitimate study activities, including not only traditional teaching approaches such as lecturing but also a diversity of other activities, including virtual activities, where teachers play a less visible but equally important role for students' achievement of learning outcomes.

A didactical purpose of the SAM model is to enable educational planners at all levels to plan a programme, a semester, a module or a session so that a diversity of study activities are included. At programme level a progression would be observed in most educational programs, from most activities being in categories 1 and 2, i.e. activities initiated by the teacher, in the early semesters of the programme to more activities being in the student-initiated categories 3 and 4 in the later semesters.

Part of the didactical purpose is to visualize the diversity of legitimate study activities, both qualitatively and quantitatively, at any level of study. At module level the choice of study activities are only one element of educational planning – other important elements are formulation of learning outcomes and design of assessment procedures which should be aligned with the study activities in order to achieve constructive alignment and thus secure quality education (Biggs and Tang, 2009).

A pedagogical purpose of the SAM model is to enhance communication and to clarify and align expectations between teachers and students about the roles and responsibilities of both parties in the teaching/learning situation. Concerning the role of the teacher it varies from category to category, but the important point to note here is that the teacher does play an important role in all four categories, as will be illustrated later. Furthermore, the model serves to assist the students in their own efforts of planning their studies – whether individually or in groups - with the aim of achieving the formulated learning outcomes. Finally, the model is also useful for sharing of knowledge about didactics and educational planning between different educations and between different institutions (Mølgaard, 2014).

Given that study activities at AAU have mostly been described and analyzed using a variety of PBL models, one of our intentions in this paper is to explore to which extent the SAM model which is new in this context may help create enhanced clarification and articulation of what students do in the Aalborg PBL model. In the next section the case study is described and analyzed, with the aim of categorizing and quantifying study activities carried out according to the SAM model.

3 The Case Study

The PBL case study presented here is the first semester of the BSc in Electronics and Information Technology (EIT) engineering programme at the Faculty of Engineering and Science (FoES), Aalborg University (AAU), Denmark. Each of the five modules included in the semester are described and categorization and quantification of study activities within each module is made.

3.1 First Semester Engineering at AAU

For all engineering programmes at AAU the first semester consists of a total of five modules: Two projects and three courses, as shown in table 1.

Table 1: First semester BSc in Electronics and Information Technology. (ECTS: European Credit Transfer System; 1 ECTS = 28 study hours)

Study activity	**ECTS**	**Assessment.**
Project P0 (5 weeks) *Technological project work*	5 ECTS	Oral group exam based on project report and process analysis. Individual grade
Project P1 (10 weeks) *Basic electronic systems*	10 ECTS	Oral group exam based on project report and process analysis. Individual grade
Course 1: ***P****roblem-Based Learning in* ***S****cience, Technology and Society* (PS)	5 ECTS	Written individual exam. Individual grade
Course 2: Program specific technical course: ***Im****perative* ***Pr****ogramming* (IMPR)	5 ECTS	Oral individual exam based on program and demonstration. Individual grade
Course 3: General course (math; IT; etc.): ***Li****near* ***Al****gebra* (LIAL)	5 ECTS	Written individual exam. Individual grade

The educational background of students following the EIT programme is predominantly either general high school (STX) or technical high school (HTX), with some few having another background. Most HTX institutions in Denmark apply a high degree of AL in the form of project organized group work and these students therefore bring valuable experience about a study form similar to the one used at AAU, an experience which nevertheless for some few students sometimes acts as a barrier for expanding their team work qualifications. Most students from STX have minimal experience with project organized group work from the general high schools. Across the cohort a good deal of students bring additional valuable experience from travelling and from jobs, such as, experience with independent decision making and accountability and experience with team work involving responsibility for service or production in a business or industry. The average age of first year BSc students at AAU is around 20 years.

In the following, the two projects P0 and P1, as well as the three courses PS, IMPR and LIAL will be described in more detail.

3.2 The P0 Project

The main aim of the P0 project is that students acquire knowledge about the problem oriented and project organised group work while at the same time gain introductory knowledge about issues and concepts related to electronics and information technology (IT).

The P0 project, Technological Project Work, is called the "Lego RoboCup" and all groups (normally around 8 – 10 groups á 6 – 7 students pr. group, with groups being formed administratively in P0) are requested to build a racing car using Lego Technics building blocks. The car must be able to drive through a laid-out racing field with different obstacles and at the end of the 5 week P0 period a race is held and a prize is given to the group which has built the fastest car that completes the racing field.

At the study start the students are introduced to the project theme, they receive the Lego building blocks needed, the racing field description, including obstacles and an introduction to the P0 project work. Based on that and on further explication of the P0 project aims, terms and deliverables by the supervisor in the first meeting, the students define the tasks they need to carry out, such as building the car, programming the car, etc. and distribute these tasks among group members. Individually or in small subgroups, students search for information using the University library or the Internet, trying to find information that may support them in their allocated tasks. They also carry out practical work in the laboratory or in the group room. At regular intervals, normally at least once a week, all members of the group meet in a formal group meeting to inform each other about progress and obstacles in the assigned tasks, as well as to teach each other about the information found and the work done individually or in the small sub-groups. Also, once a week there is a meeting with the supervisor who will give comments to work papers submitted by the students as a result of their work. The supervisor may also give advice on how to go about a given task if the group is stuck somewhere.

An important part of the project work deals with writing the project report that is handed in at the beginning of the fourth week of the P0 period. Again, writing tasks are distributed by the students among members of the group, each member being responsible for writing a part of the report. The writing process is accompanied by regular peer reviews of the written work where again students share knowledge, teach each other and comment and critique the work performed, in order to ensure a high quality of the written report.

Hand-ins in preparation for the exam include a technical report of 20 pages and a process analysis of 5 – 10 pages, the latter aiming at developing students' reflective skills as well as explicating the group's achievements of competences within the fields of project management, group collaboration and collaboration with the supervisor. The racing car is also part of the required hand-ins.

The P0 exam is an oral group exam, based on the written report and the written process analysis. In the exam the students present their project work, followed by a general discussion of the work performed, as documented in the report and the process analysis. Since the P0 project is the first project and the P0 report the first academic report, the quality is normally not impressive – but the students learn a lot by being given the chance to try out the project organized group work in a ‘play and learn’ situation like the Lego RoboCup and students’ evaluations of the P0 project in their process analyses are normally very positive.

Categorizing the study activities in the P0 project according to the four categories of the SAM model gives the following result: In category C1 activities found are: The joint introductory presentation of the P0 project theme, the racing field and the P0 project work (2 h); the first supervisory meeting (2 h); the oral group based P0 project exam (2 h); the Lego RoboCup, i.e. the race on the laid-out racing field, including the prize giving (4 h), a total of 10 hours in C1. In all of these activities the teacher plays an active role, giving information to students, conducting the exam and overseeing the race.

In category C2 the activities identified are: Searching for information (30 h); lab work focused on designing and building the racing car (40 h); preparation of supervisory meetings and processing of information received in three meetings (9 h), a total of 79 hours in C2. The role of the teacher in these activities is not as an active participant but as the one orchestrating the activities which are narrowly defined before study start.

Category C3 contains the following activities: Group meetings (9 h); report writing, incl. peer review (28 h); preparation for the oral group based project exam (8 h). C3 total = 45 hours. Although this category is initiated by students and with participation of students only, the teacher still plays a significant role by providing formative assessment in the form of feedback to students’ work.

The last category C4 contains only one type of activity: Supervisory meetings called by the students (6 h). And even this activity may be categorized otherwise because in P0 students often find it difficult to make good use of their supervisor who therefore often has to take the initiative and arrange meetings with the project group. Thus, this activity may also be categorized as C1. The role of the teacher is to be consultant for the project groups and may in this role be more or less active, depending upon the students’ ability to define their needs for supervisory assistance.

In summary for the P0 project the study activities are categorized as follows: C1 = 10 hours ~ 7 %; C2 = 79 hours ~ 57 %; C3 = 45 hours ~ 32%; C4 = 6 hours ~ 4 %. Total 140 hours ~ 100%.

3.3 The P1 Project

The overall aim of the P1 project is that students acquire knowledge within the field of electronics and IT engineering through theoretical and practical work, with the point of departure in a relevant societal or industrial problem.

The P1 project starts approximately 5 weeks after study start. The theme is “Basic electronic systems” and a catalogue with project proposals is prepared by the supervisors before project start. Students are invited to also propose projects, fulfilling certain criteria, but this happens seldom at this stage of the study. Group formation in preparation for P1 is led by the students themselves, with needed assistance from the semester coordinator (a teacher). Once groups are formed, each group has to choose 3 prioritized project proposals, following which the semester coordinator allocates a project, two supervisors and a group room to each group. In P1 each group has two supervisors, one technical and one contextual supervisor.

Again, the first meeting with the supervisors is important for the startup of the project work and it is important that both supervisors are present in this first meeting, in order to create agreement on the goals of the project. The technical supervisor will explicate the technical contents while the contextual supervisor explicates the contextual contents of the proposed project. The proposal may change during the first weeks of project work, depending upon the students’ interests and availability of information on the project topic.

Many of the activities in the P1 project are similar in form to the activities carried out in the P0 project, i.e. searching for information and processing information into knowledge that can be applied in solving a real life problem. The main difference lies in the fact that while the theme of the P0 project is narrowly defined by the teachers and thus most P0 activities that students perform are initiated by the teacher, in the P1 project the students themselves have to define which activities they need to do in order to analyze and solve the problem they work with. Another difference is that in P1 sources of information include sources outside the university, i.e. stakeholders interested in the problem. Also the length of the projects is different, 5 weeks for P0 and 10 weeks for P1. A new activity in P1 is the mid-way status seminar where each group presents their project progress to date and discusses the work with an opponent group, i.e. one of the other project groups in the EIT 1st semester and two supervisors, one of whom is new to the project. The aim of the midway seminar is to create opportunity for peer learning and to develop the students' academic skills of reviewing other academics' work.

An example of a P1 project is the design of a sensory device that can be used to train deaf and/or blind children. This project was proposed by the local Centre for Deaf-blindness and Hearing loss (CDH) and illustrates the fact that quite often projects are solicited in collaboration with stakeholders outside the university. In this project, as in most other project, there are both technical issues and contextual issues that the students need to deal with. Some of the activities included in this project were interviews with staff at CDH and observation of the children in the center with the purpose of identifying their abilities and skills when playing and learning.

Hand-ins in preparation for the project exam comprises an 80 page technical report and a 10 page written reflective process-analysis, covering the same three fields as the P0 process analysis plus learning processes. Most engineering student groups will also hand in some kind of a tangible product, related to the problem they have been working on solving. The P1 project exam is again an oral exam based on the written report and the written process analysis, with individual marks given to each student.

In C1 the following study activities are found: Joint introductory presentation of the semester, including project proposals (3 h); introduction to the project proposal and the project work by the supervisor (2 h); the midway status seminar (3 h); the oral group based project exam (5 h). C1 total = 13 hours. The teacher is active in the presentation of the project theme and proposals and is responsible for conducting the exam, while in the midway status seminar the teachers are present but often play a more withdrawn role.

The category C2 study activities include: Preparation for and processing after supervisory meetings (24 h); preparation for and processing after the midway status seminar (12 h). C2 total = 36 hours. Here the teacher, while not being present, provides guidelines for and inputs to the students' work, in the form of facilitating questions in preparation for meetings as well as inputs in the meetings that students need to process afterwards.

The brunt of study activities and thus study time in the P1 project is found in category C3. Here the following activities can be identified: Search for information, incl. information from informants outside the university (30 h); lab work, incl. prototype development (70 h); group meetings (15 h); peer teaching and peer learning (30 h); report writing, incl. peer review (50 h); preparation for the oral group based project exam (20 h). C3 total = 215 hours. Although the teacher is absent while these activities are undertaken by students, his/her role is still quite important as the provider of regular feedback and feedforward to the work papers produced by the students as a result of their activities. This feedback is a form of formative assessment and is as such a very important element in the learning processes of students.

The last category C4 contains the supervisory meetings (16 hours). These meetings are called by the students, often once a week or whenever they are in need of supervisory assistance and the students are in charge of the meetings but the supervisor plays an important role by providing needed and required assistance to the students.

In summary for the P1 project the distribution of study activities is as follows: C1 = 13 hours ~ 5%; C2 = 36 hours ~ 13%; C3 = 215 hours ~ 76%; C4 = 16 hours ~ 6%. Total 280 hours ~ 100%.

From the second semester onward all projects at FoES, AAU are credited with 15 ECTS and have a length of 15 weeks, starting at semester start and being carried out in parallel with the 3 x 5 ECTS courses that is the norm.

3.4 The PS Course

The aim of the course "Problem-Based Learning in Science, Technology and Society" is to support the students, theoretically as well as practically, in planning and carrying out a group based scientific project work, taking its point of departure in a real life problem that is relevant to society and thus needs to be analyzed and solved in context. The course serves to develop both process competences and contextual engineering competences. In this case study only the study activities related to development of process competences will be exemplified, whilst also study activities related to contextual competences are included in the overall categorization and quantification according to the SAM model.

The course consists of 15 sessions, most of which are 4 hour sessions supplemented with 2 one-hour group consultations per group. For each session an elaborate agenda is produced, specifying learning outcomes and expected benefits from applying knowledge and tools as well as expected preparation and subsequent processing. The agenda also outlines recommended literature for the session. All course materials are made available via the MOODLE online platform.

The teaching approach includes a wide range of different study activities: Assignment, case, consultation, debate, dialogue, discussion, facilitation, feedback, lecture, logbook, observation, peer-feedback, portfolio, presentations, readings, role-play, seminar, team-building, tests, video, workshop, etc. Examples of course sessions are given below, describing 4 of the 15 sessions.

Session 3 is titled 'Oral project communication' and is a half-day activity that focuses on oral communication in connection with meetings, knowledge sharing and project presentations. A short 1 hour introductory lecture is intertwined with 3 short dialogue exercises, followed by a ½ hour group exercise ("Broken Squares") illustrating principles of group work. Another ½ hour plenary session sharing the project groups' reflection on this exercise, mixed with teacher directed feedback and summaries, is followed by a 1 hour communication exercise ("Murder at the Black Horse") in large groups (20-30 students). As students' reflections are crucial for extracting the intended learning from the exercise, again guided reflections are summarized. Finally, on basis of the learning acquired from readings, lecture and activities the project groups are encouraged to regularly analyze and evaluate their own procedures for debate, dialogue and discussions in connection with their P1 project.

Session 5 is titled 'P0 experience exchange' and is a full day activity with focus on preparation of the P0 process analysis. An introductory 1 hour lecture including 3 short student activating exercises (individual writing; dialogue with other students) is followed by a 1 hour group assignment categorizing the P0 project experiences; a 1 hour exchange of experiences in mixed groups and a 5 hour continued analysis and evaluation of the P0 project experiences, resulting in a written P0 process analysis that covers the three areas of project management, group collaboration and collaboration with the supervisors. The writing process is supported by material available and course teacher facilitation. This session can be ideally illustrated by Kolb's learning cycle (Kolb, 1984), in which the reflective processing of previous experience is a key component and the two process analyses (P0 and P1) are central outcomes of the PS course.

Session 6 is a half-day activity titled 'Creative processes' in project work, focusing on developing the P1 project proposals into academically acceptable proposals and on reaching joint agreement on project goals. An introductory 1 hour lecture on project design (including 1 dialogue exercise) ends with an assignment for each project group to develop thorough visual and verbal project overviews that are to be discussed in a later consultation and workshop presentation. Following this lecture and assignment project groups are guided through a 2½ hour process of applying creative tools for explicating and delimiting project ideas, testing problem formulations, and sketching a project outline.

Session 11 is titled ‘Project Planning’ and consists of a half-day activity focusing on project planning and -management. During a short introductory lecture students are activated with short dialogue exercises. A 1 hour planning exercise building a small LEGO vehicle exposes the project groups’ skills in communication, collaboration and process management. The subsequent guided group reflection is further put in perspective during a ½ hour lecture. Lastly, project groups are encouraged to revise their plans, planning procedures and project management functions and to regularly perform follow ups.

The PS course is assessed through a final individual written take-home exam, lasting 7 hours and graded Pass – No Pass. Students are free to work with the exam either individually or in their project groups but answers to the exam questions have to be individual. This completes the course requirements.

Given the multitude of different study activities in the PS course it is somewhat complex to specify and categorize study activities in this course according to the SAM model. Nevertheless, an estimate has been made but without referring to specific activities.

The distribution is as follows: C1 = 29 hours ~ 21 %; C2 = 59 hours ~ 42 %; C3 = 39 hours ~ 28 %; C4 = 13 hours ~ 9%.

3.5 The IMPR Course

The course "Imperative Programming" is a basic course on C programming that has been taught for a number of years to students from EIT and Internet Technologies (IT). In 2012 students from Health Technologies (HT) were included in the course. This caused a problem because HT students do not need programming skills in their first semester but later in their education. Therefore, in 2013 it was decided to change the course, from a standard programming course with no elements of user interfaces and physical world integration, to a more interactive approach, keeping the programming language C while also introducing the Arduino platform, “an open-source electronics platform based on easy-to-use hardware and software [i]ntended for anyone making interactive projects.” (http://arduino.cc) for hands-on active learning. Arguments for the change were the following:

1. It is important for the learning of programming that students achieve immediate and observable "results"
2. The Arduino platform is an effective way to get access to a variety of sensors and actuators
3. Pricing is so low that every student can afford to buy the platform
4. The teacher may supply more advanced sensors if needed

The approach to teaching was also changed, from a teaching/learning paradigm based on traditional lecturing and exercises to a more active hands-on approach to learning, based on a mix of activities: Short lectures (< 1 hour), incl. live coding on screen or on blackboard; short introduction videos; group based programming assignments using Arduino to solve real world programming problems (2 – 3 students per group); individual home work such as readings and exercises; on campus workshops; project related coding exercises, incl. teacher consultancy; developing the program for oral exam and the oral exam.

The course consists of 15 sessions á 4 hours and most of the sessions have a standard format, consisting of a short lecture, incl. coding, followed by the group assignments. The assignments contain a rough specification of the system students have to develop, in some cases illustrated with code fragments. Program size for the assignments is normally within the range of 20-200 lines of coding. Interfacing to hardware (buttons, LEDs, sensors like temperature and pressure) is an integral part of the assignments and is targeted the project work (EIT and IT).

The course exam is oral and is based on a program that they have app. 12 hours to develop. In the exam situation they have to demonstrate the functioning of the program and explain the code - line by line if needed. Two to three students may jointly develop the program but the exam is individual and each student has to be able to explain and demonstrate the program and answer any questions related to the code and program.

The distribution of study activities according to SAM is as follows: C1 = 14 hours ~ 10%; C2 = 60 hours ~ 43%; C3 = 46 hours ~ 33%; C4 = 20 hours ~ 14%. The categories C2 and C3 take up the majority of students' study time in the course, indicating that students are studying with minimal guidance from the teacher, in accordance with the saying 'less is more'.

The course redesign has not changed the SAM distribution very much; nonetheless, the redesign to a more student centered approach has had very positive results. Students are now more actively engaged, including students with no programming in their first semester project.

3.6 The LIAL course

The Linear Algebra course is an example of a general mathematics course that is taught to almost all first year students at FoES and the main aim of the course is that students acquire knowledge about linear algebra that will enable them to use the theories, concepts and methods from this field of mathematics in connection with engineering tasks. The teaching approach applied in LIAL is a mix of lectures, exercises and four group based mini projects. The course includes a total of 22 sessions á 4 hours each, 18 lecture sessions and 4 mini project sessions. The lecture sessions are standardized, each session starting with a 30 minutes recap of last session's material, then a 2 hour exercise part and finally a lecture presenting new material lasting the remaining part of the time. During the exercise part students work in their project group rooms and may choose to work individually or with other group members. They have access to assistance from tutors (older students) or from the lecturer. Only the first and the last of the 18 sessions do not have the standardized format. In the four mini project sessions students carry out the mini projects in their project groups, using MatLab and with assistance from tutors (older students).

The course exam is a written 4 hour exam where students are allowed to bring books, notes etc. but no electronic devices. Active participation in a minimum of three out of the four mini projects is required to sit the exam, otherwise the student will have to complete and hand in any missing mini projects before being allowed to sit the exam.

The teaching format of the LIAL course is rather standardized making it fairly easy to quantify and categorize the study activities. In category C1 where the teacher is the main actor the following activities are categorized: Eighteen 2 hour lectures, partly recap, partly presentation of new material (36 h); an individual written exam (4 h). C1 total = 40 hours. Here the role of the teacher is clearly the active lecturer, as well as the person responsible for exam preparation and implementation.

Category 2 study activities include: Eighteen exercises, each lasting 2 hours (36 h); four mini projects, each lasting 4 hours (16 hours). C2 total = 52 hours. In these study activities the teacher and tutors assist students in solving the exercises, according to needs.

In category 3 is located the students' work with readings and out-of-class exercises, as well as preparation for the exams. This category takes up the remainder of the 140 hours allocated to the LIAL course, i.e. C3 total = 48 hours. The role of the teacher in this category is indirect, providing guidelines to the students on readings and exercises, including former exam questions.

There are no study activities in category 4 in the LIAL course.

Thus, in summary for the LIAL course the distribution of study activities is as follows: C1 = 40 hours ~ 29 %; C2 = 52 hours ~ 37 %; C3 = 48 hours ~ 34 %. Total = 140 hours ~ 100%.

In this section the case study: First semester of the BSc Electronics and Information Technology engineering programme at FoES, AAU has been presented, with focus on the study activities that students carry out in connection with the five modules that constitute the first semester study. Also these activities have been categorized and quantified according to the four categories in the SAM model. In the next section the results achieved from this categorization and quantification will be discussed.

4 Discussion of the Results

In this section the results of applying the SAM model to the case study: The first semester of the Electronics and IT engineering programme at AAU, will be discussed. Firstly, results of the quantification of study activities in the five modules as well as in the full semester will be discussed and reflected upon. Following this the suitability of the SAM model will be discussed, with regard to the two key concepts and to the categorization process. The third and last subsection deals with the relationship between the SAM model and learning how to learn.

4.1 *Quantification of EIT modules*

The quantification of the study activities in the five modules has been carried out by counting duration of all activities in categories C1, C2 and C4 and then subtracting the sum of these activities from the total study time for the module, based on the ECTS credit, to get a number of hours for category C3. The results in percentages thus obtained are shown in figure 2 for each of the five modules.

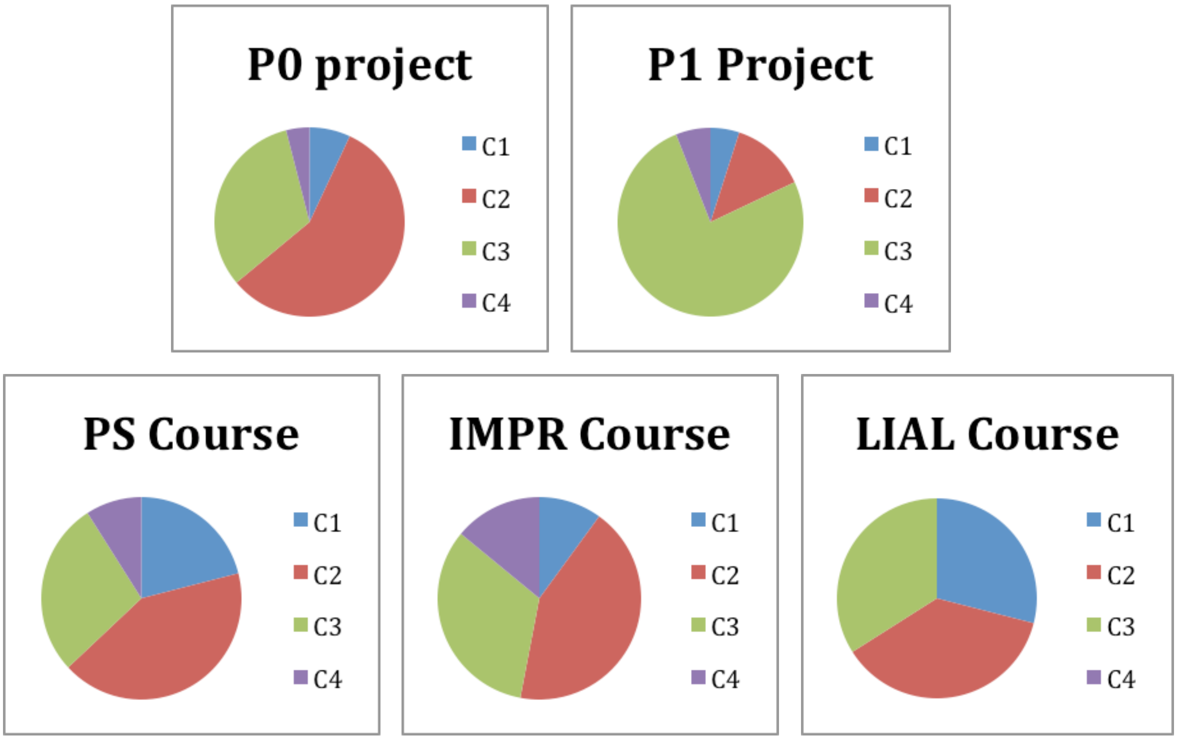

Figure 2: Percentage wise categorization of study activities in the five modules of the case study.

As can be seen from the figure, in both of the two projects categories C1 and C4 activities are minimal. In P0 the C2 activities dominate because of the teacher designed project work, while in P1 the proportion of C3 activities is more than ¾ of the credited study time for the project (10 ECTS = 280 hours).

The PS course is relatively low in C3 activities compared with the other 4 modules which may be explained by the nature of this course. The PS course is a study introductory course which is conducted for almost all first year students at FoES, with course contents being customized to the specific engineering programme. The course is essential for the success of the Aalborg PBL model within engineering programs because it supports the students in their project work, providing essential tools for project management, group collaboration, problem orientation, report writing etc. The course is closely aligned with the P1 project and students are expected to apply concepts and tools from the PS course in their P1 project work and reflect upon this application in a written process analysis that is part of the PS course. Ongoing formative assessment and feedback to students on the application of tools from the course is the responsibility of the supervisor, while the PS course teacher provides oral or written feedback on course activities and deliverables (e.g. the project group's project design, time schedule, process analysis etc.). Thus, the course aims to establish (self)-confidence and safety for students in the PBL environment, specifically the ability to handle category C3 activities.

In the IMPR course the two categories C2 and C3 take up approximately ¾ of the credited study time, a result that has not changed drastically with the course redesign. Nonetheless, the redesign has had a very positive impact on students' learning: They are more actively engaged and benefit from learning by training on relevant problems and exercises, they take initiatives, individually as well as in the group and they get immediate feedback when interfacing to simple sensors and actuators which helps them see the idea in programming. The course and the project work are more aligned and also the students with no programming as part of their first semester project are more engaged in the course. Weaker students benefit from peer teaching and –learning in the groups and the individual exam puts enough pressure on students to ensure deep learning which is necessary for the programming components of the semester project to become a success. In this sense, category C3 activities in the course are a must and are regarded as very important.

Of the three courses the LIAL course has the highest proportion of C1 activities which is hardly surprising because this course is a rather traditional, i.e. lecture based course. Even so, the proportion of C3 activities is approximately a third of the total study time, demonstrating that even in teacher-controlled teaching students have to study on their own to comprehend the material.

The combined semester result is shown in figure 3.

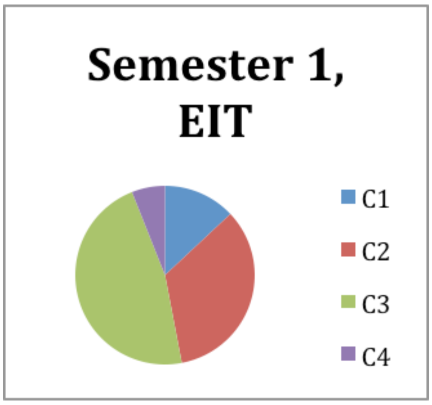

Figure 3. Accumulated quantitative categorization of study activities in the first semester EIT.

From this figure is becomes clear that almost half of students' study time (47 %) during their first semester falls within category C3, i.e. initiated by students and with only students as participants. Another 34 % is in category C2, i.e. teacher initiated but with only students as participants. Activities where the teacher participates (C1 and C4) amounts to only 19 %.

To the authors, even if very familiar with the AAU study program, it was an eye-opener to realize how much time students are investing (or at least expected to invest) in independent studies, i.e. C3 activities, without any teacher assistance, whether in courses or in projects. As mentioned in section 1: Introduction, the first semester case study was chosen because this semester plays a crucial role in students' transition from high school to university and it is in this semester that good study habits need to be established. In later semesters at FoES, AAU, this distribution of study activities may be expected to have even more emphasis on C2-C3 activities.

4.2 Suitability of SAM

In connection with the attempt to use the SAM model on the AAU case study two important discussions have appeared. One is about the concepts used in the model and the other about the categorization process. These two discussions form the core of this subsection.

The two key concepts in the SAM model are 'participation' and 'initiation', both of which may be broadly defined. 'Participation' might specify any position along a continuum from simply being present (physically or virtually) to being actively engaged. In our use of the SAM model we have interpreted 'participation' to lie at different positions of this continuum depending upon the category in question. Thus, in C1, students' participation has been interpreted as 'being present' while teacher's participation is 'being active', while in C4, students are active participants and the teacher is 'the guide at the side'.

'Initiation' implies responsibility for structuring and organizing study activities but again a continuum is possible, from merely initiating an activity to planning, organizing and structuring activities. Finding the balance along this continuum is one of the challenges for the teacher in an active learning environment: Too much teacher-controlled planning may render the students inactive and unwilling/unable to organize and structure their activities, too little planning may leave them confused and wasting time.

At AAU, the teacher is responsible for initiating, i.e. structuring and organizing, activities in C1 and C2 as well as for providing feedback and formative assessment to results of students' activities in C2 and C3. Students are responsible for initiating, i.e. structuring and organizing, the C3 activities. Furthermore, part of the teacher's role is to be a 'backstop' in cases of insecure, lazy or non-capable students' groups. In C4 the students have responsibility for initiating, i.e. structuring and organizing, the activities, while the teacher's main responsibility is to be available as consultant.

Concerning the categorization process, SAM, as any other simplifying model, has natural limitations when being applied on the real world. One inherent problem is the difficulty of distinguishing between the different categories of the model – where exactly to draw the line between, say, C3 and C4 activities? This problem which is emphasized by the broad definitions of the two key concepts, as mentioned above, cannot be completely solved but the more precise the descriptions of study activities, the more precise the categorization. While the model is well suited for analyzing how study activities are initiated and carried out, it says little about whether learning is achieved and to which level the students achieve knowledge, skills and competences. Two very different modules may score the same SAM distribution but the outcomes of teaching and studying may be widely different.

Another problem related to the categorization is that different project groups work differently, some groups seeking more consultancy from the supervisor than others. Yet another problem related to category C3 activities is that, even if the teacher may provide tools, frames etc. to assist students with C3 activities, (s)he can never know precisely what students are doing in this category. This is reflected in the way the calculation was carried out in the case study – C3 is simply calculated as the study time that is NOT time tabled for C1, C2 or C4 activities. Therefore, quantification of C3 activities is uncertain, which may leave teachers wondering whether students are studying as much as they are supposed to according to the credit points. This can only be assessed by analyzing the results of students' C3 activities and by giving feedback in the form of formative and summative assessment to these results.

4.3 SAM and learning to learn

In AAU, as in many universities around the world today, an overarching objective is to foster autonomous learners with a high academic standing who are capable of taking responsibility for their own learning. In this subsection the discussion focuses on the concepts of 'responsibility for own learning', 'learning to learn' and the SAM model.

In the discussion on 'initiation' it was mentioned that students are responsible for structuring and organizing C3 activities, whether in courses or in the project work. Before first semester students can do that efficiently they need to be guided by the course teacher or the project supervisor. Course teachers have to enter into dialogue with students about the traditions, modes of thinking and requirements for the specific course. Similarly, supervisors need to negotiate project requirements and learning outcomes of the project with students. Thus supported, students may be able to constructively engage in effective approaches to learning, including self-management beyond trial-and-error.

Responsibility for structuring and organizing the activities is closely linked to 'responsibility for own learning', that leads on to 'learning to learn. The PS course described above includes a session on individual and collective learning that aims to provide students the terminology for talking about their own learning processes, whether individually or collectively in the group. This C1- C2 activity is supplemented with C3 activities, such as students reflecting on and becoming aware of learning processes, including peer teaching and -learning. This approach has a much greater and lasting impact on student achievements than only C1-C2 activities, especially when supported by feedback from the course teacher and the project supervisor. The foundation provided through the alignment between the PS course and the P1 project is viewed as vital for the success of the Aalborg PBL model.

This section has discussed some of the important findings from using the SAM model on the case study. In the last section the research questions will be answered and perspectives for further use of the SAM model will be discussed.

5 Conclusions and future perspectives

This last section contains the conclusion in the form of answers to the three research questions. It further presents perspectives for future use of the SAM model at AAU. The research questions are repeated here for convenience:

1) *To which extent can the study activity model SAM be used to visualize the diversity of study activities in a problem based learning environment in engineering at Aalborg University?*
2) *To which extent can the study activity model SAM be used to explicate and clarify the role of the teacher in relation to different study activities?*
3) *To which extent can the use of the study activity model SAM lead to enhanced understanding and clarification of the study activities involved in the Aalborg Problem Based Learning model?*

The questions will be answered based on the discussion in the previous section as well as the experience of the authors with the use of the SAM model.

5.1 RQ 1: Visualizing diversity

When applying the SAM model to the first semester EIT programme at AAU it was found that the model is indeed useful in visualizing that studying to become an engineer at AAU involves taking active part in a number of different study activities. The multitude of activities taking place in connection with especially the project work may not be easily categorized into only four categories; nevertheless, we have found the SAM model to be a useful framework for describing activities within the AAU PBL environment and the model provides a transparent overview of activities.

The weakness mentioned above, i.e. the broad definitions of the two main concepts, might be overcome by positioning study activities along the two continua described, but that would at the same time create a more complex model with many more categories, possibly rendering the model useless. Another weakness of the model is that is says nothing about learning outcomes, such as knowledge, skills and competences that students have to acquire. Therefore, in connection with educational planning, whether by educational managers or by the individual teacher, the model has to be accompanied by learning taxonomies such as Bloom or SOLO for formulation of learning outcomes.

As was mentioned in the discussion, the high percentage of C3 activities in the case study was a surprise, but maybe this is part of the explanation for the fact that candidates from FoES, AAU are highly acclaimed by Danish industry because of their competences?

5.2 RQ 2: Clarifying role of the teacher

While the role of the teacher is visible and may be clearly described in C1 and C2, in C3 and C4, where the students have the initiative the role is less visible and less clearly specified but equally important. For students to study and learn on their own they depend upon feedback and formative assessment in order to be able to further develop their knowledge, skills and competences and this feedback is one of the most important roles of the teacher. To accept the situation where the initiative rests with students the teacher has to possess the courage to accept uncertainty, the flexibility needed to adapt to students' needs and the trust in the students' ability and willingness to study and learn on their own. In the experience of the authors a useful tool for getting a clearer overview of the role of the teacher in C3 and C4 is for teachers, whether course teacher or project supervisor, to negotiate mutual expectations with students. More specifically, project supervisors may negotiate contracts of collaboration with their project groups. In spite of the challenges related to the teacher's role in C2 and even more so in C3, the SAM model is useful for explicating and clarifying the multiple tasks of the PBL teacher.

5.3 RQ 3: Enhancing understanding of Aalborg PBL model

Developing this paper has brought up more ambiguities than envisioned about the SAM model but also ambiguities about our understanding of what students and teachers do in the Aalborg PBL model. We have had differing perceptions embedded in our values, our language and our approaches to teaching. Thus, in applying the SAM model to the case study we have been forced to turn more stones than usually when exchanging views on and explaining rationale behind study plans. This process of scrutinizing our values and language in connection with describing and categorizing the study activities has been very enlightening and informative and has given cause for deeper than usual reflection on the diverse roles of both students and teachers. For us as teachers the SAM model is useful to discuss study activities with our students and to clarify mutual expectations. Furthermore, the model is recommended for overall study programme planning, looking at progression of the study from semester to semester. Analyzing a complete study program, from 1st to last semester would be a useful exercise that might reveal new views on the Aalborg PBL model.

5.4 SAM in AAU perspective

Aalborg University is presently in a process of discussing a new 5-year strategy for 2015 – 2020. Two of the key action areas deal with education, one called 'PBL – next generation' and the other called 'Education with a difference'. In connection with the discussions related to the strategy formulation the SAM model might be a useful tool for renewed discussion about the next generation PBL. The model could be used to mark out guidelines for planning of study programmes so that the high quality presently found in the Aalborg PBL model is maintained and industry will remain satisfied with Aalborg University graduates.

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The “Game of Ethics” used as an active learning approach for engineering students

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Abstract

The professional engineer performance has concerns relating to the technical quality of services in addition to their ethical relationship with society and other professionals. Several international agencies have sought to establish principles and ethical limits in order to ensure quality and honesty in professional practice. Explaining and discussing ethics and its importance to future engineering professionals is a challenge that arises for higher education institutions. Thus, teachers of São Judas Tadeu University have created the “Game of Ethics" in order to show students the importance of ethical behavior, and confront them with situations that appear frequently in the workplace.

The game is adapted from a traditional African board game, Lilah, which consists of a board with 36 or 64 numbered squares (or “houses”). Over the board, ladders and snakes of various sizes are distributed, connecting the houses. During the game, the class is divided in teams, which are represented by pawns of different colors. Different ethical situations are given to each team. Students discuss their positions and opinions and, by convincing other groups, the team advances the houses. The objective is to reach the last house. On the board, if the team goes to a house occupied by a ladder, the pawn moves the boxes to the top the stairs, on the other hand, if occupies the house of a snake head, the player returns to the house where the tail of the snake is located. That is, the stairs always mean a breakthrough and the snake is a step backwards. After the game, a debriefing section invite students to think about ethical behavior.

1. Introduction

Ethics is a branch of philosophy dedicated to understanding of moral values, principles and ideals that govern the behavior of society. The term "ethics" is derived from the Greek ἠθικός, meaning "that which belongs to the 'ethos', that is, the character or a genuinely human action and that comes from the inside of the moral subject”. In other words, ’ethos' is the impulse that leads us to act. On the other hand, one can also interpret the "ethos" as being what it refers to the habits, customs, practices and rules, which materializes in the social assimilation of values (SPINOZA, 2009).

We can say that ethics commands the action of the individual, according to his/her principles, while the moral guides social relations.

Engineering is an occupation that requires, in addition to professional training, posture and ethics to its customers, employers, and especially with the whole of society. Due to this professional qualification, the ethical action of an engineer is essential because it often depends on the very security of society (HOLTZAPPLE, 2006).

Among the various aspects of professional action, ethics is perhaps the most difficult to be seen. The creation of a code of ethics by professional associations seek to a regulation of professional practice and often by the companies themselves can help to guide the ethical attitude, but the day to day of profession often puts tough questions to answer.

The "Ethics Game" was created to awaken the student reflection on the subject. Not intended to be a handbook of conduct nor to give definitive answers. We understand that, in reflecting on the matter, the future professional will know how to analyze according to their values and have the ability to make their own decisions.

The proposal to use a game is linked to the fact that "with the game, one can work various aspects of the intellectual, social and ethical development, as there are rules to follow. He collaborates developing attention, being with rules and teamwork" (DOHME, 2008).

2. The Game Development

The class is initially divided into five or six groups, each group will be a "player" represented by a piece (pawn) of different color. Each group initially receives a situation related to professional practice or social positions, in which the ethics of professional behavior must be analyzed.

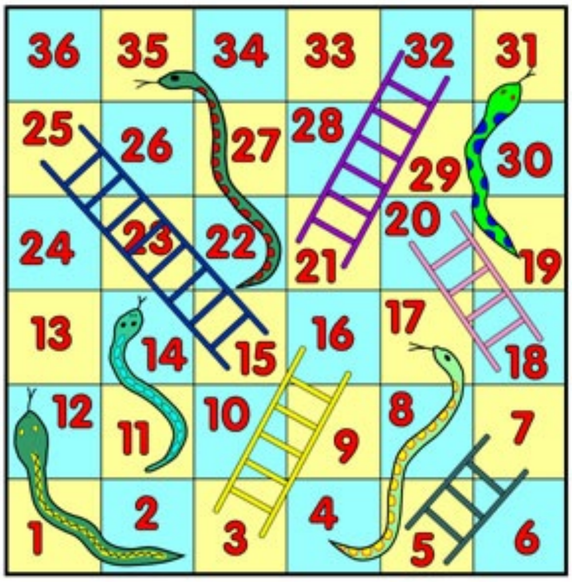

Figure 1: An exemple of the board game

The group has a time to discuss, enter into an agreement and issue its opinion to the other groups, which must fit into one of five positions, according to the Likert scale (LIKERT, 1932): "I totally agree"; "I agree in part"; "I have no opinion"; "Somewhat disagree"; "Strongly Disagree". The group presents the case (situation) and its position, without argument, through a sheet on which its position is written. The other groups quickly discuss and present their positions to then the group with the case, argue and justify their position.

At this time, when there are different positions, the other groups discuss and argue. The groups may, then, change position according to the argument. The teacher's role is to manage time and organize the discussion, ensuring that every student can give his/her opinion.

At the end of discussion turn, each group presents its final position, for each group to agree exactly with the group's position that the presented case, your pawn walk a house (a numbered square). Respecting the rules of the board game "Lilah", if the pawn occupies a house in which there is the bottom of a ladder, the group moves to the top of it, occupy a house with the head of a snake, the pawn returns to the house with the tail.

The move goes to another group with another case, the procedure is repeated for all groups.

At the end of the game, teacher performs a debriefing section and students individually are invited to discuss about their ethical behavior during the game: "Do you give your opinion based on your beliefs or in order to win the game?"; "What was most important: win the game or give your opinion?"; "Did you change your position during the game? If yes, why?"

2.1. Some exemples of cases

Most of the situations presented to students are related to professional practice, which often appear in issues related to ethical behavior, some situations are related to social positions. Some of these situations are real. Some cases are presented more than once with different outcomes. Below are some examples:

I. An engineer is responsible for lead concentration measurement. The engineer used two different methods: The first result was 0.95 ppb (parts per billion). Using the other method, the result was 1.13 ppb. If the presence of lead exceeds 1.0 ppb, the company (where the engineer works) will be fined. In the report, the engineer cited just results of the first method. What is your opinion regarding the attitude of the engineer? (This is a case in which appear different outcomes, in another situation, the Engineer omits the measure that would harm the company)

II. A government company allowed a bidder, which is known technically did not meet the specifications of the bidding documents, participate in a competition in order to force the other competitors to lower their prices. What do you think of the public company action?

III. A sales engineer, about to win a competition for his company, attended to increase in 30% the value originally offered. This value was offered to the seller as a tip to ensure that he would help to close contract. Do you agree with the attitude of the engineer?

IV. A sales engineer was reprimanded and subsequently fired because he lost a big sale after refusing to lead a team of buyers for a party in a brothel. Do you agree with the attitude of the engineer?

V. An aeronautical engineer is adept of a religion that calls for complete non-violence. Contracted to design commercial airplanes, was recently appointed to the sector of military combat aircraft design. To stay true to their religion, it quits without even having another job in sight. Do you agree with the attitude that engineer? (HOLTZAPPLE, 2006).

VI. A company requests that the responsible engineer to develop a descriptive project that will serve as a reference for the writing of fraudulent government bidding, in which his company should be chosen. Even opposing the practice, he kept quiet and drew up the tender to maintain his job. Do you agree with the attitude of the engineer?

VII. One must not trust a person with a tattoo.

3. Final Comments

In general, students engage hard in the game, often causing passionate discussions. The teacher has to coordinate the discussion, ensuring that everyone can express themselves and to do so in ways that respect the contrary positions.

The curious thing is that this dynamic, discussing ethics, students can play unethical way. As the movement of pawns in a group depends on the other, a group could "agree" with the position of another (even not agreeing) to make it "fall" in a house occupied by the head of the snake, which would kick, or even to prevent the other group "fall" in the house of the stairs, which would evolve faster in the game. We also observed both for the answers as the comments during and at the end of the class that the majority of students feel that they could manipulate the game to win but prefer to mark the opinion, not caring to "win" the game.

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An active workshop for learning the pathological role of money in the market place

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Extended abstract

We present this workshop as an example of active learning. The workshop offers a comparison among bartering, alternative (free) money, official money (based on credit), and natural economies (ask and give). The comparison is based on a workshop where the different kinds of exchange are simulated by means of playing cards.

We aim to show that the real goal of natural economies is to produce enough to satisfy true necessities. To that end, the best strategy is to ask and give without offering or giving anything in exchange. The game is compared with a computer network for data distribution, where "exchanging information" clearly makes no sense (like having nodes say: "I'm giving you no information unless you give me something in exchange").

The results show that bartering stagnates (dead-lock), alternative money leads to inequalities, and banks claim back money that never was created (interest). On the other side, ask and give strategies escape from the "double coincidence of necessities" by escaping from exchange altogether. Ask and give strategies add up to sharing, and they are the way that living beings relate to each other (you cannot payback an apple-tree with money).

In our lives, many of our relationships take place in the natural economy domain (family, friends, amusement, love, etc), whereas others require money, because we believe that we cannot go without money. The point is realizing the existence of those natural spaces, and progressively moving back from money-based relationships to ask and give relationships.

In this workshop active learning is used to present the different economies by means of playing cards and the main problems in each economy become apparent. Participants are learning by doing, the activity is fun, and it fosters reflection.

- Introduction (5') We will Introduce the topic and present the game
- Play and Learn (65')
    - Set-up: The game is played with a standard deck of playing cards. We first separate groups of 4 cards with the same number, one for player. For instance, if there are three players, we take four aces, four twos and four threes. And so on, for a total of 4 equal-number cards times the number of players. Numbers represent *necessities*, whatever participants expect to get from the market. And cards represent *resources*, whatever participants bring to the market for sale or exchange. Each player is then assigned one of these numbers, which represents her necessities. Cards with and ace represent the resources that satisfy the needs of player one, cards with a two represent the resources that satisfy the needs of player two, and so on. Then, the objective of each player in the market place is to try and find the four cards that

satisfy her four necessities. Player one looks for aces, player two looks for twos, and so on. For each stage of the game (each market model), cards are shuffled and dealt, four to each player, and the exchange begins, according to the market model's rules. Notice that, with this set up, all the available resources satisfy all the necessities, and that for each participant there exist exactly the amount of resources that they need. This is a particular setting, but it is useful to make clear the *differences* among the four models, under the same context.

    - Bartering: playing cards are shuffled and dealt, and participants enroll on a bartering fair (they exchange cards one to one). One extra rule: players can only take cards with their corresponding number. Results are observed.
    - Free money: cards are shuffled and dealt again, and 13 ecos (green papers) are given for free to each participant. Now, participants enroll in a market, buying and selling cards with each other. Prices are set independently at each transaction. Results are observed.
    - Bank money, with interest: cards are shuffled and dealt again. Each participant borrows 13 *euros* (red papers) from the bank, and at the end of the stage they have to pay 15 euros back to the bank (2 euros of interest). At the end, the bank will seize a card for each unpaid euro, as mortgage. Results are observed.
    - Ask and Give, without exchange: cards are shuffled and dealt again. Now, participants ask each other the cards that they need. The rule is: if you have the card that another person is asking for, you must give it to her, without asking for anything in exchange. Results are observed.
- Summing-up and conclusions (20'): Participants are prompted to observe the results of each stage, compare them and draw conclusions. Special emphasis is made on the fourth model, natural economies. What makes it different from the other threes? Is natural economy utopic, or are there any real examples of it? Where does the strength of natural economies lie? What are the reasons why natural economies are not more extended? What are the cultural prejudices that prevent natural economies to be more common? What is the frontier between monetary economy and natural economies?

Expected outcomes/results:

Feedback about the activity plus a fruitful discussion among participants about economic factors and active learning. Ask and give strategy emerges as the simplest and most effective way of allocating resources to necessities.

Experiential Active Learning Exercise for Developing Skills Needed in the Design of Research or Industrial Experiments

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Abstract

The classroom exercise is a single session that does not assume prior knowledge. It can be used as part of an academic or industry course in quality engineering or experimental design, or at a conference.

An important issue that arises in the application of statistical design of experiments (DOE) is the need to take into account variation in a raw material used in the process or product being investigated. This issue provides the focus and motivation for the exercise, but the wider aim is to develop skills: deciding which background data is needed; interpreting graphs showing variation in the raw material and showing the results of the experiment; identifying assumptions and deciding if they should be checked and if so, how; developing a strategy that can be used in future projects rather than solving a particular problem.

The experiential aspect of the exercise is that methods are not taught and then applied. Instead, participants are provided with graphs and minimal explanations. They experience that interpreting the graphs enables them to make decisions effectively, and are motivated to learn the statistical methods lurking behind the graphs.

A second ambitious aspect of this exercise is the use of alternative versions of the problem. Participants see four versions of the variation in the raw material, three experimental strategies commonly employed to deal with this variation and three versions of the true underlying dependence of the quality measure of interest on the raw material and the experimental factors being investigated. This provides a wider experience than working through one case study, and encourages them to identify and examine assumptions, consider "what if" scenarios and develop a broad strategy.

In each of four stages, participants receive worksheets with information, graphs and questions. After working in pairs to answer the questions, a group discussion is held.

1. Topics for Discussion in the Hands-On Session at ALE Workshop

Is the departure from the standard case study approach by showing alternative versions of the problem useful or confusing? Should the questions on the worksheets include more or less guidance? Is it a good idea to throw participants in at the deep end with the interpretation of results before teaching the methods used to obtain the results? Plus anything else that participants want to discuss!

2. Detail Regarding the Alternative Versions of the Problem

a. *Variation in Raw Materials*

In a simple situation, a process or product can have a single raw material with a clear structure (batch, for example) and a single, known quality characteristic which can be easily and accurately measured. For example, we use a solution in a chemical process and the concentration of an important component/ingredient varies from its nominal level from batch to batch. In a more complicated situation, the raw material could have many quality characteristics, and we may not know which are important, or how to measure some of them. We may buy the raw material from a supplier rather than preparing it ourselves, and may have no knowledge of the structure of its production e.g. we have several bottles of the solution and don't know which bottles came from the same batch. In addition, the raw material may be related to the factors of the experiment e.g. we may want to investigate a nominal concentration of 1% or 2% of the ingredient. In some cases, the quality characteristics of the raw materials can be treated as "noise factors" following Taguchi's robust design approach: we can then explore their interactions with the factors of the experiment and seek a product or process design which is robust to variation in raw materials.

In this exercise, we consider the situation where a single raw material has a batch structure, and we do not know which of its quality characteristics are relevant. For this limited situation, the four versions of the variation in the raw material that we see in the exercise are: small variation both between and within batches; large variation both between and within batches; small variation between batches and large variation within batches; large variation between batches and small variation within batches.

b. *Experimental Strategies*

There are numerous ways to take variation in one or more raw materials into account when designing an experiment using the tools of statistical design of experiments (DOE). In this exercise, we consider three common strategies: carry out the whole experiment using one batch of raw materials; use four different batches of raw materials in an organized fashion; use raw material selected at random from several batches, ignoring the batch structure.

c. *Nature of the True Underlying Dependence of the Quality Measure of Interest on the Raw Material and the Experimental Factors Being Investigated*

The three versions that we consider are: the quality measure depends on the experimental factors but not on the raw material; the quality measure depends on both the experimental factors and the raw material, following an additive model; the quality measure depends on both the experimental factors and the raw material, following a model with interactions: the effect of the raw material on the quality measure depends on the levels of the experimental factors.

3. The Active Learning Exercise

In the first stage, the participants receive two worksheets with four graphs, with a very brief explanation of how to interpret the graphs, and a number of questions to be addressed after interpreting the graphs. The four graphs correspond to the four versions of the variation in the raw material, and characterizing the four versions is straight forward. The questions include: What data would we need in order to prepare these graphs? How could we obtain this data? How can we proceed if we don't have this data? At this stage we focus solely on the variation in the raw material, not on the experiment. The whole stage is "upside down": we don't give a file and ask which graph to prepare using the given data, but rather give the finished graph and consider how we could obtain it. In this field there is a huge gap between how we could work and how we do work, and this exercise offers an experience of a "better world".

In the second stage, the participants receive a single worksheet with the story, basic design and aim of the experiment, and a question regarding how to take variation in the raw material into account when designing the experiment i.e. how to choose material from the batches. The experiment considered is very simple and generic. This stage of the exercise has elements of a TV cooking show: the pie is assembled, and it magically appears minutes later fully baked. Here the participants suggest alternative strategies in the second stage and are then given the three common strategies and results from several experiments run using these strategies in the third stage.

At this point the exercise becomes complicated, because a full picture of what can happen given any combination of variation in the raw material (four versions), strategy for dealing with this variation (three versions) and underlying dependence (three versions) becomes apparent. Students like a neat, packaged conclusion, and in this exercise the fourth and final stage is completing a table which provides a broad strategy: what to do when.

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Activating learning via the use of Classroom Response Systems (CRS)

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Extended Abstract

In this hands-on workshop the authors will address the ALE theme of 'ACTIVE LEARNING AND ICT'. This workshop will showcase the use of Classroom Response Systems or CRS. The authors will describe how modern CRS allow students to use their mobile devices (phones, tablets, laptops) to respond to a variety of problem based questions during a lecture (Bakrania, 2012). The CRS generates a digital graph that provides an immediate and anonymous picture of how well the entire group have understood a particular problem. If the graph shows a complete understanding of problem the class can move on. If not, then the lecturer can take steps to remedy misconceptions and revise the key threshold concepts that are embedded in the problems. A interactive way of doing this is to divide the students into groups and have them discuss how they arrived at their solutions. Using groups allows the stronger students to explain how they approached and solved the problems. They reinforce their own learning and develop generic competencies such as leadership and the ability to communicate clearly. The benefit for struggling students is that they can learn from their peers without being embarrassed and or pressured. The groups' agreed on solution can then be canvassed and a new graph produced using CRS.

In the workshop we first critique the research literature on the use of CRS and explain their advantages and disadvantages (10 mins). The authors cite some research that indicates how CRS can increase student engagement and participation, and provide immediate feedback (Brown, 2012; Biggs,1987). They also refer to other studies that argue that the use of CRS can result in a decrease in the amount of material that is covered in lectures (Judson & Sawada, 2002; Kay & LeSage, 2009). We recommend that those wishing to participate in the workshop look at one or two of the references below. There are hyperlinks to articles. Cut and paste the link into your browser if you have problems opening the link. To solve the problem of decreasing the amount of material one can deliver because of CRS the normal teaching and learning sequence is *flipped* and students are asked to work on the problems at home before coming to the lecture and bring their solutions and how they arrived at them to class. The lecturer can then use the CRS to determine how much they have understood. After teaching or using interactive groups to revise the correct approach to solving the problems the lecturer can then use the CRS to check that all have understood and can answer the questions correctly. The lecture can be rounded off with a preview of the content that will be covered in the next set of online problems that students will work on at home.

This way of using lecture time has been called 'flipping the classroom' and there is now a pedagogical movement that advocates it and a body of research literature that argues for its efficacy in teaching and learning. In the hands-on section of our workshop (60 minutes) both the notion of flipping a learning sequence and the use of the CRS will be trialled. The participants will have an opportunity to solve a set of generic engineering problems on their own and, if the technology allows, be quizzed on their answers using the CRS. Since this is a demonstration of the process the individuals will then be divided into groups made up of some individuals who found the problems hard and some who had had no difficulties solving them. The groups will have time to discuss their approaches and solutions and agree on a response before the CRS is used again to determine shifts in the correct response rate. The last 20 minutes will be used to discuss and evaluate both the use of CRS and the notion of flipping the classroom. The authors will conclude by summarizing the results of the session and handing our some key references, a list of common CRS devices and systems, and a tips sheet on how to best use the flipped classroom. We recommend you attend our PAEE session (paper number 115) if you are particularly interested in the flipped classroom pedagogy.

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How to make Engineering Students master problem identification and problem formulation

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Abstract

The focus of this paper is how we make engineering students master problem identification and problem formulation. The authors take inspiration in their own experiences as lecturers and supervisors in a PBL learning environment at Aalborg University to develop a workshop. Aalborg University has a rather well-defined approach that takes the engineering students through different phases in order to develop these skills. The workshop aims to engage participants in an exemplary process, where they reflect upon their problem understanding, their own knowledge as regards problem identification and problem formulation and the skills needed to formulate an authentic problem and argue for their relevance. Being the target group of this workshop, academic staff is also expected to reflect upon their own teaching practice and relate it to the need to enhance students' skills for problem identification and formulation.

1. Introduction

Active learning strategies prepare engineering students for a career of creative thinking and independent decision-making. A core premise of active learning is that students are responsible for their own learning and development of knowledge, skills and competencies. Examples of active learning strategies are CDIO, role-play, problem based and project organised learning (PBL). A lot of these strategies imply development of problem solving skills, which is one of the core skills for engineering practice and stressed by accreditation bodies (see for example, UK-Engineering Council, 2004; ENAEE, 2008; ABET, 2010). Even though it is rather straightforward for students to learn how to solve problems; identifying and formulating a 'relevant' problem is often a challenge and frequently neglected in learning processes (Felder *et. al.*, 2000; National Academy of Engineering, 2004; Shepard *et. al.*, 2009).

This paper proposes a workshop, which will enhance participants' skills in identifying, analysing and formulating relevant problems. By relevant problems the authors mean a problem that is well-argued in terms of need, authenticity and implications.

The following workshop overview and aims elaborates on the reasoning behind the workshop activities, whereas the consecutive activities section elaborates on the workshop structure and its different activities.

2. Workshop overview and aims

The workshop overall purpose is to provide to academic staff, and consequently students, an approach to enhance and develop problem formulation skills. To do so, the workshop is inspired by the authors' experiences as lecturers and supervisors in a PBL learning environment at Aalborg University. Aalborg University has a rather well defined approach that takes the engineering students through different phases in order to identify, analyse and formulate a relevant problem. The problem formulated is then solved and documented through a project period of approximately ½ year.

In this context a problem can be defined as a *wondering*, often originated from an observed phenomenon (i.e. situation, event, person or thing), between how things are (present state of being) and ought to be/could be (idealised or hypothetical way of being). A problematic situation causes contrasts, conflicts, contradictions, stress, frustration, sorrow and/or indignation, which impel people to act in order to change its current state. Problems do not have to have a negative character. They can also be defined as an un-explored potential of a situation or object (Borrows & Tamblyn, 1980; Qvist, 2004; Jonassen, 2011). For example, the primary function of a mobile phone is to make and receive calls, nowadays mobile phones include photographic and video cameras, agendas, emails, GPS applications and so forth.

The learning process starts with students being acknowledged with and involved in situations that can possibly be problematized and analysed. These processes are known as *problem analysis and formulation*. The analysis and understanding of what is observed (problematic situation) and what is aimed for involves the application of both emotions and cognition. In order to change a situation defined as problematic or potentially promising, students need to understand what is observed, why it is the way it is, how, where and when it can be changed. These are examples of questions which help to deconstruct and identify elements of the problematic situation. The problem analysis demands mobilisation of prior knowledge, understanding one's knowledge, analysing the situation and culminates in a formulation of a problem normally in the form of a question to be solved (Qvist, 2004; Savin-Baden & Howell, 2004; Jonassen, 2011).

The workshop aims to engage participants in the exemplary process similar to the one engineering students at Aalborg University experience every semester. Thereby the workshop's hands-on activities can serve as a specific example of a more general methodology of formulating relevant problems in engineering fields. By reflecting and generalising on concrete experiences of the hands-on activities the participants can reach a broader and more general understanding of how relevant problems can be formulated in his/her own field of study. In this sense, problem identification, analysis and formulation skills become a transferable skill, i.e. participants apply a similar approach to formulate new problems within their specific disciplines of study (Pedersen, 2008).

3 Workshop components

Three parts compose the workshop. (1.) The first part is an introductory lecture, where PBL learning principles are presented as well as relevant concepts (i.e. interdisciplinarity, problem theme/ area, problem statement, mind map, etc.). (2.) The second part is a set of hands-on exercises, where participants form groups and work with given tools to identify, analyse and formulate a relevant problem. (3) The third and last part is a sum up, where participants reflect upon the process they went through in part two and draw some conclusions. At Aalborg University, this reflection takes place mainly at end of semester, where students are call to reflect upon their own working and learning process and report it through a small report. . See the following table 1, where the three parts of workshop are laid out in more details.

Table 2 Workshop structure, content and goals

Parts	**Content**	**Tools/ resources**	**Goals**
(1.) **Introduction**	PBL definition and learning principles; Problem definition; Problem theme, area, and research problem/ problem formulation	PowerPoint	Define and understand PBL and its learning principles Understand different types of problems
(2.) **Hands-on activities**	Identify problem areas or themes (brainstorm) Mind map the problem areas Initial problem formulation Final problem formulation Evaluate the problem formulated	*Tool 1*: Brainstorm to identify problem area *Tool 2*: Organising brainstormed ideas *Tool 3*: Problem landscape *Tool 4*: Matrix for analysis *Tool 5*: Problem formulation *Tool 6*: Evaluation of problem formulated (checklist)	Develop an approach to identify and formulate problems Relate the hands-on activities (exemplary process) with competencies, skills and knowledge needed to formulate relevant problems within field of discipline
(3.) **Sum up**	PBL curriculum alignment PBL process as process and product oriented Development of competencies and skills Reflection on workshop process and generation of knowledge by using Kolb's learning cycle (Illeris, 2007).	PowerPoint Kolb's learning cycle and organisational cycle Open questions for reflection	Reflect upon the hands-on activities (experienced learning), generalise into the learning processes to develop engineering students problem formulation skills.

Tool 1 and 2 will bring out the potential ideas and organise them in an apprehensive structure arguing why they could be relevant problem areas to look into. Tool 3 and 4 will enlarge and enrich the problem area looking into relevant perspectives of the problem area and the potential problem solving horizon and thereby prepare for the first initial formulation of a relevant problem. Tool 5 and 6 will help the participants formulate the actual problem formulation and evaluate the appropriateness of the specific question.

The sum up part is mediated/ chaired by the authors, where they also collect feedback from participants in order to revise and improve the workshop for future use, namely in staff training and teaching activities. Being the target group of this workshop, academic staff is also expected to reflect upon their own teaching practice and relate it to the need to enhance students' skills for problem identification and formulation. It is also aimed for participants to reflect upon their problem understanding, their own knowledge as regards problem identification and problem formulation and the skills needed to formulate an authentic problem and argue for its relevance. Thus, the authors develop the workshop by combining a series of hands-on activities and tools to engage participants in specific experiences; the followed discussion and reflection are part of summing up and aims to generate knowledge (i.e. interpretation and generation of knowledge).

Depending on the setting the workshop is expected to last for 1½ - 2 hours.

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Designing for Atypical Bodies and Minds: Politics and Practices

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Extended Abstract

Working in and around "design for disability" seems like a compelling way to combine active, project-based, user-centered engineering learning with a focus on social impact. However, it's all too easy to make the "Disability Theory 101" faux pas of "othering," or recreating narrative that separates "those poor disabled people" (who are, of course, not engineers) from abled "saviors" who will "fix" their "problems" with STEM. How can we sensitize well-meaning engineering students to the sociotechnical complexities involved in working with users of assistive and adaptive technologies?

The last decade has seen enormous advances in prosthetics engineering and assistive technologies: refined controls and dexterity in artificial limbs, for example, and the dramatic affordances of the iPad's novel interface for developmental challenges. The last decade has also brought about lively, unresolved debate about the very meanings of ability and disability -- as seen in the contested understanding of the autism spectrum as a disorder, or as mere neurodiversity, and the political visibility of the capital-d Deaf community and its general refusal of cochlear implant technology. How, then, do engineers-in-training position their research and development of prosthetic or assistive devices amid such cultural complexity?

This workshop embraces the challenge of navigating disability as a rich site of both cultural meaning and technical innovation. We explore ways in which participants and facilitators aspire to leverage educational opportunities that combine engineering-as-problem-solving with social relevance and concrete positive impact. The aim here is to incorporate the benefits of engaging with disability research without perpetuating insensitive understandings and practices that marginalize members of disabled communities, including some of our own students.

During this workshop, faculty and researchers from Olin College of Engineering will support the group's collective and critical sensemaking of culturally inherited ideas about people with atypical bodies and minds. Together, we will reflect on the implications of our unexamined assumptions for pedagogical practices regarding engineering projects with and for end-users with disabilities. Our premise is that we must distinguish between the dominant "medical model" of disability (which views atypical bodies and minds as "problems" to be "fixed") and the "social model" of disability (which positions atypical bodies and minds as "limited in capacity" only in the context of environments, technologies, and cultural structures not designed to support them). The facilitation team includes a mix of engineers, social scientists, and education researchers, disability theorists and activists, and abled and disabled scholars.

Background: Engineering And Disability Studies

We will start with a basic primer in disability studies and its usefulness to engineering education.

The field of disability studies is not a discipline. Instead, it is a framework of concepts that are useful across the disciplines to draw attention to the ways people with disabilities have been understood by cultures throughout history; it draws an attentive eye to the politics of inclusion and rights in the contemporary era. These matters are critical for teaching engineers-in-training, who must understand the complexity and cultural constraints around medical diagnostics and the categorizing of bodily difference. Training engineers for an inclusive future requires a subtle and meaningful engagement with these contested matters, to better prepare them for designing tools, technologies, systems, services, and environments that are both desired and viable in the marketplace. We will use the beginning of the workshop to broadly introduce attendees to some ways to broach that complexity: by indicating the usefulness of disability studies to technical design-build coursework.

ACTIVITY 1: EMPATHY (20 minutes):

Facilitators will set up various “empathy stations” around the room. Each station will have a facilitator running an activity designed to help engineering students develop a sense of empathy with the disabled. Participants will rotate between facilitator-staffed stations, playing the role of “students.” Participants will bring with them to each station a worksheet with prompts and questions to consider.

Each station will draw from facilitators’ experiences with co-design partnerships between undergraduate engineering students and various “disabled” populations—older adults, young children, young working professionals, and so on, including engineers who are themselves disabled. Stations represent a range of disabilities (mental and physical, visible and invisible, lifelong and acquired) and utilize methods from anthropological interviewing and observing and user-oriented design thinking. Stations include mobility, dexterity, vision, hearing, and sensory processing.

Participants will be provided with materials for reproducing and adapting these “empathy stations” to their home institutions: ideas for reaching out to community partners or class guests, for structuring class sessions with appropriate tools, and so on. Our goal is to further empower participants (and facilitators) to explore this rich area, in all of its complexity, with their own students, colleagues, and collaborators.

ACTIVITY 2. DISCUSSION (30 minutes):

We will break into small groups of 6-12 participants, with at least one facilitator at each group. Using a circular small-group discussion format, facilitators will lead a debriefing discussion on the experience of the empathy exercises. What are the advantages and dangers (ethical and otherwise) of creating empathy via simulation and other means? The “circle” dialogue format is focused on holding a space for stories with attentive listening; participants are specifically instructed *not* to judge or criticize the stories of others, and *not* to give advice or try to “fix” the problems of the storytellers.

We will also encourage participants (who are comfortable and willing) to share their own lived experiences working with and within disability and engineering. The workshop facilitators will model this with their own varied relationships to the lived experience of disability and engineering -- as disabled people, as friends, family, and colleagues of disabled people, as engineers, and as friends, family, and colleagues of engineers.

ACTIVITY 3. DEBATES (30 minutes)

The final activity is designed to examine the nexus of technology and social issues at stake in distinguishing a medical model from a social model of disability. Facilitators will briefly describe some of the debates about disability, focusing on the autism spectrum and/or cochlear implants as examples.

Participants will break into groups of 3-4, and each group will be given a choice of multiple scenarios to work with, and there will be group discussion afterward. Each scenario will consist of imagined narratives and dialogue between student engineers and a person with a disability. Participants will be asked to take the role of instructor, and respond as if the scenario took place in their class. How would they respond? Students may inadvertently bring implicit assumptions about desired bodies and technologies to their co-design interactions. Similarly, the person with a disability may bring her own assumptions about engineers as heroic fixers to the interaction. With the intention of creating a more authentic and productive exchange, how and when would the instructor coach both parties?

Jigsaw, Gallery Walk, and Controversy – Combining Three Active Learning Techniques to Promote Self-Directed Learning

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Abstract

Using specific techniques, active learning can be especially valuable in its ability to promote self-directed or student-centered learning and individual accountability. In a 90 minute hands-on session, three techniques are presented as a single activity: the Jigsaw, the Gallery Walk, and Structured Academic Controversy (also referred to as Subject-related Debate). When presented together, the activity becomes a unique form of problem-based learning. At Lawrence Technological University, this activity has been successfully implemented with students and for faculty training workshops. The particular topic for the session's activity will be energy generation/production, although the combined techniques can be used for a variety of engineering topics. This paper describes some general features of the Jigsaw technique, reviews various forms of the Gallery Walk, and describes Structured Academic Controversy. The objectives of the active learning techniques are outlined in addition to their effectiveness, especially in regard to student motivation, accountability, self-directed learning, and depth of knowledge that cannot be gained from lecture alone. In addition these activities require the practice and development of professional (or soft) skills including communication and teamwork. The paper also describes how the techniques can be used separately, how they can be extended outside of the classroom, and pitfalls to avoid.

1. Introduction

Active learning requires students to engage in discussion, work problems, and/or construct deliverables in the classroom, rather than listening passively to a lecture. If students informally assist one another in this process, the technique is collaborative learning. If formal structures exist to guide student interaction, the process is considered cooperative learning (Smith *et al.*, 2005; Smith, 2011). Problem-based learning (PBL), a form of cooperative or collaborative learning, introduces an engaging problem at the beginning of the instruction cycle for students to solve, usually as part of a group (Prince, 2004). These problems are often real-world, ill-defined, and scaffolded (i.e., staged or progressively disclosed). Previous work has shown that PBL activities can substantially improve student learning (Yadav *et al.*, 2011) and that cooperative learning in general promotes academic success, quality of relationships, and self-esteem (Johnson *et al.*, 1998).

Active learning is used in many different forms, and the various techniques allow for diverse outcomes which may be retention, classroom alertness, depth of knowledge, etc. Using specific techniques, one especially attractive aspect of active learning is its ability to promote self-directed or student-centered learning and individual accountability. In a 90 minute hands-on session, three techniques are presented as a single activity: the Jigsaw, the Gallery Walk, and Structured Academic Controversy (also referred to as Subject-related Debate). When presented together, the activity becomes a unique form of problem-based learning with its six common core features: learning is student-centered, learning occurs in small student groups, teachers are facilitators or guides, problems are the organizing focus and stimulus for learning, problems are the vehicle for the development of clinical problem-solving skills, and new information is acquired through self-directed learning (Barrows, 1996). In particular, each of three methods have the essential elements of highly effective (i.e., successful) active, cooperative learning: positive interdependence, face-to-face promotive interaction, individual accountability/personal responsibility, teamwork skills, and group processing (Smith *et al*., 2005). At Lawrence Technological University, this activity has been successfully implemented with students and for faculty training workshops.

2. Jigsaw

The Jigsaw technique is named after the jigsaw puzzle, simply because it is analogous to breaking up a puzzle and putting the pieces back together as illustrated in Figure 1. The pieces of the puzzle are the students, and when placed together in their "home group," they form a complete picture. Jigsaw is a cooperative learning strategy that enables each student of a "home" group to specialize in one aspect of a problem (Clarke, 1994).

At the beginning of the activity, a problem is presented. Each student in a home group is assigned a particular aspect of the problem; all students assigned to an aspect are temporarily grouped into "expert groups." Within the expert group, students learn (and possibly master) their assigned aspect of the problem. They may also plan how to teach the material to the other members of their home group. The students then re-join their home group, and the accumulated knowledge is disseminated and synthesized into an overall solution to the problem with sufficient justification. Each student's role is essential for the completion and full understanding of the final product, thus this technique engages all students. "*It is the element of 'required' interdependence among students which makes this a unique learning method, and it is this interdependence that encourages the students to take an active part in their learning*" (Aronson *et al*., 1978, p.28; emphasis in original).

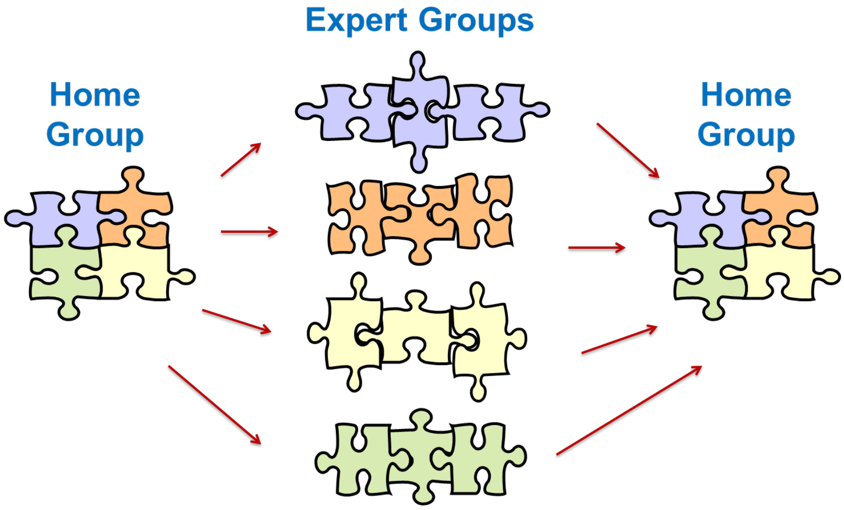

Figure 1: Graphical illustration of Jigsaw technique.

In summary, Jigsaw learning allows students to be introduced to material and yet maintain a high level of personal responsibility. At the same time, students develop teamwork and cooperative learning skills. The technique helps develop a depth of knowledge not possible if the students were to try to learn all of the material on their own. Because students are required to present their findings to the home group, Jigsaw learning will often disclose a student's own understanding of a concept as well as reveal any misunderstandings.

3. Gallery Walk

A Gallery Walk is a presentation or discussion active learning technique. This technique gets students out of their chairs and actively involves them in synthesizing important concepts, in consensus building, in writing, and/or in public speaking. There are several variations possible with the Gallery Walk, but in general the technique is as follows. Learning material or questions that relates to an important class concept are posted on charts or just pieces of paper located in different parts of the classroom. Teams rotate around the classroom to each chart or "station," composing answers to questions (or forming questions about the material), while also reflecting upon the responses/answers left by other groups. The technique closes with an oral presentation or "report out" in which each group synthesizes comments to a particular question (Francek, n.d.).

One advantage of the method is its flexibility. Instead of Gallery Walk, the instructor can conduct a "Computer Tour," wherein computers (or tablets) are situated around the classroom. Student groups can leave responses on paper, posted chart paper, or even in a comments section on the computer itself. Gallery Walks can be as short as five minutes (a "Gallery Run") incorporating a lower level of Bloom's Taxonomy, or can take several class periods (for higher level learning).

Another advantage is the variety of benefits possible for students and instructor alike. For students, it's a chance to share thoughts in a more friendly (perhaps anonymous), supportive (small group) setting rather than to a larger class. For instructors, it's a chance to gauge the depth of student understanding of particular concepts and to challenge misconceptions.

A variation to this technique (used in the example in this paper) is to have each group post a solution to a problem. Each group rotates around the room to compose questions about the other groups' solutions. At the conclusion of the rotation, each group presents to the whole class their solution and answers the questions posted.

4. Structured Academic Controversy / Subject-related Debate

Despite the term "academic controversy," this is not a technique focused on controversies within academics or at an educational institution (e.g., institutional policies or structure, educational reform, pedagogy) although it can be. Instead, Structured Academic Controversy (SAC) is a cooperative learning technique wherein students in small groups learn about a controversial issue in any particular subject from multiple perspectives. The students are typically tasked to seek consensus on the controversy. Unlike traditional classroom debate, which typically forces a decision between two ideas that may or may not be mutually exclusive, groups completing an SAC session often do not resolve into a single correct answer or solution.

The format of an SAC can vary widely. Typically, students are assigned one or two specific positions to research. As an example, an SAC could be focused on, say, climate change. Each group can be assigned a different role such as elected official, environmental protection group, economic investor, or ecologist. After researching their assigned role, each group will present their findings to the entire class. The goal is not to "win" the assigned position, but instead to give insights into others' points of view. In particular, SACs "encourage students to think about the complexities and ambiguities that often characterize controversial issues," while helping "students change their perspectives and enhance content knowledge" (Khourey-Bowers, n.d.).

5. Methodology of the Session

This 90-minute hands-on session has been successfully implemented with students in the classroom and for faculty training workshops. The learning format will combine all three techniques (Jigsaw, Gallery Walk, and SAC) into a single activity that will form a problem-based learning module. The SAC will serve as the problem statement and set-up the structure for the expert groups. The Jigsaw technique will facilitate the self-directed learning in the expert groups and the solution consensus in the home group. Finally the Gallery Walk will serve as the basis for the report-out and class discussion of the various solutions.

a. Introduction and Problem Statement (12 minutes)

The particular topic for the session's activity will be energy generation/production, although the combined techniques can be used for a variety of engineering topics. The session will begin with an overview of the three techniques explaining what they are and how they are implemented. The participants, playing the role of the students, will be formed into home groups. Before the problem statement (i.e., task) is presented by the instructor, each student in the home team is randomly assigned their expert group topic. Assigning each student to a topic prior to the problem statement helps to ensure that a student does not pick a topic that he/she is particularly fond of or already an expert with. The topics are energy sources: coal, petroleum/oil, biofuel/ethanol, wind, solar, nuclear, hydropower. Depending on the number of participants, fewer of these topics can be assigned. One method to randomly assign topics is to have the students share their birthdate with their home group. Next the chart shown in Figure 2 is displayed, and each student they will be assigned the topic based on the order in the figure. Other possibilities could include dice rolls or drawing a topic from a basket.

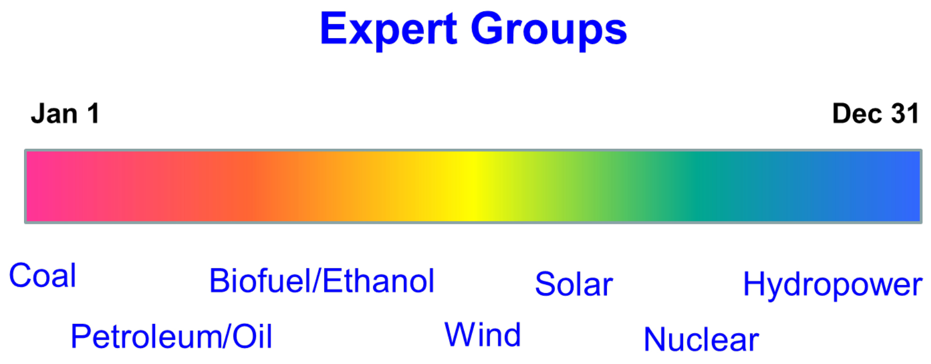

Figure 2. Example method for assigning roles using birthdate as the selection criteria.

The problem statement is given as follows:

> The National Science Foundation (or any other grant funding organization of your choosing) will soon be distributing a call for proposals. As they look to the future of energy needs, NSF would like to determine which energy conversion technology should be pursued with research and development. They have assembled a blue ribbon panel of engineers to rank or pick the top choice of a variety of energy conversion technologies. Prepare a defense of your selection(s). Your panel will be required to submit your recommendation in poster format. (Be creative with your posters.) In addition, one member of your panel will have three minutes to explain your recommendation.

b. Hands-on Activity

20 minutes: Expert Groups Research. The hands-on activity will commence with home team members separating to their assigned "expert group" to begin research into their energy conversion technology.

At this stage, students are encouraged to use any resources to learn about their assigned topic. Because of the limited time frame, laptop computers, tablets, and smart phones are the best reference sources. It is important to stress that the expert groups are not tasked to create a defense for their topic. They are simply gathering objective facts and information.

25 minutes: Home Group members share information about each topic and make decisions. At the conclusion of the timed research session, the "home teams" will reconvene to (1) teach each other their topic, (2) debate various solutions to the problem based on the presentation from each "expert" in the team, and (3) decide on a solution.

5 minutes: Create a poster for a gallery walk. It is difficult to "turn-off" the learning and home group discussions. Therefore, it is crucial that a separate time is set aside to create the posters. Past experience has revealed that if the poster creation time allotment is combined with the home group discussion time, the posters will not be completed by the deadline, and/or they will be hastily created, sloppy, or indecipherable.

5 minutes: Gallery Walk. Home groups will rotate around the room, discussing each poster and creating a list of questions.

10 minutes: Poster reports. After each participant has walked the room to view each poster, a representative from each team will briefly present their solution and answer questions. Depending on the number of home groups, each group is given 90 seconds to three minutes for presentation. To enforce individual accountability, the presenting student from each home group should be chosen at random. This can be accomplished with a dice roll or other means such as choosing the person that lives farthest from the classroom.

3 minutes: Wrap-up. At the conclusion of the hands-on activity, the moderators will present some additional research concerning the problem, details of which can be found in Kreith, 2012. (As related in the Kreith article, this is also a good opportunity to point out that the "best" energy conversion technology is not necessarily the one that "should be pursued with research and development.")

c. *Final Discussion (10 minutes)*

During post-activity discussion, the moderators will review the objectives of the active learning techniques, while raising awareness of their effectiveness. Of special note will be the excitement generated during the research/study period, and how that led to student motivation, self-directed learning, and a depth of knowledge that cannot be gained from lecture alone. In addition the activity will have showcased individual accountability since each team member had been required to acquire part of the solution for the entire team, as well as having prepared to report-out to the entire class. Finally the activity will demonstrate the practice and development of professional (or soft) skills including communication and teamwork. The moderators will also discuss variations to the techniques, how they can be used separately, how the activity can be extended outside of the classroom, and pitfalls to avoid (detailed below).

This session can accommodate up to approximately 50 participants. The room must be sized to accommodate up to 7 teams of up to 8 participants each. In addition, there must be space to allow for poster presentation (usually around the perimeter of the room). The moderators can supply the poster materials.

5.3.1 Variations

While this paper presents details of combining three structured (i.e., formal) active cooperative learning techniques into a PBL, this is not necessary. Any one of the three or combinations of two can be implemented within a course. One of the joys of using the Jigsaw in particular is observing the excitement to learn. In fact, it can be difficult to stop the learning process so that the instructor or teams can move-on to another task/learning objective. Therefore with limited classroom time, an instructor may want to consider moving the expert group meetings or the home group meetings outside of the classroom, between two class periods. This resulting additional time can allow for a deeper level of research and learning. If the expert groups are expected to meet outside of class, there is a possibility that the students will not work together; each student may research his/her topic individually defeating the purpose of cooperative learning. At least two possibilities exist to ensure group accountability. Before the end of the first class period, each expert group could decide upon a common meeting time and submit the meeting schedule to the instructor. Alternately, each expert group could be required to submit a brief group report to the instructor at the following class period. Because each home group must have all members present to form a complete solution, it is less likely that they will not work together outside of class.

A Jigsaw, of course does not have to be centered on a Structured Academic Controversy. A multi-faceted technical/engineering topic works very well with the Jigsaw.

Likewise, Structured Academic Controversy combined with a Gallery Walk work well without a Jigsaw format. Each student in a team can be tasked to individually research a particular topic or role within the topic. The team can then present their findings in a Gallery Walk format as proposed in the last paragraph of Section 3 above.

5.3.2 Pitfalls to Avoid

In class, monitor timing of each activity carefully. Each technique takes much longer than anticipated, so be certain to allow more time than might be anticipated. In addition, the teams will usually request additional time for work if they are not kept on task. Therefore the authors have discovered that a countdown timer (with an audible alarm) should be visible to all the students.

Often the number of students in the classroom does not divide evenly into home and expert groups. A perfect arrangement for a Jigsaw occurs when there are the same number of home group members as there are expert group topics. If there are *less* members in a home group than there are expert group topics (e.g., four members in one of the home groups and five expert groups), one of the topics will not get researched for inclusion in the home group solution. If this is unavoidable and one of the topics is less critical, ensure that the least critical topic is excluded for that home group. If one of the home groups has *more* members than expert group topics, send two members to a single expert group. It will be more difficult to ensure individual accountability if two members are reporting back to the home group on the same topic, so if possible, send two members to the most complex topic.

Think ahead about room arrangement. There must be an appropriate amount of teamwork stations both in terms of home groups and expert groups. In addition, there must be space for the Gallery Walk. Also consider the amount classroom supplies necessary. The number of students present in class will affect the number of posters and markers needed. Consider having extras, especially if a team needs to scrap their original poster and begin anew.

6. Conclusion

Three active cooperative learning techniques (Jigsaw, Gallery Walk, and Structured Academic Controversy) have been successfully combined into a problem-based learning activity, wherein learning is student-centered, learning occurs in small student groups, teachers are facilitators or guides, a problem is the organizing focus and stimulus for learning, the problem is the vehicle for the development of clinical problem-solving skills, and new information is acquired through self-directed learning. Each technique encourages positive interdependence, face-to-face promotive interaction, individual accountability/personal responsibility, teamwork skills, and group processing. When used together, the three techniques create an enjoyable learning environment that keeps each student engaged and attentive. The example presented in this paper can be modified (e.g., simplified or extended outside of the classroom) for a variety of course material. Careful preparation by the instructor will ensure a well-structured, yet pleasurable experience for the student.

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The Meaning of Life and Active Learning in Engineering

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Extended abstract

The main topic of this conference is "What is The Meaning of Active Learning". In this hands-on we try to answer the question with another question: the meaning of active learning, *with respect to what*?

Our purpose is to bring the subject all the way to the very ultimate question: "What is The Meaning of Life?" Hence, the question we expect to discuss now is "What is the Meaning of Active Learning in Connection to the Meaning of Life?"

So, what is the meaning of Life? We wonder. Life does not *have* a meaning. Life *is* the Meaning, we suggest. Then, active learning does not have a meaning *unless* it is connected and enhances life.

No matter how "active" learning may be, active learning does not make sense unless what is to be learned is worthwhile. So we need to reconsider *what* are we trying to learn, and with what purpose. In the ALE context, we are trying to teach/learn engineering, with the purpose that our students become good engineering practitioners. And this is so because we somehow believe that the practice of engineering is intrinsically worthwhile. But, under the premises of this paper, is that true? Are we sure that engineering always enhances life?

When you are on a boat, it becomes hard to question why you are on that boat, and where is the boat heading to. You just follow the stream and move forward. Yet, if only you move your "anchor point" slightly, if you place your point of view out of the boat, then you get a different picture. You may notice that the boat is astray, and you may wonder if the boat should be stopped altogether, or brought to a totally different destination.

The problem with engineering is that it has never been questioned enough. It has always been assumed to be "good" under the much too vague idea of "*progress*". The more technology, the better, we seem to believe, and we become proud of each new technological gadget as if this were the ultimate achievement of humanity, unconscious of how much we become dependent on them. But in life, when something changes on the one side, everything changes on the other side as well. The reductionism of science-technology-engineering should no longer be accepted. Nowadays, the side effects of engineering on the environment, for instance, are very clear.

The way it works in our western society, technology is just a procedure for providing new goods for the market, in order to provide profit. Profit for just a few.

So, we need to think of a new technology, new ways of making engineering, such that enhance rather than destroy Life. After all, engineering is the use of human wit to solve what needs to be solved. And what needs to be solved nowadays is what has been destroyed in the past.

The hands-on session (90'):

- Introduction (5’). After a short introduction, groups will be formed.
- Group discussion (20’). Every group will be asked to discuss 2 questions. Question 1 suggested by the facilitators, and question 2 posed by themselves
- Debate (40’) All participants will engage on a debate and every participant will be asked to write down their own conclusions (to be kept by themselves)
- Summing-up and conclusions (20’)

A few of the suggested facilitator questions could be the following:

- Has Engineering historically lead to an enhancement of Life? In what sense?
- Who benefits from the results of Engineering?
- What kinds of engineering enhance Life, and what kinds do not?
- In the context of enhancing Life, what does Learning mean?
- In order to enhance Life, what is worth to be learned?
- What are the ways to learn the endeavors of Life?
- Is there any way to learn that is not Active?
- Does Life have a Meaning, other than itself?
- What does the word progress stand for?
- Are current times in some sense better than they used to be?
- Is Life in other cultures, with less technology, worth less? Or more?
- Etc.

Expected outcomes:

A fruitful discussion among participants about the meaning of active learning in connection with Life.

Papers from the Discussion sessions

Applicability of Principles of Cognitive Science in Active Learning Pedagogies

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Abstract

The objective of this research is to employ a simple active learning strategy in conjunction with the principles of cognitive psychology to enhance student learning in an undergraduate mathematics course. The investigation was done for a first year undergraduate engineering mathematics course, namely, *complex analysis*. Specifically, quantitative investigations were made in which the course was taught using (a) the traditional lecturing approach to over 100 students and (b) the *intervention* and *reinforcement*-based active learning method to a second group of over 100 students. The first approach involved the use of a standard white board to write and explain the concepts. Subsequent to this, the students were given practice problem sets to master the concepts. In the second method, the classroom was completely *flipped*, i.e., the students were assigned reading assignments and had to take a quiz before joining the classroom. In the classroom, the lectures were replaced with group-problem solving sessions. In this, students were divided into small groups where they solved worksheets containing several problems. By design, these worksheets integrated the principles of cognitive science in learning that are conducive to long term retention of the topics. All students took four term tests, one every 3 weeks. From a quantitative analysis of the test results, it was found that unlike the traditional lecturing approach, the students were able to retain the material for longer durations in the second method. This enhanced performance of the students is attributed to the *effective* reinforcement of the concepts as well as the intervention strategy employed in the classroom. The former was achieved via (a) practice, teaching/learning/communications with their peers inside the classroom and the latter via compulsory homework and reading assignments that the students undertook outside the classroom.

1 Introduction

In a bid to pursue the global challenge of providing quality education, there is a lot of focus on effective teaching and learning, and long term retention of the concepts taught to the students. In traditional lecture settings, students master only about 20% of the course's concepts that are taught (Wage *et al.*, 2005). With this in mind, several investigations have focused on developing an optimal approach to deliver lectures to improve upon this low percentage. Some investigations have advocated the use of computer-based active instruction to enhance student learning (Redish *et al.*, 1997; Murray, 1999) However, as discussed by Kirshner *et al*. (2006) these approaches can either be too expensive. Besides, these approaches can place an enormous amount of work load on the instructors.

Among others, it has been found that active and co-operative learning can significantly improve student learning (Prince, 2004; Crouch and Mazur, 2001). Also, studies have used the principles of cognitive science to deliver lectures and have found success in improving student learning and retention (Deslauriers *et al.*, 2011; Sidhu and Srinivasan, 2014). Keeping these in mind, in this work, we integrate the principles of cognitive science with an active learning methodology to teach an undergraduate course in mathematics for engineering students. This report presents the results of this experiment on the student learning outcomes.

The specific details of the study including the course, materials, data collection and analysis procedure, are described in the Sec. 2. The results found from the analysis of the data are discussed in Sec. 3 and pertinent conclusions are drawn in Sec. 4.

4. Methods

The study was conducted in an undergraduate course on *Complex Analysis* taught over a period of one term (13 weeks). 124 students in the first group (control section) were taught the course using the standard lecture (SL) format. On the other hand, 115 students in the second group (experimental section) received an intervention-based active learning (IBAL) instruction. The details of these teaching methodologies and the student assessments are discussed in the ensuing sections.

5. Course Design

In the control section, four hours of lectures were delivered every week, and practice problem sets were assigned for the students to work at home. The students were encouraged to pursue the questions and contact the instructor either during the posted office hours or by making an appointment at a mutually convenient time.

On the other hand, in the experimental section, the students took a quiz on a topic before coming to the classroom. Subsequent to this, after a short lecture of about 15 minutes, the students were divided in small groups of 4-5 students and were assigned worksheets containing several problems pertaining to the topic. More than 90% of the questions on the worksheets were from the same practice problem sets that were assigned to the students in the control section. The remaining practice problem sets were also made available for these students to work at home through the week. This work was checked in the following week when the students returned to the classroom. In almost every class a problem from the previous week's topic was assigned again as part of the new worksheet. Thus, the students had to retrieve the concept to solve the problem thereby reinforcing their understanding.

The IBAL strategy involved the integration of the key principles of cognitive science, namely, Reinforcement, Spacing and Feedback into an active learning environment. 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. Three key aspects of this strategy are 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 must be practiced over a longer span of time. (c) Instant Feedback: An immediate corrective feedback can help in better understanding of the material more effectively.

6. Materials

Students in both sections were taught the same material. Specifically, the course focused on complex numbers, complex planes, complex functions and mappings, analytic functions, integration in complex plane, series and residues. Student performance in the course in both sections was evaluated using four term tests and a final exam. The terms tests were administered once every three weeks, immediately after the predetermined set of topics for the respective tests were taught in the class. The topics of the 4 term tests given to the students in both sections are summarized as:

Test 1: Complex numbers, complex plane, complex functions and mappings, limits and continuity, differentiability, analyticity, Cauchy-Riemann equations.

Test 2: Harmonic functions Real integrals, complex integrals, Cauchy-Goursat theorem, Independence of path.

Test 3: Cauchy's integral Formulas, complex form of Green's theorem and sequences and series.

Test 4: Taylor's series, Laurent's series, residue theorem and its applications.

Each test was for a duration of one hour. In both sections three best out of the four tests were considered towards the final grade. The final exam was comprehensive and was for a duration of 3 hours. There were about 12 to 13 questions, some with multiple parts.

7. Procedure

For the students in the control section, all the topics were taught by first explaining the concepts and subsequently solving a few examples on the white board during the in-class instruction period. At the end of each topic, the students were provided with problem sets for practice outside the classroom. The students were encouraged to seek assistance if needed either during posted office ours or by making appointments.

In the experimental section, the IBAL strategy described earlier was employed, incorporating the principles of cognitive science to enhance the long-term retention of the material. In this, the students were encouraged to discuss the solution approach within their respective group. Additionally, the instructor was also available for them to seek clarifications or intermittent feedback as soon as they complete their problems. Thus, by the end of the each work period, every student in the class had arrived at the correct solution and had a good understanding of the solution methodology (**Instant Feedback)**. In addition to this, the students were also asked to pursue some of the unsolved problems (mostly due to lack of time) at home and return to the classroom with the solutions in the following week. By spreading the work through the entire week the principle of **Spacing** was introduced into the learning strategy. The fact that the students were able to solve several problems in class encouraged them to pursue the remaining outside the classroom and most students returned with solutions to other questions. By pursing the problems for a longer duration outside the class, the concepts were **reinforced**.

Specifically, by participating in the quiz before the class, solving the worksheets in the class and doing homework outside the class, the concepts were continuously reinforced over a period of at least one week. The instantaneous feedback in the online quizzes as well the worksheets in the classroom ensured that there is a proper understanding of the concepts by the students. Thus, the course was designed to inculcate all three key principles described in Sec. 2.1 for improved student learning.

2 Results and Discussion

8. Term Tests

The 4 tests were administered after finishing the respective topics outlined in Sec. 2.2. The performance of the students in the 4 tests is summarized in Table 1 and the average scores of the students in these tests are shown in Figure 7. As seen in this figure, in all but the 3rd test, the performance of the experimental section is significantly better.

Table 1: Test results from the control (1) and experimental (2) section.

	Test 1		**Test 2**		**Test 3**		**Test 4**	
Section	1	2	1	2	1	2	1	2
Average	57	88	52	73	61	54	40	57
Std. Dev.	25	12	28	13	28	22	25	20
Effect Size	**1.9**		**1.2**		**-0.5**		**1.5**	

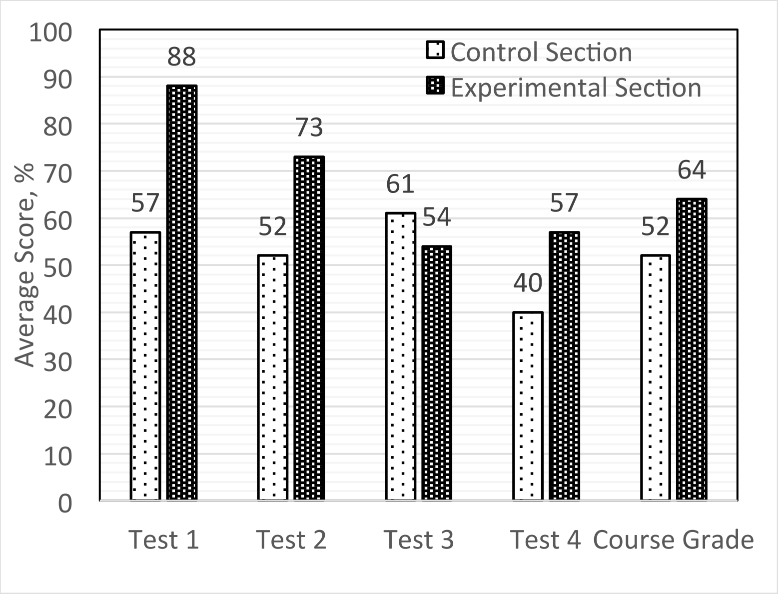

Figure 7: Average score in the tests and the final course grade indicated at the top of each bar in the graph.

In the first test, covering elementary principles of complex analysis, the experimental section's average score was about 30% higher. In the more difficult tests, i.e., Test 2 and Test 4, these students' average grade was about 20% and 17% higher in the respective tests. The anomalous case of Test 3 is most likely due to the fact that the experimental section was taking a test in another subject within a day of this test. This could have resulted in a severe under preparation for this test. Interestingly, the control section performed the best in this test.

In general, the student performance in both sections gradually decreases from the first test towards the last test. This was expected because (i) the students are faced with increasingly difficult topics in each test and (ii) the students are aware that only the three best tests are considered towards their final grade. Thus, given that the students are overwhelmed with several other courses and their respective deadlines closer to the end of the term, they are likely to focus on other courses knowing that their performance is not likely to improve any further. In other words, they would optimally utilize their time to improve their performance in other courses. This is consistent with the postulates of Love and Kotchen (2010) who have proposed a detailed mathematical model on the resource allocation practiced by students while handling multiple courses in a single term.

9. *Effect Size*

To obtain a quantitative estimate of the influence of the factors varied in the experimental section, an effect size is calculated as

$$d = \frac{\bar{x}_1 - \bar{x}_2}{s}, \tag{1}$$

where d is the effect size, $\bar{x}_1$ and $\bar{x}_2$ 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 i^{th} section, respectively.

As summarized in Table 1, with the exception of Test 3, the effect size indicates that by integrating principles of cognitive science with active learning strategies in the classroom, there is a significant improvement in student learning. Without considering the anomalous case of Test 3, an average effect size of about 1.5 has been observed in this course. This is in close agreement with the findings of Sidhu and Srinivasan (2014), and Bloom (1984) who has reported an effect size of 1.2 by using reinforcement strategies. This is close to the limit value of 2 which is likely to be achieved via individual tutoring (Bloom, 1984).

10. Final Course Grade

The performance of the two sections is summarized in Figure 7. As seen in this figure, the average course grade of the experimental section improved by over 10% or a full letter grade. Given the toughness of this course, this is a significant improvement in the student performance. The improved performance of the students clearly reflects an improved learning and better long-term retention ability of the concepts in the students when they are taught using the IBAL strategy.

3 Summary and Conclusions

In this study, the effects of use of principles of cognitive science, interlaced with an active learning strategy have been explored. Specifically, a 2nd year undergraduate course, namely, *Complex Analysis*, was taught using the standard lecturing format (control section) as well as the intervention-based active learning (IBAL) approach (experimental section). In the control section the same material was presented to the students via lectures (Two 2-hour lectures each week) and the students were given practice problem sets to work at home. On the other hand, the students in the experimental section were expected to take online quizzes before joining the classroom. Inside the classroom, the students were divided in groups of four or five and were assigned worksheets containing the problems from the practice sets, to solve. The questions solved by the students were examined immediately by the instructor and the students had a feedback for the questions, elucidating the concepts for their improved understanding. Subsequent to these, they were given the remainder of the problems in practice question sets to work at home that were checked the following week. Thus, for this group of students, the key principles of cognitive science, namely, reinforcement, spacing and instant feedback, were embedded in the learning strategy. While the former two were accomplished by asking the students to solve a host of problems through a period of over a week for each topic, the latter was implemented by giving feedback on the worksheets inside the classroom.

Comparison of the four term tests and the final course grade showed that the performance of the students taught via the IBAL approach is significantly better (average effect size of 1.5) than the students who learn the material via the traditional lecturing approach. Further, the final course grade was about 10% higher in the experimental section than in the control section. This improved performance can be attributed to the design of the course delivery in which the content was reinforced through repeated retrieval through each week and students learnt the concepts via co-operative learning with minimal instruction from the instructor.

It can be concluded that student learning can be significantly affected by employing active learning strategies inside the classroom and combining it with intervention-based teaching for retrieval, understanding and long-term retention of the material. The latter has a more significant positive impact on the student learning outcomes.

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Flipped Learning and its effect on teaching statistics to engineers

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Abstract

The use of Flipped Learning is a common and growing practice in primary and secondary education all over the world. The first attempts to include this type of active learning methodology in university level studies are recent, and the research and literature is scarce.

For two consecutive semesters an experiment on the effect of using Flipped Learning when teaching statistics to second year engineering students took place in the Universidad Europea de Madrid (UEM). The experiment included two groups of students with which the methodology was followed and a third control group; all three raised the total student count to 85.

During classroom time, students were divided into groups of three and they had to solve a number of proposed statistical problems involving the topics covered in the suggested learning materials for that session.

The methodology was not implemented from the very start, but during the last six weeks (half) of the course. Before the implementation a survey covering motivation and self appreciation of learning and a regular knowledge test took place in each group. At the end of the course this was done again.

All the collected information was then statistically analyzed in search of proof of any benefits the methodology could have had on the grading and motivation of the experimental groups compared to the control group. It was discovered that the experimental groups had bettered their grades, by a mean of around a 15%, and motivation widely over that of the control group. Drop-outs plummeted and the general rate of attendance rose noticeably in flipped learning groups.

This paper will cover not only the precise way in which the methodology was implemented in this particular case, but also the statistical analysis and later results derived from the study of the recovered data.

1 Introduction. The concept of Flipped Learning.

Flipped Learning, or alternatively, Flipped Classroom is the name given to a number of learning methodologies that sought to banish lecturing from the classroom, leaving it as a place to practice theoretical knowledge acquired at home by the student.

In 2012 Jonathan Bergmann and Aaron Sams (Bergmann, J & Sams, A. 2012) published “Flip Your Classroom. Reach Every Student in Every Class Every Day”, this was a breaking point for the methodology that ran through the North American education scene like wildfire.

The ways of doing so are diverse and there are a myriad of books and papers explaining examples of best practices and how to implement it in primary and secondary education. Higher education is starting to catch on, but is still far from the levels of scientific production generated by teachers and professionals studying earlier stages of instruction.

The concept itself is nothing new, but it's systematic implementation and the use of multimedia materials produced by the teacher or third parties has only recently been a realistic possibility due to the mainstreaming of multimedia devices and edition software.

The following is an alternative definition that this paper's authors consider encompasses and extends most of those the Literature offers:

"Flipped Learning defines an educational methodology applicable in cases of face to face education where the student becomes an active agent of his own learning. Students acquire theoretical knowledge outside the classroom through multimedia contents selected by the teacher or through personal research (either model is applicable, enabling even a mixed model with as much weight on each side as desired). The classroom becomes a place where, individually or in small groups, students will face tests and practical exercises that contextualize and settle their autonomous learning. The teacher's role in this methodology is to act as a figure of guidance and support".

2 The experiment

The authors of this paper are all teachers in different institutions of higher education in the area of engineering. One of the major dropout factors in this field of learning is the lack of motivation students stumble upon when trying to tackle the basic science knowledge (mathematics primarily) that builds up during the first few years of any engineering studies.

Flipped Learning offers a unique opportunity to motivate students to overcome these "less attractive" lectures, presenting also a chance to enhance knowledge acquisition and persistence on the way.

During the academic year 2013/2014, an experiment was designed in order to determine the effect of Flipped Learning in the context of Engineering Degrees in private higher education in Spain.

11. The phases of the experiment

The first half of the subject

The first half of the subject would be taught through traditional lecturing (Master classes). This way students could compare traditional vs. flipped in the context of the same subject.

During this first half, an individual project corresponding to a 10% of the assessment of the whole subject was commissioned.

At the end of this first half a students were asked to take a mid-term test that added another 20% to the total grade.

The first survey

After the mid-term test, students were asked to fill in a survey about their self-perception of learning. This way results could be compared qualitatively before and after the experiment.

The second half of the subject

The second half of the subject was approached through Flipped Classroom. A moodle LSP served as a backbone for hosting links to videos and PDF files that students would have to work on outside the classroom.

The classes themselves consisted in collaborative work sessions, where students were challenged to solve a number of complex problems in groups of 2 to 4. Members of a group could not repeat from session to session so as to ensure a complete randomness, avoiding polarization of better vs. worse students. These problems would be handed in and assessed adding up another 30% to the final grade.

At the end of this second half, there was a Final Exam that covered the entirety of the subject's contents. This last assessment would add the remaining 40% of student's grades.

The second survey

After the final exam, a second survey on self-perception of learning was handed out so students could express their opinion on the second half of the subject and their perception upon the implementation of the Flipped Learning methodology.

Long term knowledge persistence test

A month and a half after the subject had ended, students were asked to voluntarily take a test (similar to those of the mid-term and final exam) in order to assess the effect of the methodology of long term knowledge persistence.

In order to make the comparison between groups possible, it is important to note that every test, exercise and exam was exactly the same for every group involved (including the Control Group discussed later on).

12. The subject

The subject chosen for the experiment was Statistics for Engineering. The reason for this choice was threefold:

1. Since it is taught during the second year of every engineering degree (except for civil engineering) in the UEM the experiment could be compared between groups from different degrees due to this common internal structure. It is also taught exclusively in English (Both in bilingual degrees and degrees in Spanish) so international students could be included with ease.
2. Length of the subject is 6 ECTS, so it is long enough to endure being cut in half (methodologically speaking).
3. Other mathematical subjects such as Algebra or Calculus are less prone to allow collaborative classwork. Statistics, on the other hand is a more than appropriate scenario for a group approach towards problems, enabling discussion and various possible ways to solve them.

Also, at the time of the experiment, Guillermo Castilla, one of the authors of this paper was subject coordinator for Statistics. The subject coordinator, although an unofficial position inside UEM, allows the harmonization of subjects taught throughout different degrees within the same faculty or school.

This position made it possible to conduct the experiment without this being a advantage or disadvantage for those groups involved compared to the rest of the student body of engineering coursing this subject thougout the institution.

The factors stated so far are summarized in Table 1, where Statistics is compared to the rest of mathematical subjects offered by UEM in 2013/2014.

Table 1. Suitability of choosing statistics among the other mathematical subjects available in engineering degrees at UEM during the 2013/2014 course.

	Reasons	Calculus I & II	Mathematical Analysis	Statistics
Flipped Learning Methodology	Modular knowledge	Yes	Yes	Yes
	Practical orientation	Yes	Yes	Yes
	Supports collaboration	No	No	Yes
Boundary	There are enough groups for control group	Yes	No	Yes
	It cuts across all engineering degrees	Yes	No	Yes

13. The groups involved

There were three groups involved in the Flipped Learning experiment developed during the 2013/2014 course in the Polytechnic School of Universidad Europea de Madrid. Two of them belonged to the Degree in Mechanical Engineering (Grado en Ingeniería Mecánica), whilst the third belonged to Computer Engineering (Grado en Ingeniería Informática). Combined, they added up to a total of 85 students.

Since one of the goals of the experiment was to determine the influence of the methodology in teaching statistics, one of the groups was taught using traditional lecturing during both halves of the subjects. That way this group could serve as a Control Group. This group would be the reference frame to see what would have happened in a scenario where the implementation had not taken place but every evaluable exercise had remained the same.

To simplify things, the following table summarizes the groups and their main characteristics. It also raises simplified names for future reference: A and C for the Experimental Groups and B for the Control Group.

Table 2. Outline of the group structure.

GROUP	A	B	C
Trimester	2	2	3
Type of class	Flipped Classroom	Control Group	Flipped Classroom
Degree	Degree in Computer Engineering	Mechanical Engineering	Mechanical Engineering
Number of students enrolled	28	22	35
Total number of weeks of class	12	12	10 (due to a late easter in 2014)

3 The content for the Flipped Classroom sessions

As previously mentioned, Flipped Learning philosophy does not specify where to source the contents the student uses to prepare the practical sessions. Is at the discretion (and technical means) of the teacher to give his students resources created *ex professo* for the subject by himself or a collaborator, resources created by a third that he finds adequate for the needs of the upcoming practical session or he decides to let the students research on their own in order to find the content that best meets their needs.

This latter scenario is dangerous (academically), since their (initial) ignorance of the subject may lead to difficulty locating quality content tailored to the practical applications that are going to be proposed in the classroom later on. Because of this, the models that are generally adopted are the first two.

For this experiment the first method was chosen, so the content would be created expressly for the course by their teacher. Youtube.com used as the hosting platform for the videos that would be the bulk of the content.

14. AULA UE

In 2012, the Science Department of the UEM prompted the creation of a youtube channel where department teachers could upload brief academic tutorials on topics covered in their subjects. The channel was named Aula UEM. The videos for Aula UEM were generated from desktop captures of the digital whiteboards installed on the Villaviciosa campus of the institution with a voiceover explanation. The format for the channel was given by the Marketing Department, but the teachers kept complete control over the topics covered and content. After barely a year online the canal was closed in favour of a new one, created in April 2013 called Aula UE. This new channel inherited the contents of Aula UEM and began receiving new content, with a better technical finish due to the greater experience of the team of teachers creating the videos.

In the second quarter of the academic year 2013/2014, Aula UE had already proven to be the perfect platform for hosting the videos that were to be used during the Flipped Classroom experiment that was about to take place. The links to the URL of the video could easily be inserted into the subject's virtual campus. In addition, students with a Google account could subscribe to the Aula UE's feed to receive notification when new material became available through the built-in Google announcement system. Because the channel administrator and teacher of the course was the same person, the incidences of technical nature could be mended quickly.

15. The length of the videos

When the team of academics that provides content to the Aula UE began to produce videos one of the first concerns that arose was how to determine the ideal time length for this sort of media.

An average duration of 4 minutes, trying to never exceed 10 minutes, was the model chosen. Although the team sought for relevant research around the matter, when the channel started, there still wasn't much literature available dealing with academic videos and their structural analysis.

Beile, P. M., & Boote, D. N. (2004), Bowles-Terry, M., Hensley, M. K., & Hinchliffe, L. J. (2010), Bury, S., & Oud, J. (2005) and Silver, S.L., & Nickel, L. T. (2005) all cover good practice in the creation for video tutorials, their relevance and a set of recommendations, but none covered actual length analysis. Even so, all recommendation agreed to note that the shorter the video was, the better. Literature did include a great deal of tutorial for the creation of tutorials, so no issues arose during the recording and editing that couldn't be easily answered.

Fortunately in November 2013, Anant Agarwal, president of edX and Rob Rubin Vice President of Engineering at edX invited Philip Guo to investigate the behaviors of users on the edX platform. Particularly, his studies centered around the length of the videos. Following this study, Guo (2013), published his findings. After a thorough analysis of the habits of MOOC users on the edX platform he recommended educational videos to be 6 minutes long or less.

This meant that most of the videos Aula UE fell within the recommendations of Guo and thus the team of content producers decided to continue with the initial model.

Long-term retention test

The effect of the implementation of this methodology on long-term learning was one of the main concerns of the study.

Knowing how much time was necessary until it was considered that the retention of knowledge was considered "long-term" was taken into serious account when designing the experiment. Thalheimer, W. (2010), in his article "How much do people forget?" studies a set of fourteen articles covering the subject from the nineteenth century to the present. From these articles it is understood that although memory varies greatly from one subject to another, an academic text that is not practiced often is forgotten in an important percentage within days and almost completely within a few weeks.

The long-term test in the case of this experiment was set at 45 days, a month and a half after completing the course. Given Thalheimer's collection, by that time memories can be considered long-term.

Setting the sample size

To establish what was the minimum number of students required to consider the sample representative and thus validate the experiment a statistical inferential system was used. Population data was extrapolated from the sample within a predetermined safety threshold is usually set at 95%.

Using a normal confidence interval, and according to the results of the experiment carried out in Clintondale in 2011, the expected improvement in student outcomes should be around 30%.

Thus the minimum sample with a confidence of 95% and an expected improvement of around 30% (admitting a variation bracket of around a 10%, so the values can go from 20% to 40% without falling into error) is set to 81 data. As the sample presented a study covered 85 cases, it is considered statistically representative of second year engineering students population in the context of Flipped Learning.

4 Survey analysis

16. Survey description

As it has been mentioned before, two surveys were done in all three groups in order to collect qualitative data over the student's perception of their learning, the content and the way the subject was being taught. The first survey was identical for all three groups and the second one had specific areas for groups A and C (which will be discussed in the following subsection).

The format of the survey followed a typical five-level Likert, where each item is valued by a student from 1 to 5. The assigned values would correspond to:

- 1 is "Strongly disagree"
- 2 is "Disagree"

- 3 is "Neutral, neither agree nor disagree"
- 4 is "Agree"
- 5 is "Strongly agree"

17. The survey items

The following table describes the eight items that were covered by the surveys. Items 1 to 6 were common to all three groups (A, B and C) and appeared in both first and second surveys, whilst items 7 and 8 are exclusive to the second survey of groups A and C (since they cover specifics of the Flipped Classroom methodology).

Table 3. Description of survey items

Item ID	**Description**	**Contraction**
Item 1	Overall satisfaction on how contents are taught	Satisfaction
Item 2	Content quality	Quality
Item 3	Time devoted to the subject (higher grade implies less time)	Time
Item 4	Efficency of time devoted to the subject	Time Efficiency
Item 5	Perception of knowledge Persistence	Knowledge Persistence
Item 6	Perception of body of knowledge acquired	Knowledge
Item 7	Influence of the change of methodology in personal performance	Better performance
Item 8	Influence of the change of methodology in personal knowledge Persistence	Better Persistence

18. Number of registered answer

Table 4. Registered survey answers and ratio of answers vs. enrollment

Group	**Survey ID**	**Enrolled Students**	**Surveyed**	**Ratio**	**When?**
A	Second survey	28	23	82%	**After Flipped Classroom**
	First Survey	28	19	68%	After standard Lecturing
B	Second survey	22	19	86%	After standard Lecturing
	First Survey	22	18	82%	After standard Lecturing
C	Second survey	35	27	77%	**After Flipped Classroom**

First Survey	35	22	63%	After standard Lecturing

19. Analysis

Students seem to be generally happy, regardless of the methodology used in during lessons, this helps to prove that there was no bias towards the Flipped Learning methodology during the experiment.

To analyze and understand the 1 to 5 answers of the survey have been grouped into three categories: 1 and 2 will be categorized as unfavorable, 3 as neutral and 4 and 5 will be considered favorable.

Students in this experiment are receiving the same teaching methods and contents, since the videos have been produced by the same instructor teaching in class with the same class distribution. In this case, the only difference for the student is the environment in which the material is received, either in class with the entire group or outside with their own schedule. This explains why the results for overall quality and content are very similar before and after using the methodology. However, there are significant differences in how students judge both methods in terms of performance and awareness of what they learnt and the efficiency of the hours invested in the subject.

Overall satisfaction of those unfavorable to the subject is lower by 5% in the second part of the subject regardless of the teaching method, traditional lecturing or Flipped Learning.

In the control group (B) comparing the first and second halves of the subject, there was a small portion of the population that swiveled from favorable to neutral.

Table 5. Summary of group B surveys.

		Second survey for B (after A+C FL)			**First survey for B (before A+C FL)**		
		Unfavorable	Neutral	Favorable	Unfavorable	Neutral	Favorable
Satisfaction	Item 1	11%	11%	79%	6%	11%	83%
Quality	Item 2	0%	21%	79%	6%	11%	83%
Time	Item 3	5%	16%	79%	6%	11%	83%
Time Eff.	Item 4	5%	21%	74%	6%	11%	83%
Know. Pers.	Item 5	16%	26%	58%	6%	28%	67%
Knowledge	Item 6	16%	32%	53%	17%	22%	61%

In groups A and C, where Flipped Classroom methodology was applied, there was a clear positive shift. About half of the unfavorable opinions on the time devoted to the subject, time efficiency and knowledge persistence, changed to neutral. All of the students with unfavorable perception of the knowledge acquired through traditional methods improved their opinion when they were taught using Flipped Classroom.

In general, student opinion favored Flipped Classroom in every one of the aspects covered by the survey. Favorable opinions grow an average 19% in all items, with the exception of content quality where opinions turned towards neutral from an originally favorable position, and the aforementioned overall satisfaction where favorable opinions remained constant.

Specifics of the Flipped Classroom methodology were covered by the second survey in groups A and C. Here, an average 84% of students felt the methodology enhanced their performance and knowledge persistence. An average 12% considered no change regarding these items, and the remaining 4% displayed a negative opinion on the effect of Flipped Classroom in these areas.

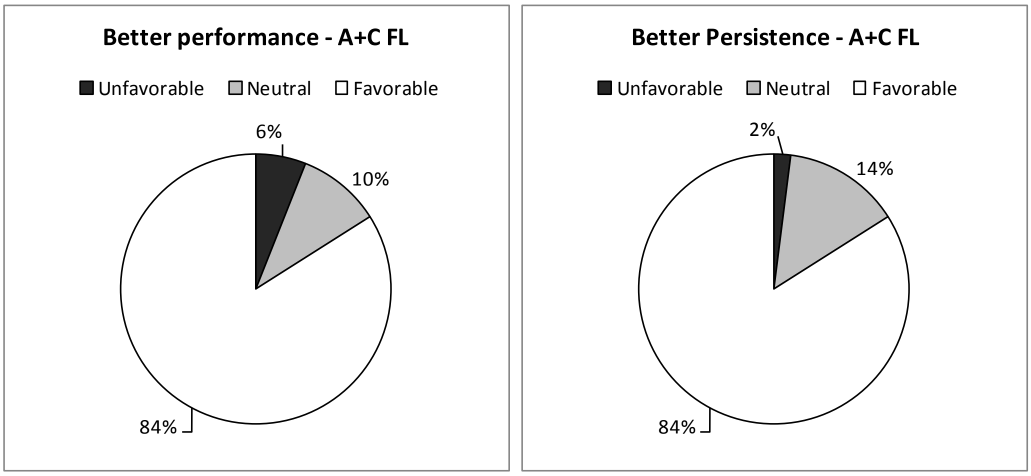

Figure 1. Comparative pie charts describing items 7 & 8 for the mixed set of students of both groups A and C.

5 Statistical analysis of the results

A number of descriptive analyses and a some simple comparative tests were run on the data from the various sources of the experiment once the experiment had concluded (including the month and a half for the long term knowledge persistence).

An ANOVA test was performed in order to decide if both experimental groups A and C were differentiated or not, ie, if the fact that they had been using Flipped Learning was enough to consider them a common population or if their internal differences were strong enough to prevent treating them in such way. The data compared using the test was the ratio obtained from the comparison between the results of the midterm test and the final assessment test. As shown in the table below, groups A and C turned out to belong to the same population. It is also seen that they belong to a different population from the Control Group B.

Table 6. ANOVA performed with class test results to determine if A and C (Flipped Learning applied) can be grouped and clearly differentiated from group B.

Group A versus Group C

Origin of variations	Sum of squares	Deg. of freedom	Average of squares	F	Prob.	Crit. value for F
Between groups	1,0464	1	1,0464	23,114	6,772E-05	4,2597
Inside each group	1,0865	24	0,0453			

Groups A and C versus group B

Origin of variations	Sum of squares	Deg. of freedom	Average of squares	F	Prob.	Crit. value for F
Between groups	0,1688	1	0,1688	2,1314	0,1540573	4,1491

Inside each group	2,5350	32	0,0792

A t test was then performed to determine if the variation in students' grades in groups A and C was consistent and not a .To determine whether the bettering of grades noted in both experimental groups, A and C, was consistent. The test proved that for a 95%, confidence interval the improving of grades in both experimental groups was consistent.

Descriptive analyses were run on all grades and surveys to understand the underlying common ground that the methodology had set in each of the groups.

This descriptive analysis, although broad, allows the following assumptions to be made for both the experimental groups involved:

- Grades of groups A and C turned out a 20% better than those of B.
- A greater long-term knowledge persistence, around an average 6%, was recorded in groups A and C compared with group B.

Conclusions and recommendations

The factors outlined in the previous sections indicate that the implementation of a Flipped Learning methodology in higher education can be an important factor for the potential improvement of quality both objectively and as perceived by the student body.

The decision of implementing a Flipped Classroom methodology in the context of a university subject must be taken with care. The implementation must be both planned and systematic.

These are the recommendations that arise from the lessons learned during implementation conducted for this study:

1. On a first-time implementation of the methodology it is strongly recommended not to do so in the entirety of the subject, this way, both students and teacher will better understand the nuances between Flipped Learning and traditional lecture system.
2. It is recommended that teachers create specifically tailored media contents for each session of the subject. Similarly, those problems or exercises that are going to be collaboratively solved in class must be created specifically for each session. Planning is everything in an implementation of this kind.
3. Paradoxically, the greatest resistance that teachers will probably encounter during a change in methodology towards an active one, as is Flipped Learning, will come from the best students in the class instead of the more disadvantaged ones. The authors believe that this is due to the fact that the most advantaged students are so within the traditional system. A change in methodology sets a common starting point for all where they are no longer inside their comfort zone. It might be recommendable to pose greater challenges to these students during the practical class sessions so they don’t feel they have lost control over their own educational development.

6. Future lines of Research

Flipped Learning is a rapidly growing field of research in higher education. Many experiments are still necessary to speak of the methodology in this context with the necessary rigor.

From the research group that has authored this paper, these are the two suggested lines of future research:

1. In order to understand and compare research in this field, adequate indicators (detecting which factors influence this learning methodology the most) must be created and standardized so different research groups can all speak upon equal terms.

2. The publishing of detailed experiments on the subject so they can be replicated and the results compared and measured in different learning environments. This way factors such as environment, the subject, the field of study could be isolated and studied to maximize the efficiency of the methodology.

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Evaluating rubrics for facilitating students' learning

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Abstract

Students generally think they do not get enough feedback. This article reports on research done to evaluate how students think about and use rubrics; both when they solve assignments and receive feedback on them. Three different varieties (including an empty rubric) of rubrics are researched. Not surprisingly, students prefer the type that gives them most feedback. However, feedback that seems personal are even more valued. Giving students' feedback by indicating the quality of their solution on a detailed rubric is not valued as much as individual feedback that is shorter. When solving a problem, the students use the rubric when they start to give an outline and when they hand-in as a checklist; but they do not use differences in the weighting of criteria or detailed information on the level of the criteria.

1 Introduction

Active learning has been on the agenda for many years (see, e.g. (Cross, 1987)). In the 1980s, several reports were made in the US with the hope that universities could create teaching that actively engaged students in their process of learning (Study Group on the Conditions of Excellence in American Higher Education, 1984). As they write in the report from 1984:

> *Much is known about the conditions under which student learning and growth can be maximized… We contend that the quality of undergraduate education could be significantly improved if America's colleges and universities would apply existing knowledge about three critical conditions of excellence - (1= student involvement, (2) high expectations, and (3) assessment and feedback (p. 17)*

Various studies have shown that feedback is very important for the student when (s) he is learning (see, e.g. (Higgins, Hartley, & Skelton, 2002; Huba & Freed, 2000)). Willis and Webb (2010) define feedback as follows: "*Feedback is a term commonly used to describe the range of processes in higher education whereby a student or group of students receives information about how well they understand concepts and are progressing with their studies*." (p. 1). In student evaluations at our university, feedback is the component that scores lowest; students do not think they get enough feedback and they need the feedback to progress through their studies. The low score on the amount and quality of feedback is also seen in other evaluations (e.g. (The National Student Survey, 2015))

The Feedback and Assessment Benchmarking Tool (National Union of Students, 2014) developed by NUS (National Union of Students) describe ten principles of effective feedback and assessment. Some of these include *assessment criteria* (the criteria should be clear, easy access by students and linked to learning outcomes), *submission process* (submission should be easily and electronically if possible) and *feedback timeliness* (the students should be able to act upon the feedback).

Solving a real case, where the students should find their own way and ask the right questions, they need feedback more than if a "normal" assignment where given. In a case, they need to know if they have found a reasonable way to the solution. In a "normal" assignment where a model for solving has been presented, the students might be satisfied with a teacher-made solution and then be able to self-assess their assignment.

This article focuses on rubrics - both to be used when the students are solving large exercises related to assessment and when they receive feedback on these. But what kind of rubric do the students find most useful? To start answering this question, we have created three different ones and investigated which students found most useful.

The rubric is seen both when the students actively solve assignments and when the students receive feedback on these using a learning management system. The general course design is described as well as the role of the assignments. The main focus of the article is an evaluation and comparison of the different feedback methods given by the different rubrics.

2 The different rubrics and their usage

This research is done in a real-world setting at an engineering institution (see section 4 for more detail). The students have to hand in four assignments (cases) as a part of the learning process (case A - case D). The cases are mandatory and 20% of the course grade is based on the cases. Because of the importance of feedback in the students' learning process it is essential clearly to specify the evaluation criteria and to give the feedback according to these. Hence, we are dealing with two perspectives; the criteria and the feedback.

Criteria and rubrics

Using rubrics gives advantages for both the students and the teacher. As described by the Eberly Centre (Teaching Excellence & Educational Innovation) at Carnegie Mellon University:

Grading according to an explicit and descriptive set of criteria that is designed to reflect the weighted importance of the objectives of the assignment helps ensure that the instructor's grading standards don't change over time. .... Furthermore, rubrics can reduce the time spent grading by reducing uncertainty and by allowing instructors to refer to the rubric description associated with a score rather than having to write long comments. (Carnegie Mellon University, 2015)

A rubric is a set of criteria and for each criterion a description of different levels of achievement of it. A rubric is typically designed as shown in **Error! Reference source not found.**.

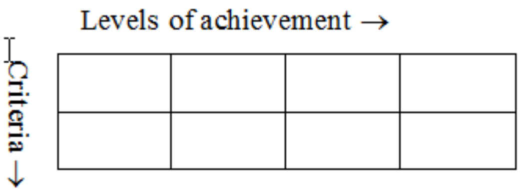
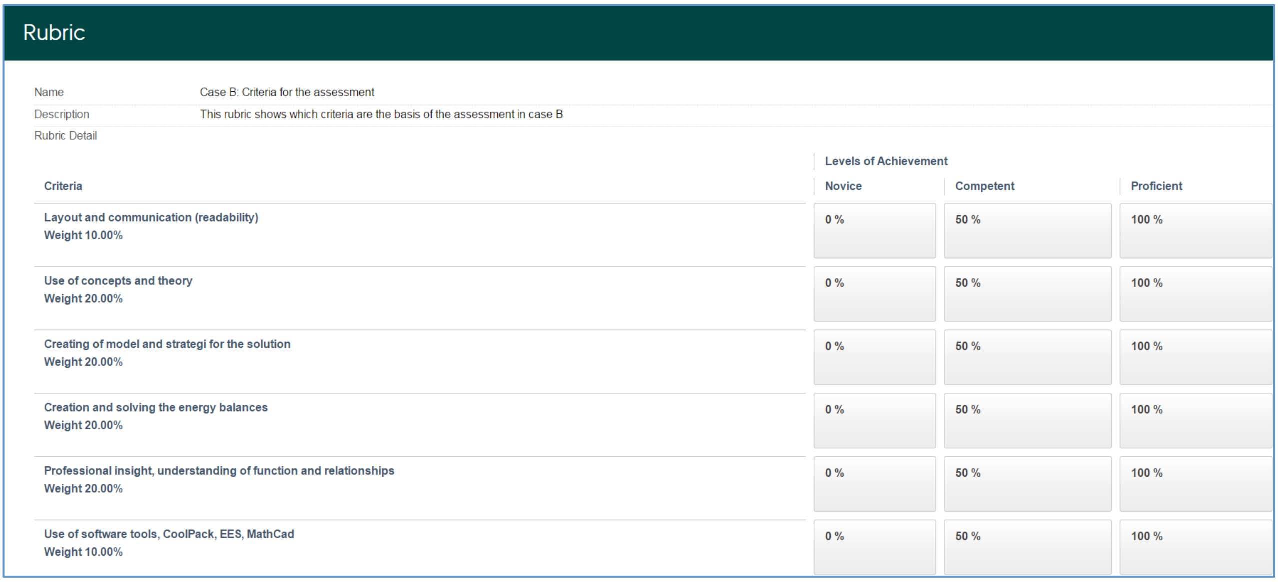


Figure 8 Structure of a rubric

The students were using the rubrics both when solving the case and when reading the feedback. As one student said: *"We read the criteria before, to see what the teacher expected, I mean the things we could not read from the assignment text... afterwards, we mostly used the feedback and not that much the grading given".*

It makes it clear to the students where and how it is possible to improve and it specifies clearly what are the requirements and acceptable performance standards of the cases: *When rubrics are given to students with the assignment description, they can help students monitor and assess their progress as* *they work toward clearly indicated goals. When assignments are scored and returned with the rubric, students can more easily recognize the strengths and weaknesses of their work and direct their efforts accordingly.* (Carnegie Mellon University, 2015).

In Figure 9 and Figure 10, the two concrete rubrics are shown (translated from Danish by the authors). The rubric for the case D looks the same as the rubric for the case C. In the first case no rubric was used. This is the normal situation at our university and served as a way to compare the use of explicit rubrics to an assignment without rubric.

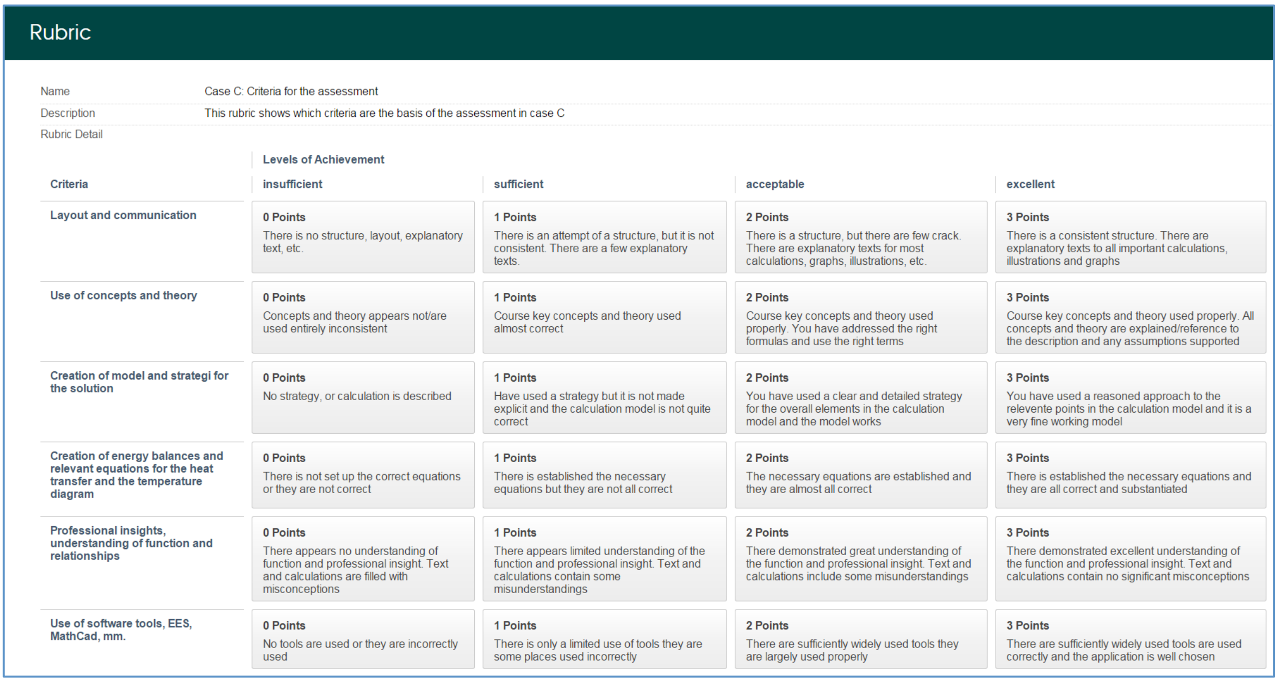


Rubric

Name: Case B: Criteria for the assessment
Description: This rubric shows which criteria are the basis of the assessment in case B
Rubric Detail

	Levels of Achievement		
Criteria	**Novice**	**Competent**	**Proficient**
Layout and communication (readability) **Weight 10.00%**	0 %	50 %	100 %
Use of concepts and theory **Weight 20.00%**	0 %	50 %	100 %
Creating of model and strategi for the solution **Weight 20.00%**	0 %	50 %	100 %
Creation and solving the energy balances **Weight 20.00%**	0 %	50 %	100 %
Professional insight, understanding of function and relationships **Weight 20.00%**	0 %	50 %	100 %
Use of software tools, CoolPack, EES, MathCad **Weight 10.00%**	0 %	50 %	100 %

Figure 9 Rubric for the case B



Rubric

Name: Case C: Criteria for the assessment
Description: This rubric shows which criteria are the basis of the assessment in case C
Rubric Detail

	Levels of Achievement			
Criteria	**insufficient**	**sufficient**	**acceptable**	**excellent**
Layout and communication	**0 Points** There is no structure, layout, explanatory text, etc.	**1 Points** There is an attempt of a structure, but it is not consistent. There are a few explanatory texts.	**2 Points** There is a structure, but there are few crack. There are explanatory texts for most calculations, graphs, illustrations, etc.	**3 Points** There is a consistent structure. There are explanatory texts to all important calculations, illustrations and graphs
Use of concepts and theory	**0 Points** Concepts and theory appears not/are used entirely inconsistent	**1 Points** Course key concepts and theory used almost correct	**2 Points** Course key concepts and theory used properly. You have addressed the right formulas and use the right terms	**3 Points** Course key concepts and theory used properly. All concepts and theory are explained/reference to the description and any assumptions supported
Creation of model and strategi for the solution	**0 Points** No strategy, or calculation is described	**1 Points** Have used a strategy but it is not made explicit and the calculation model is not quite correct	**2 Points** You have used a clear and detailed strategy for the overall elements in the calculation model and the model works	**3 Points** You have used a reasoned approach to the relevente points in the calculation model and it is a very fine working model
Creation of energy balances and relevant equations for the heat transfer and the temperature diagram	**0 Points** There is not set up the correct equations or they are not correct	**1 Points** There is established the necessary equations but they are not all correct	**2 Points** The necessary equations are established and they are almost all correct	**3 Points** There is established the necessary equations and they are all correct and substantiated
Professional insights, understanding of function and relationships	**0 Points** There appears no understanding of function and professional insight. Text and calculations are filled with misconceptions	**1 Points** There appears limited understanding of the function and professional insight. Text and calculations contain some misunderstandings	**2 Points** There demonstrated great understanding of the function and professional insight. Text and calculations include some misunderstandings	**3 Points** There demonstrated excellent understanding of the function and professional insight. Text and calculations contain no significant misconceptions
Use of software tools, EES, MathCad, mm.	**0 Points** No tools are used or they are incorrectly used	**1 Points** There is only a limited use of tools they are some places used incorrectly	**2 Points** There are sufficiently widely used tools they are largely used properly	**3 Points** There are sufficiently widely used tools are used correctly and the application is well chosen

Figure 10 Rubric for the case C

In the rubric for case B (Figure 9) only the different criteria, are described and three different levels of achievement are given but with no explicit description on what to do to e.g. be proficient. However, there is a different weighting between the different criteria to indicate that something is more important than other. The levels of achievements were based on the standard from Blackboard (Novice, Competent, and Proficient).

The rubric for case C and D were more elaborated in order to evaluate the effect of that. There were four levels of achievement based on the official grading scheme. Each of the levels of achievement were described (still with room for the students to interpret). The difference in weight between the criteria were removed and the grading were more coarse-grained (0-18 points instead of 0-100%).

Feedback

Feedback is important for the students' learning (see, e.g. (Higgins et al., 2002; Huba & Freed, 2000)). Therefore, it is important to find a form of feedback that is useful to the students. It should be:

- Accessible and easy to find
- Understandable and precise
- Clearly related to the criteria
- On time
- Etc.

Race (2004) describes and discusses many different forms of feedback: oral<>written, individual<>group, hand written<>electronically.

In the course written, individual and electronic feedback was given using Blackboard Learn. The decision was based upon:

- Written; because it makes it easy for students to save the feedback and use it for solving the next case and also to use it in other contexts,
- Individual; because it was important for the teacher to give precise feedback on the pros and cons of the individual assignment. General feedbacks to all students do not have these advantages.
- Electronically; it was obvious, because of the Blackboard Learn platform was where the communication took place

3 Context

The course used for this research is a fourth semester course on Thermodynamics at Mechanical Engineering at Aarhus University, School of Engineering. It is a mandatory course for mechanical engineering students (they need to take four mandatory courses during their fourth semester as well as a semester project).

As a part of the course, the students shall complete four cases. The cases are graded by the teacher. The cases are an important part of the learning process in the course; it is where the students have to do calculations on realistic problems and here they are forced to read the learning material more in depth. In the evaluation of the course, almost all students state that this is where they learn most - and also state it is hard work. Due to the importance of these cases, a lot of effort is made to give the students proper feedback.

The four cases in the course are somewhat different in form and content. It is debatable whether they in their form actually meet the definition of a case.

Lau *(2007)* write:*”in Case Based Learning (CBL) the problem space is defined by the case. Typically, the presentation of the problem comes first in the CBL instructional sequence, which is a reversal of* *the traditional use of problems in science teaching. The introduction of a case(Race, 2004) problem early in the instructional sequence encourages learners to use the case to generate a set of questions that they then try to answer. This makes them more motivated in subsequent lectures, labs, and discussion because they have a problem of their own to work on. In short, students are asked to learn new materials, mainly by themselves, and also to pose intelligent questions, develop accountable approaches to investigate these questions, and present their methodology and conclusions to the class". (2nd paragraph)*

A case has to be a real problem which is presented with a realistic (or real) story. With this story as a base, a question (or a series of) are formed for the students to answer. These questions should help the student create a number of hypotheses and questions to validate the hypothesis, thereby fostering new knowledge.

The first case in the course is in that sense not a real case. It is more a design assignment (the students have to make a poster) with some disciplinary questions connected to it. The poster should describe an energy system by function and energy balance.

The last three cases are formulated as cases, that is, they have real stories as a basis. But in the text very specific questions are formulated, that in some way guides the student through the problem-solving. The student does not really have to generate their own hypothesis and questions. The cases are chosen from the course content to cover different topics.

The feedback has until now been given by commenting the paper version of the assignment. Now Blackboard Learn (Blackboard, 2015) was introduced; the feedback was therefore given using this platform. Is has been given in different ways in each of the four cases. In this paper, we describe, elaborate and evaluate the different feedback methods. Because the platform was new to the students some of them had some problems to find the rubrics, the assignment and where to upload the solution. As one of the students said in the interview: "*It should be clearer to us that we can find rubrics, where to find it and how it works…"*

4 Research design

The research is done in a real setting - a real engineering course with real students. An alternative to this could have been asking students for their view on different rubrics. Our rationale for choosing a real course is that it gives a much more realistic view on pros and cons of different designs; we expect that when the students actually have tried to use the rubric both when solving cases and receiving feedback they will have a much more conscious view on the rubrics. One downside of this design is that students might have difficulty in just focusing on the rubrics - they are seen as a part of the learning design. Another downside is that the rubrics are presented and used within a system - it could be the system and not the rubrics that became the focus point. We find that the research design is good, but one needs to take the concerns into account when analyzing the results.

> ***The research question in focus here is "How do students experience rubrics in their case work - both when answering cases and when receiving feedback on them? And do they have preferences for a special kind?"***

In order to evaluate the effect of the different rubrics, we decided to use a mix method approach: A questionnaire was sent out to all students in the class and in-depth interviews with six students. The researcher (first author) was performing the interviews; he was not involved in teaching this course or other courses that students have had or will participate in. The students participating in the interviews were chosen by random (out of a total population of 48 students for the course). They were not given any credit for participating in the interview nor the questionnaire.

1. *Research method*

In the last two or three decades an increasing number of researchers have argued that it is better to combine quantitative and qualitative philosophies than to use only one of them, in order to better answer the complex research questions in, e.g., educational research (see e.g. (Angen, 2000; Howe, 1988; Johnson & Onwuegbuzie, 2004; Onwuegbuzie & Leech, 2005)). As Johnson and Onwuegbuzie (2004) notice:

> *We hope the field will move beyond quantitative versus qualitative research arguments because, as recognized by mixed methods research, both quantitative and qualitative research are important and useful (p. 14)*

2. *Questionnaire*

The questionnaire was given to the students electronically through their learning management system. They were informed that their answers would be used in this article and by no means influence their marks in the course. The questionnaire was divided into two major parts: 1) using the rubric when solving the case, 2) using the rubric for feedback from the teacher.

The questionnaire had 21 questions in total. Most of the questions were on a five-point Likert scale followed by a free text field asking the student why (s)he answered the way (s)he did. The students were asked to answer the questionnaire in their own time just before finishing the course. A reminder was sent out after two weeks.

3. *Interviews*

Prior to the interviews, we prepared an interview guide consisting of of keywords as a framework for the interviews. The guide worked well, and the structure was almost followed.

We began the interview with a brief introduction to the purpose of the interview. As a starting point, we asked about the age and prior knowledge about the field as well as if the cases were done alone or in collaboration with a fellow student. After that we got into the different questions about rubrics:

- Usage of rubrics when solving the cases
- Usage of rubrics for feedback from the lecturer
- The learning management system
- The structure of the course (including the cases)
- General comments

The interviews were recorded on audio files.

5.3.1 Participants

48 students participated in the course. Out of these were four females. The interviewed students were all male. Six students were interviewed. Most of the interviews were done in the weeks after the examination. Initially, 10 students were asked if they would participate, we had some challenges getting the students to accept the request and it ended up with 6 students, randomly chosen from the participants. The students were from 21 to 36 in age, all of them in their second year of their bachelor study.

4. Analysis of the data

The qualitative data were analyzed by both of the authors. The authors listened to the interviews and noted relevant views on the general topics as well as read the answers to the free-text questions.

There has been no transcription of the interviews in their entirety, but a condensed view of relevance to our perspective in the study. Specifically, we use keywords from the interview guide to first organize and then condense the six interviews. By selecting this method, we are aware of some errors that may affect the conclusions. First of all, because we do not get the precise readings and secondly when we translate to English some meaning might get lost. We considered this acceptable as what we want to retrieve from the interviews are general views and status more than it is facts. Furthermore, we are using a mix method approach; when we need "hard data", we can conclude from the questionnaire.

5 Findings

As described before, we evaluate the use of the rubrics in two situations: when the students are solving their case and when the students receive feedback. This section will describe our findings in these two areas

5. Solving the case

5.5.1 Rubrics in general

The first interesting question is whether the students used the rubric at all when solving the case. From the interviews we know that it is rare in the courses that students have taken so far to have very precisely described requirements for assignments. As can be seen from Figure 11, almost half of the students looked at the criteria when solving the case. This could be seen as a large number; when interviewed about the usage of the rubric for solving the case, some of the students said that they were not aware of the rubric in the beginning. Other said that they expected the case to be like the written exam in the end (which it is not) and consequently they would like to use it in an exam setting without rubrics to help.

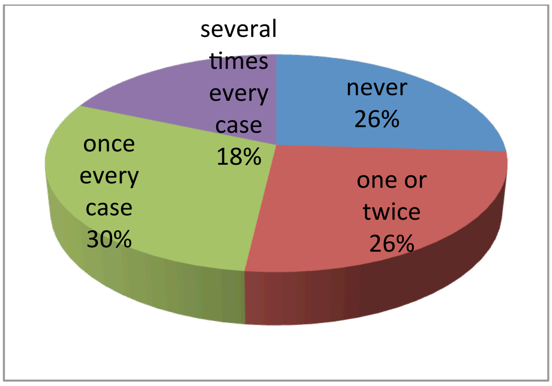


Figure 11 Did you look at the criteria when solving the case?

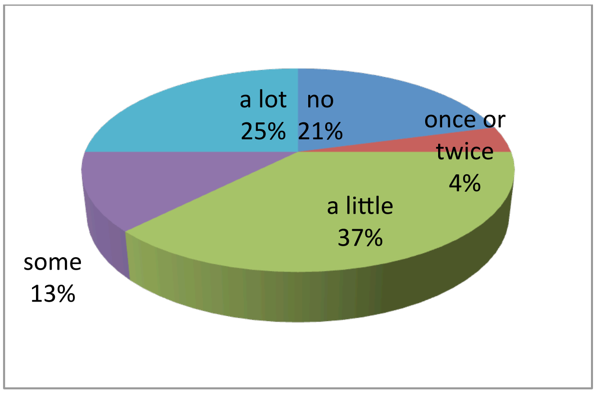


Figure 12 Dsolveriteria help you to solve the case (74% of the students who have looked at the rubric)?

Almost 80% of the students who used the criteria found them helpful when solving the case as can be seen in Figure 12. Some used the rubrics to find out what the case should contain others used the criteria afterwards to ensure that their solution covered all requirements. As one student said:

I used them with reference to the solution of the case. At the end of the process I went through the table to see if I had got it all - if not, I made additions.

From Figure 13 it can be seen that more than 2/3 of the students used the rubrics as a checklist when the handed in the solution. As one student said:

Yes, after I had finished the case I checked the criteria to ensure that I have remembered all e.g. to note that I had used different programs

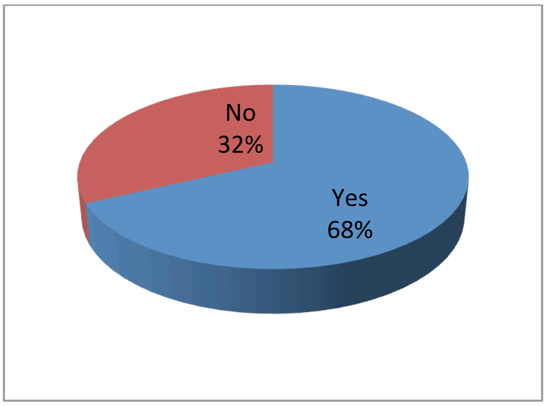


Figure 13 When you have finished solving the case, did you use the criteria to ensure that your solution fulfilled the criteria?

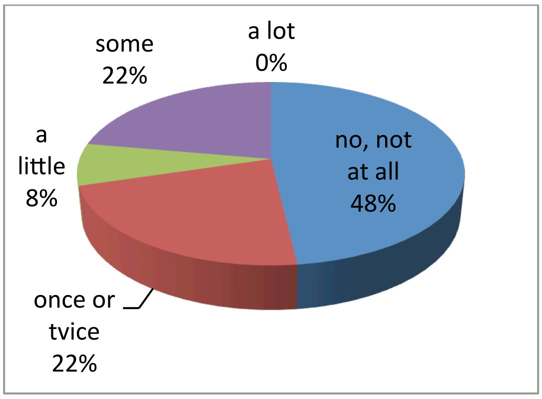


Figure 14 Did you or your group discuss the criteria with the teacher?

Another important quality of the criteria is understandability. From the questionnaire and interviews, we conclude that most of the students found the criteria understandable and precise. In a few cases, a student asked the teacher about the precise meaning of a criterion (see Figure 14)

When students discuss and debate technical topics, their understanding of these topics normally increases. The criteria could have been a source of debate when solving the case - did the students understand the same thing by the criteria? However, none of the rubrics fostered much discussion among the students (see Figure 15).

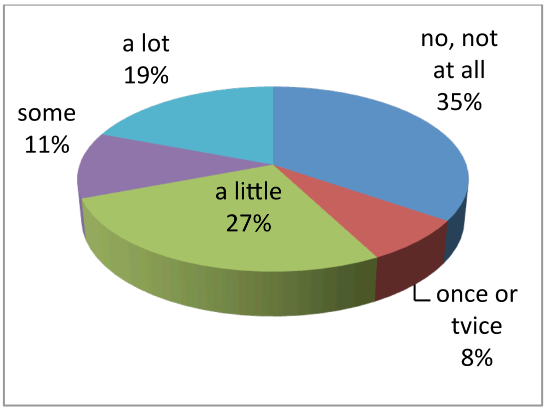


Figure 15 Did you discuss the criteria with your peer/study group?

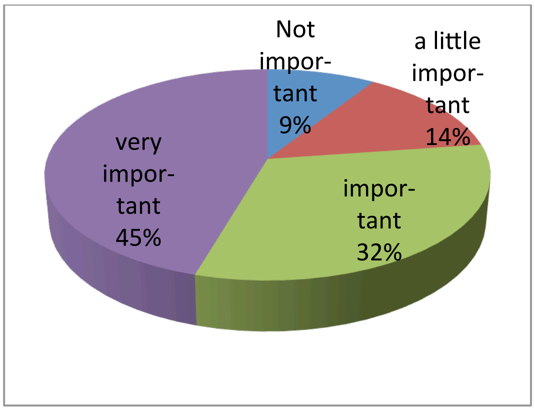


Figure 16 When you solve an exercise, how important is it for you that the criteria are precisely described?

This is the first time students have been exposed to rubrics in this precise form. Students in general find it important that the expectations are precisely described (Figure 16) and they find that the rubric is a handy way to express the expectations. When interviewed about how they normally find the information, most of the students said that the types of assignments they have are typically calculations - apply the theory to a problem and calculate something. For this type of assignments, they know what they are expected to do.

5.5.2 The different rubrics

In general the students used the rubrics as a checklist when they handed in their solution. And in general the students prefer more information. When asked to rank the three different rubrics, most of the students prefer case C (see Figure 17), as one of them said:

My ranking is based on the fact that rubric C had the most detailed description

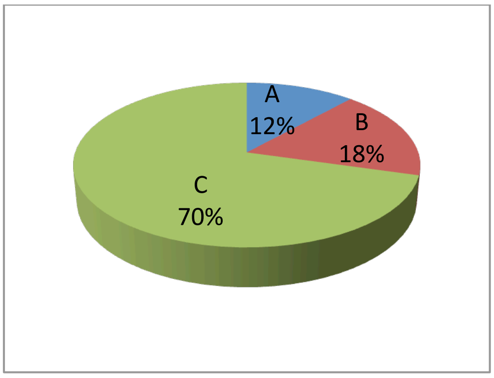


Figure 17 What rubric did you prefer for solving the case

From the interviews, however, it is clear that the students haven't had a very precise understanding of the difference - when we asked them about the different rubrics many of them found it difficult to remember what the differences were. In the questionnaire the students were presented with the different rubrics to help them remember them.

Only a few of the students noticed the difference in the importance of the criteria in case B (see Figure 9) and it had no impact on their solution.

We conclude that the students in general were very positive with the use of rubrics as a tool for making the criteria more precise, they use it as a checklist and the more information the better. It has not had a big impact on their work during the case, neither as a guide nor as a source of discussion.

6. *Feedback*

5.6.1 Rubrics in general

When the teacher gave feedback, the rubric was used to structure the feedback. But did the students read the feedback? As can see from Figure 18 all students read the feedback and 92 % read it one or several times for each case. Furthermore, the students used the feedback to improve their following cases - from Figure 19 you can see that only 7 % of the students did not use the feedback to improve.

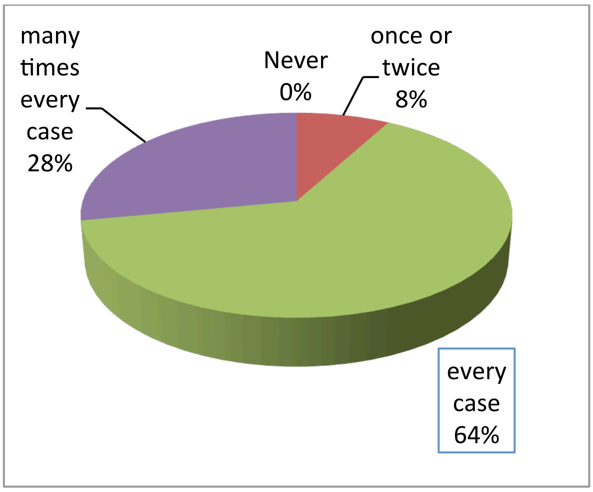


Figure 18 Did you read the feedback?

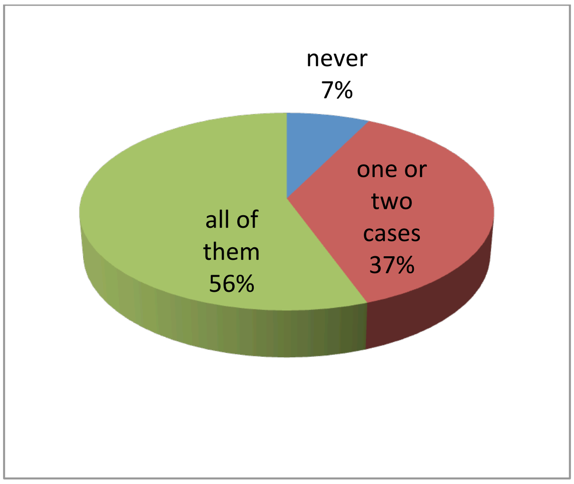


Figure 19 Did you use the feedback to improve the following solutions?

As described in section .. the rubrics were used directly for feedback. The teacher found this to be a good way to give the feedback. The students found this to be the case as well; in Figure 19 the students indicate that they receive much more feedback in this course than others and from you can see that more than ¾ of the students found the quality better.

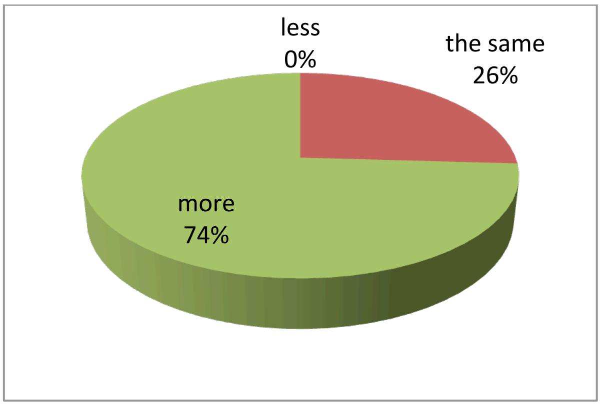


Figure 20 In relation to other courses in your study program, how did you find the amount of feedback in this course?

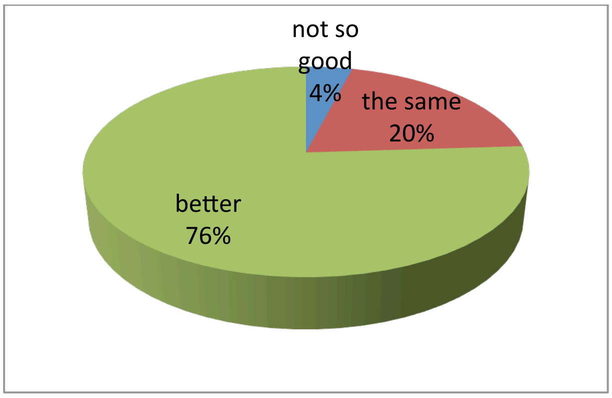


Figure 21 In relation to other courses in your study program, how did you find the quality of the feedback in this course?

5.6.2 The different rubrics

We did experiment with different weights for different crtiteria to make the students focus more on the more relevant things. From Figure 22 we can see that the students did notice the difference. From the interviews we can conclude that the students did not use it in the intended way, as described above the students used all criteria as a checklist rather as a guide for focusing on the things to spend the most time on.

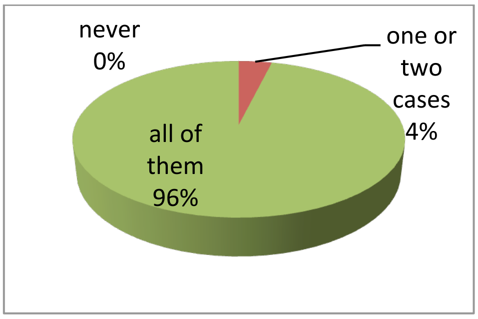


Figure 22 Did you notice the different points for the criteria?

When asked about what rubric the students liked the best seen from a feedback perspective, there is no clear pattern; the students' preference is almost uniformly distributed between the three rubrics. When asked why they found the particular rubric the best, it in all cases has to do with the amount of individual feedback. As one student says:

There were the most feedback with case B, in case C some of the criteria were not individually commented but just "dotted out". Feedback on the first case [without rubric] was also good. The schema gives a good overview and a better understanding of the total points

6 Discussion

Students favor detailed criteria. It is clear from this research that the rubric they liked the best were the last one where they had a more detailed description of each of the criteria. However, a university degree also should make the students more independent so they independently can solve a typical engineering problem. Giving the students a detailed rubric could be seen as a way to reduce the independence. Consequently, it is important to adjust the level of detail to their expected level of proficiency in the case they solve. The students in the study had not been taking courses in thermodynamics before, so detailed rubrics were seen as appropriate. Naturally, it is debatable how detailed the rubrics are and if it is obvious to the students when their solutions is on a given level. The most detailed rubric was inspired by the formulations in the general Danish marking scale and their description of the levels of proficiency. It is important to bear this in mind when; if we should make more general conclusions we need many more different rubrics and investigate e.g. if the students prefer individual feedback over feedback based on different rubrics.

Learning outcomes define the learning goals of a given course and when creating the rubrics it is important to align the criteria with the related learning outcomes. It is also important to choose the most important part of the course elements, the elements where the students are mostly challenged. When we design the cases it is very important to consider if the case must be a real case, from real problems, or it can be created from the teacher's mind to fit into what he exactly wants the students to learn. Real problems might be more motivating, but also include some elements that are not a part of the learning outcome. The formulation is equally important; do we serve the guide for the students calculation so that they do not need to go through the considerations with model to choose and what strategy to follow; or do we present the text as an open problem.

This research did not cover the teacher's perspective. The teacher indicates that the use of rubrics in this course also gave him a clearer picture of the students' challenges and strengths as well as a more structured way to give feedback to the students.

7 Conclusion

As concluded by many others: Feedback is useful and appreciated by the students. In this course the students found the amount of feedback to be higher than what they normally experience in their study. One student put it this way:

There is much feedback in this course compared to others. Normally we do not get feedback, that we do not like and normally we do not have so many mandatory assignments, which was good. I think it is easier to get the right overview with these matrices.

The students like to have a detailed description of their assignment. The two rubrics that supplied the most information were liked best by the students. Nonetheless, personal feedback was preferred even more. When the students were asked about their view on the feedback given by indicating the quality of their solution on a detailed scale, they preferred the individually written one.

When they solved the cases, the students used the rubrics as guidelines in the outset. They did not use the level of achievement, just the different criteria. Using different weights to indicate the importance of the criteria was not used. When the students handed in the case, they used the criteria to check if everything was present in their solution.

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Improving the development of engineering projects through informational competence and the introduction of social web tools

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Abstract

This paper describes the improvement plan conducted in the "Engineering Projects" course, aimed at increasing the quality of academic work in the preparation, writing and structuring of the course final documents.

The course is lectured in the last term of the degree courses at the Terrassa School of Industrial and Aeronautical Engineering of the Universitat Politècnica de Catalunya (UPC). The lecturers of this subject provide guidance and mentoring to the final degree projects, encouraging the participation and interaction of the students in an active way.

During the 2013-14 academic year, the following deficiencies were identified: lack of proper structure in the work, mistakes in bibliographic references, breach of copyright, low use of resources for the organization of information and lack of use of 2.0 tools. Therefore, a diagnostic survey was given out to identify the previous knowledge level which confirmed the existence of the above mentioned deficits.

The UPC Libraries have extensive experience in the acquisition of informational skills to improve the use, management and communication of scientific-technical information in the technical studies. Because of that a partnership with training purposes has begun in which the Library staff has participated in the lectures of the project's course. Many of these tools are Web 2.0 and social software.

The Web 2.0 concept has been introduced and its application in active learning activities for minimizing time and effort, has encouraged collaboration and communication and promoted both critical thinking and knowledge sharing.

During the academic year 2013-2014, the lecturers of the "Projects" course, along with library staff, jointly defined the goals for the improvement Plan, drew up a guide and developed teaching materials.

In the current academic year, the collaboration in the lectures is still going on. The members in charge of assessing the FDP (Final Degree Project) evaluate the progress all over the period using a rubric with criteria linked to the objectives of the collaboration.

1 Introduction

The Engineering Projects Department of Terrassa School of Industrial and Aeronautical Engineering (ETSEIAT) of the Polytechnic University of Catalonia · Barcelona Tech (UPC) offers, amongst others, the compulsory subjects related to 'Projects' to undergraduate and graduate engineering students of the school. Such courses are done during the last year of the degree. Their objective is to give the students the necessary theoretical and practical knowledge in order to address the realization of any type of engineering project. During the teaching of these subjects, the students are compelled to acquire the notions and the capacity to use the tools involved in the definition and conceptualization of the project, as well as its management, alternatives evaluation and decision making relative to feasibility, considering the environmental component, together with the technical, economic and social feasibility analysis. Likewise the topics information management, documentation and teamwork in engineering projects are covered.

In the practical lessons of these courses, the students are divided into groups so that they carry out an engineering project. Also, as a part of their duty, they must produce the basic documents that constitute the project itself: drawings, memory report, technical sheets and budget. At the end of the course, they will have to defend their project orally. Thus, the students are required to acquire the knowledge and to learn how to use the appropriate tools for its accurate preparation and elaboration.

The objectives of such subjects contribute to the student’s active attitude in class. Within the framework of reduced workgroups, students feel committed and connected towards a common project. That helps them learn autonomously and meaningfully, thus retaining what they learn longer. Participative learning is a permanent feature even in theory lessons, with a large expositive tradition. In this type of lessons, the lecturers, after a brief theory instruction, suggest an activity that is relevant to the taught contents. In that fashion, the students focus more on the lecture. Also, this technique eases the understanding of the concepts explained.

The collaborative work of these subjects becomes a realistic - as in real world - experience, as most of the students will spend a significant part of their career working as part of teams that pursue common goals. As a matter of fact, regarding the final work that each team must present at the end of the subject, the professors detected that the major flaws in the students' performance lie in the process of elaboration, composition and construction of the work.

Consequently, the Engineering Projects Department of ETSEIAT, in early 2013-2014 academic term, approached the Terrassa Campus Library (BCT) staff with this issue. UPC Libraries have a great amount of experience regarding the acquisition of informational know-how aimed at the improvement of the use, management and dissemination of scientific and technical information in polytechnic studies (Serrat-Brustenga *et al* 2011). It was agreed that BCT staff would participate in one of the theory lessons, in order to introduce resources and tools that might be useful for the project elaboration. A significant proportion of these are resources and tools from the Web 2.0 and social software - a compendium of innovative techniques developed in recent years. The title 'Web 2.0' assembles software tools that allow content creation and organization, evaluation of information produced by others and explains how to record, present and reuse it in new ways. All these applications are partly or fully Internet-based (*cloud computing*) and can prove to be useful along the elaboration, composition and defence of the project.

Because of this agreement, the Terrassa Campus Library, in collaboration with the faculty team responsible for the 'Projects' subjects at ETSEIAT, elaborated specific academic material for the students. This included a selection of resources and applications from the Web 2.0. The name Project 2.0 (Puertas-Molina *et al.* 2014) was given to this material, which is presented in infographic format (Figure 18). This type of graphical resource is very useful to bestow the information in an attractive and comprehensible manner. At the same time, it is easy to update. The objectives of such subjects contribute to an active attitude in class.

Figure 18: Infographics

Although students usually handle technological and social network applications with ease (Cabrero, 2013), one cannot always anticipate this behaviour, whether in the social or academic background. (Gallardo, E. *et al.*, 2015). Scarce use of these tools is observed, especially, during the investigation, synthesis and composition processes. The same can be said about collaborative and communication tools.

First, the student accesses to and uses these resources because of the influence of his/her classmates. Second, professors do so on their own initiative, together with the project managers and the library staff (García-Ruíz, 2014). Students must develop new abilities to use them on their own, going beyond the simple use of digital tools. To achieve this, it is critical that the professor creates a favourable environment where teacher-student interaction is encouraged, shows successful techniques and offers technological resources that adapt to the student’s needs.

After the first year of collaboration, both professor and students confirmed that all the proposed methodologies applied contributed to uplift the work. In general, the projects presentations have improved both in structure and quality, together with the citation of the consulted bibliography. The cooperation with BCT remained during the following year (2014-2015). Due to the interest in strengthening the 2.0 resources in all the elaboration process of the projects and in the knowledge itself stored within, the student body was surveyed before the collaboration. The results of this survey were used on a continuous basis to develop the courses. Also, they influenced how the 2.0 resources were introduced. The basics of ethical use of information and the academic work structure were presented, too.

2 Methodology

The Improvement Project started in the academic year 2013-2014. In total, 395 students attended the session given by library staff - 81% of the total enrolment. As indicated in the introduction, students were asked to complete a questionnaire (Questionnaire on the guidelines for preparing documents in Projects) and 112 responses (75 % participation ratio) were obtained (see **Table 3**).

Table 3: Attendee students in the Library session and students who answered the questionnaire

	Enrolled students	Attendees	Answers
First term of 2013-2014	213	153	
Second term of 2013-2014	124	112	
First term of 2014-2015	149	130	112

From the beginning, the goals for both teachers and library staff were to get students to use the resources and recommendations for developing project documents following the guidelines set by ETSEIAT for preparing the Final Degree Project (TFG) and to promote reflection and critical thought of what they were doing. These key points of a strategy of active learning (Bonwell & Eison 1991) were achieved thanks to class discussions among the participants or the members of the working group. The students had to write down their ideas in the minutes of the meetings and give and receive feedback both in-class and out-of-class.

Projects in the subjects of active learning are introduced through cooperative work, one of the key strategies used in these subjects is organizing students into groups from the first day of class students work together in order to maximize their own and each other's learning. As in the professional practice, group members have different roles: coordinator, secretary, quality department, department of mechanics, etc. The groups are made up by teachers in order to provide equal opportunities to participate and feel included, because when students "self-select", then tend to do so based on their affinities. All group members must meet, keeping a record of all their actions (calls, meetings, agenda, etc.) on the BSCW platform (García-Almiñana *et al.*, 2003) and they meet weekly in class, where the teacher can evaluate their progress or detect certain gaps.

Previous work suggests that one possible explanation for cooperative learning's success is that effective learning often occurs through an individual's interaction with his or her environment, and language is the means by which learning and meaning are made meaningful to the student (Tsay and Brady, 2010). Interaction with others enables students to make sense of what they are learning as they become responsible for articulating and discussing class content with their peers (Adams and Hamm, 1994). Having students do in - class role-plays – when skilfully designed and facilitated, is an especially effective active learning instructional strategy for (a) arousing student interest and engagement, (b)providing a realistic and relevant way for students to connect essential course content to their personal and/or professional lives, (c)teaching students to develop and apply critical thinking skills, (d) creating opportunities for knowledge transfer as well as developing deeper self-awareness and understanding, and (e) helping students develop increased empathy for others and valuing and respecting for cultural diversity.

The teacher-student out of class interaction has been conducted through the platform BSCW (Basic Support for Cooperative Work), tracking all conversations, minutes of meetings, process-related documents, etc. This communication flows parallel to that given in class, minimizes the risk of missed conversations or little participation from timid students who otherwise would not express their opinion.

Students are assessed using summative assessment. Teachers share a rubric with students where the issues the review panel will consider of their project are listed.

The rise in new digital media technologies and Web 2.0, smart classrooms equipped with online capabilities, and the use of course management tools and social media outlets, has changed cooperative learning as a pedagogical concept (Tsay and Brady, 2010). The proposed methodology for the implementation of resources 2.0 in the cooperative work of the project groups is set in this context.

In the first phase (first term of 2013-2014 course), an interview was conducted by three professors of engineering projects that teach the same subject in different degree courses. In a second phase of work, a survey was designed and resource uses 2.0 and attitudes toward new web technologies among students were documented. Knowing the needs and based on the regulation for the ETSEIAT, tutorial sessions of classroom presentation used jointly were prepared, as well. This presentation (Terrassa Campus Library, 2014) is available both from Athena, the teaching platform of the UPC, and from the space available on the Library SlideShare.

The constant referral to the responses collected in the questionnaire, during the session of the Library, led to the increasing student engagement as well as fostered critical / creative thinking.

3. Results

There is an agreement amongst professors to identify a number of obstacles in the implementation of active learning strategies. On the one hand, they can't cover as much course content in class with the available time. The fact of spending class time in the library session to introduce the 2.0 resources to be used in preparing their TFG has increased existing problems of time to achieve all the objectives set in the subject.

Another factor that has hampered the introduction of this strategy has been resistance by the student to participate and provide feedback. For the student, the role of passive listener is quite common and more comfortable than attending an exhibition class that does not form part of a less traditional activity.

The results achieved in the survey that was distributed among students are analysed. Figure 19 shows that in the organization of information for the project, most students use schemes (75 %), notes (67%) and abstracts (66%). It is noted that the use of other tools such as conceptual maps (37%) or summary tables, mostly associated with the application of 2.0 resources are still a minority.

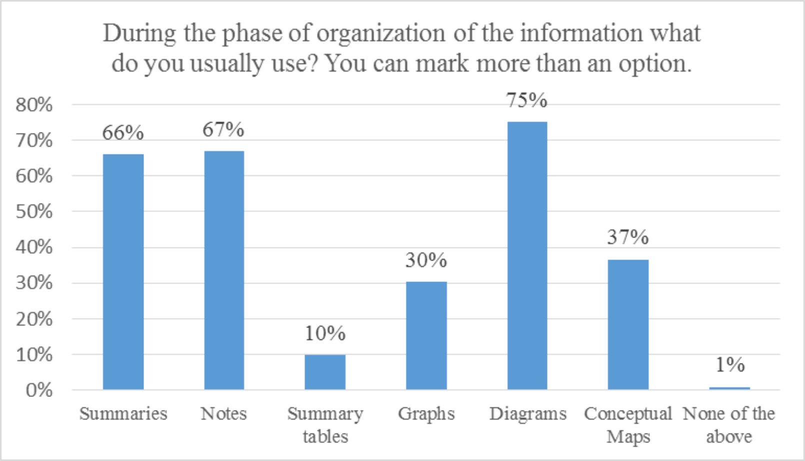

Figure 19 : Tools for organizing information

From the summary of the survey results shown in Figure 20, it appears that they are aware of the regulations related to intellectual property law, we also found that students raise serious questions about the ethical use of information when writing their work, and that 69 % still think they can use images regardless of license. These include images of others without indicating its source, phrases of others as of their own without using quotes, or paraphrasing without indicating authorship.

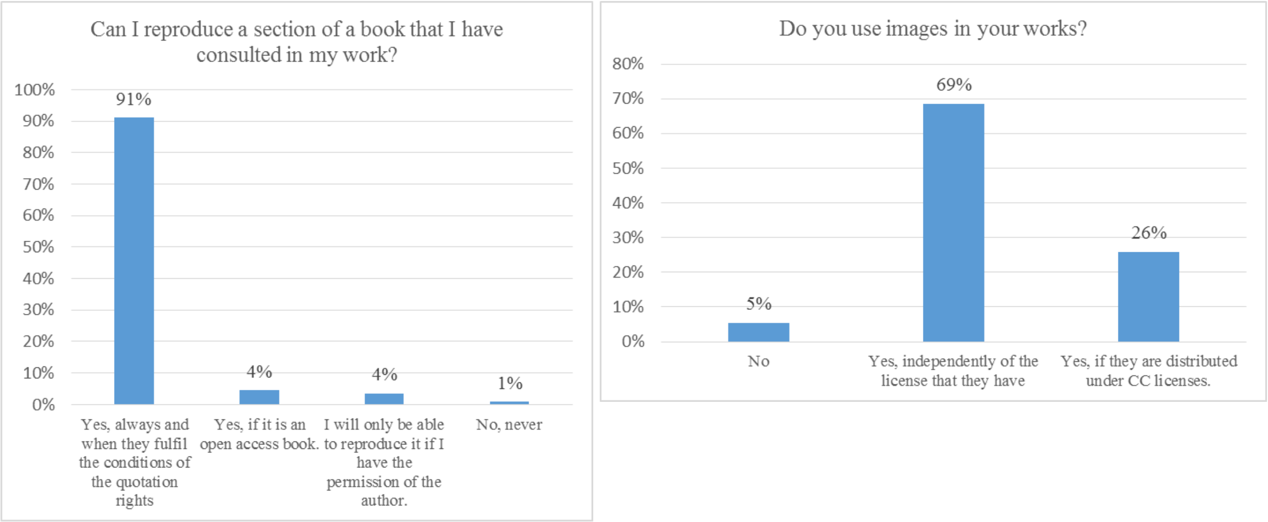

Figure 20 : Knowledge about intellectual property and ethical use of information

From the results, another relevant aspect is the limited use of reference managers and even ignorance of their existence (31 %), as shown in Figure 21. The students of these subjects had to successfully complete all three levels of "solvent use of information" skills. At the third level of the skill, the main objective is the introduction to the Mendeley Premium citation manager, which takes two hours of class and ten hours of virtual work with the obligation of submitting certain exercises and answering some questionnaires.

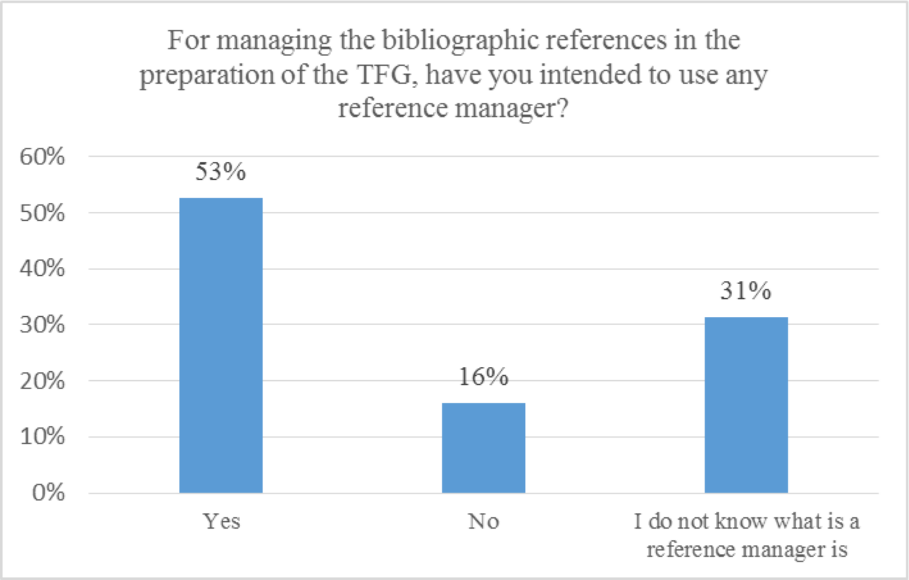

Figure 21 : Use of reference manager

Figure 22 shows that even 50 % of students think that they do not have ownership of copyright in the work or projects undertaken (48 % believe that it lies in the University and 2% in the tutor) . These works or projects have to be entirely developed by the student, despite having a tutor or director assigned. For this reason, it is the student who owns the rights under this creation.

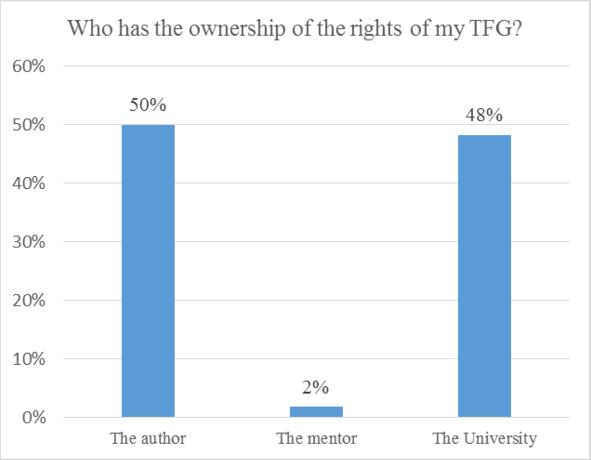

Figure 22 : Copyright in the work or projects undertaken by students

Therefore, the ownership of the intellectual property of the academic works directed or coordinated by UPC professors belongs to the authors (students) of the work. They are also the ones who can allow copying, distributing, publicly communicating, transforming and/or yielding the rights of exploitation to a third party. This issue encourages debate when discussing this issue at the session.

Most of the students, according to the results shown in Figure 23 have it clear that the work can’t be published without permission (62 %), or when it violates the intellectual property rights (76 %), or when they have confidentiality agreements (65%). However, they seem to have more doubts in the case of patent applications.

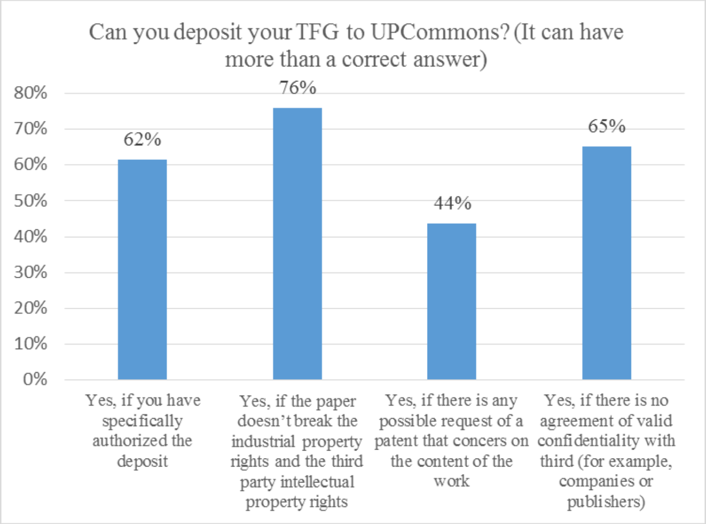

Figure 23 : Condition to publish under UPCommons

Figure 24 shows the limited use of the options that word processors are also offering. For example, only 14 % of respondents admitted to be using the automatic generation of summaries, a useful feature for the development of academic papers. Although the vast majority say that they are using the processor to review the typographical and spelling errors, more often than not the reviewing panel finds work with serious mistakes of this kind, even when considering just the title of the chapter.

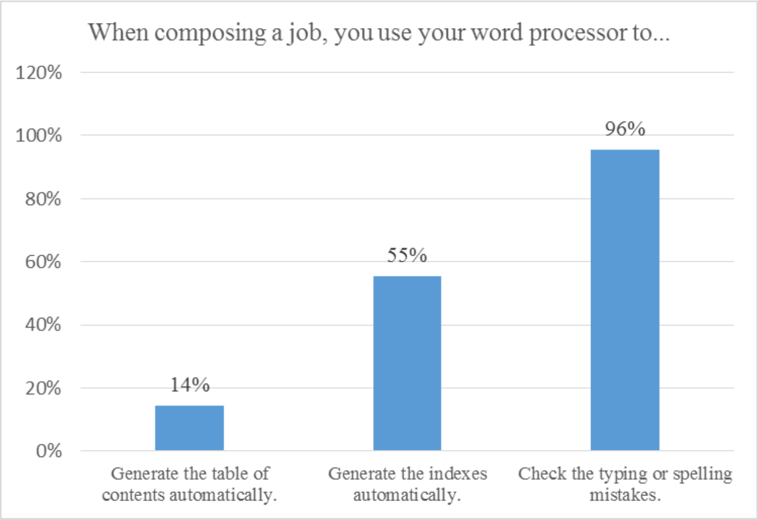

Figure 24 : Tools used for composing a job

In general, the presentation of projects has improved the structure, the wording and the citation of references of consulted documents. The evaluation of teachers is also very positive, because it has revealed another way to motivate students, which encourages their participation in a constructivist learning environment.

Students have repeatedly come to the Library or have contacted the library staff trying to answer questions, mainly regarding the structure of the work and the use of copyrighted images.

Outside the specific field of the subject, the teaching materials produced (graphics, presentations on Slideshare) have been well received in the professional academic environment related. Its distribution in social networks (Twitter, Facebook, etc.) has facilitated an inquiry beyond the one in the subject and the university environment.

3 Discussion / Conclusions

In this paper we have shown how an active learning framework has been applied to the teaching of the project subject at the graduate level. The active learning educational approach, the informational skills and 2.0 resources provided the students with an excellent opportunity to experience the interaction between theory and practice.

The overall course assessment demonstrates the value and effectiveness of the active learning model as a means of improving students' personal, collaborative and informational and communications skills. Results have not been as positive as expected.

Lack of time to register, use and discuss the utilization of resources 2.0, since the Library already has experience in scheduling training sessions on the use of some of them (ex. Prezi, using processors text, Science 2.0, how to prepare a presentation, etc.), has brought the decision to organize this kind of meetings outside university schedule during the course 2015-2016. The professors of the "Project" courses will suggest attending such meetings.

Adoption of Web 2.0 tools in the implementation phase of the project has become increasingly important for students. It facilitates the development and acquisition of skills that go beyond the use of digital tools. Some are specific to the subjects of projects, such as the ability to manage and organize projects, and others are generic, such as teamwork or effective communication. From the professor's view, it requires a favourable attitude towards the use of technology, a digital skill that favours their application to the teaching and learning skills. To promote this attitude it is planned to organize workshops for professors in order to familiarize them with the use of Web 2.0 tools and so gradually integrate them in their day to day academic activity.

Some attitude change is required in assuming that knowledge must be shared and that its production includes many stakeholders. This change occurs slowly in a field that is quickly moving. Despite the emergence of excellent Web 2.0 tools, a general lack of knowledge has been observed. The described actions are trying to change this reality.

All actors in the initiative are considering this experience as a very positive one, thus significantly improving the learning and skills development, achieving greater student motivation and higher quality in practical projects. Therefore, the will of our team is to continue the cooperation and gradually strengthen it by using the "Project 2.0" tools at the stage of developing a project.

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Who is the Learner in the DelftX Engineering MOOCs?

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Abstract

The Delft University of Technology (TUD) deployed her first generation of massive open online courses (MOOCs) in 2013-2014 delivered through the edX platform. These DelftX MOOCs were engineering courses designed at the level equivalent to that of a bachelor-program entry level. Almost 140 thousand students registered, around 3,7% received certificates of completion, and the rest participated to a degree reflective of their needs. To better understand and ultimately enhance the MOOCs, TUD conducted the collection and analysis of data about learners and their contexts. This exploratory paper focuses on the specific analyses pertinent to describing the demographics of an Engineering MOOC participant, as observed in the first generation of TUD MOOCs. The implications of the observed participant demographics are analysed and discussed.

1 Introduction

In the last few years, the variety of online education provisions has grown to include massive open online courses (MOOCs). The number of universities offering MOOCs is low, for example, 8% of higher education institutions in the US are currently offering one (Allen & Seaman, 2014; Hollands & Tirthali, 2014). Still, these educational offerings have caused numerous discussions, including those about the quality of online education, access and openness, and learner privacy, to name a few (Dillenbourg *et al.*, 2014; Haggard, 2013). In order to make sense out of their experiences with MOOCs, universities engage in internal practices of learning analytics – "measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs" (Gaševic, Dawson, & Siemens, 2014). These endeavors have been captured through institutional MOOC reports that provide external audiences with an overview of learner populations, their motivations, course design, etc. (Edinburgh, 2013; Harrison, 2013; Ho *et al.*, 2013).

Delft University of Technology (TUD) offered its first five MOOCs in 2013-2014. At that time little was known about those enrolling and due to the lack of specific information about the potential target audience, the initial MOOC designs have been mainly based on the existing campus courses. These were adapted to become online versions using design specifications developed earlier for regular online courses and with additional features that showed to be of value in other MOOCs (Mohamed *et al.*, 2014). This paper raises a question of whether a mere translation of existing face-to-face or online on-campus practices into an open course is well suited to serving those learners who become interested in taking these courses.

Despite the fact that MOOCs are a variety of an online courses typically offered for free to those outside of the institution's student body (Allen & Seaman, 2014), there are noteworthy differences between MOOCs and conventional online courses (DeBoer, Ho, Stump, & Breslow, 2014; Mullaney, 2014). MOOC participants are not necessarily registered students at the school; MOOCs are designed for unlimited participation, usually without a fee, and are generally unaccredited (Allen & Seaman, 2014). These idiosyncrasies help MOOCs appeal to a very diverse mix of participants from all parts of the world, with a very different background, learning experiences and motivations. Naturally one of the first research questions at TUD was to understand who are the thousands of individuals signing up for free, online courses that offer no qualification or credits and what are they hoping to achieve (Macleod *et al*., 2015)? Understanding how these individuals participated is critical for highlighting what is actually on offer by course designers: who benefits from taking part in the course, and whose needs are not met (Merriam, Caffarella, & Baumgartner, 2012).

This paper reports on a series of descriptive and inferential analyses pertaining to the characteristics of the learner engaged with TUD MOOCs. Reported analyses focused on demographic factors, such as age and gender, as well as prior background in the subject, education level, belonging to a particular culture, and preference for individual or collective learning.

2 Data Collection and Analysis

Framework for Data Collection

The multi-layered setting of the framework for data gathering allowed for the collection of a substantial amount of data for analysis (table 1). The focus and interest of this first evaluation effort concerning MOOCs was twofold. In the first place the evaluation should deliver basic quantitative information about the number of participants, dropouts and completers and the progression of these numbers and achievements during the course. Secondly the intention was to gather qualitative information that would help to better understand the behavior of the students. Table 1 shows an overview of the data sources and the resulting information that was inferred from these sources and used in the research.

Table 1. Data sources, instruments and information categories

Data sources & Instruments	Information categories
edX subscription data	Number of participants, dropouts, location, age, gender, schooling
edX student data	Progress, tests results, quizzes, exams, etc. Forum participation
External data, other media (i.e. Facebook groups, discussions)	Social networks, content and discourse analysis
Surveys (pre, mid, post): students	Information about demographics, intention, expectations, satisfaction, media use, etc. Interventions embedded in surveys
Semi structured interviews: teachers, NMC, DelftX	Experiences with workflow and organization Questions and expectations for evaluation

Contextual Considerations

The first five MOOCs delivered by TUD were all engineering courses (table 2). These courses differed in the pedagogical approaches adopted by teaching teams: in learning design, in academic disciplines, in the degree of teacher's control and learner autonomy, etc. The numbers of the enrolled varied, as did the numbers of the individuals who received the certificate of completion. Since we found these five contexts not comparable to a degree that allows full aggregation of data (De Vries et al, 2015), some of the analyses presented in this paper show course-by-course breakdown of demographic variables.

Table 2 Overview of the first five DelftX MOOCs (For a detailed description, see De Vries *et al.*, 2015)

Course Name	Period	#Students	# Receiving Certificate of Completion	Level	Description
#1 ET3034TU Solar energy	16.09 – 6.12.2013	57.091	2.730 (4,8%)	Bcs	A foundation course in Solar Energy, requiring basic knowledge of physics and some mathematical skills. The main learning goals were the discovery of solar energy power and the design of a complete photovoltaic system.
#2 CTB3365 Introduction to Water Treatment	16.09 – 25.11.2013	29.088	545 (1,9%)	Bcs	An introduction to Water Treatment systems with a focus on basic drinking water and wastewater treatment technologies for urban water services
#3 1110X Introduction to Aeronautical Engineering	03.03 – 19.5.2014	15.820	578 (3,7%)	Bcs	This course provides an overview of and introduction to the fundamentals of aeronautics, using the history of aviation as a story line. It comprises a general introduction to aeronautics taking a closer look at aerodynamics and flight performance.
#4 TW3421 Credit Management	18.04 – 30.6.2014	20.925	709 (3,4%)	Bcs	This course offers an introduction to credit risk modelling and hedging. The approach of credit risk is taken from the point of view of banks, but most of the tools and models can be beneficial at the corporate level as well.
#5 NGI101x Next Generation Infrastructures	23.04 – 8.7.2014	16.091	517 (3,2%)	Bcs	Covered the general discussion on infrastructural systems in the world with the purpose to develop a broad understanding. Originated from the encompassing 10 year THE research program on New Generation Infrastructures.
Total		139.015	5.079 (3,7%)		

3 Results and Discussion

This section summarizes findings in relation to the question '*Who is the learner?*'. Participant demographics are compared across the courses, concentrated on the differences in groups with regard to the measured performance metrics, such as grades and engagement. The analysis was exploratory, rather than focused on a specific factor or topic: the intention was to come up with a characterization of the learner using the variables at hand and to address a wide array of factors that are considered relevant for (open) online education. Depending on the statistic, different populations were examined. Some analyses were conducted over the entire cohort of registered participants. In other cases, all the students who have not attempted a single assessment, have been removed, i.e. those with the grade below 0.01. Finally, some of the findings only related to the students who completed all required assessment tasks, i.e. received a grade above 0.55.

Age

Figure 1 demonstrates that the average age of a student who enrolled in an engineering MOOC, across all five courses, is thirty years old, or above. The median age falls between 25 (as in AERO) and 30 (as in other courses).

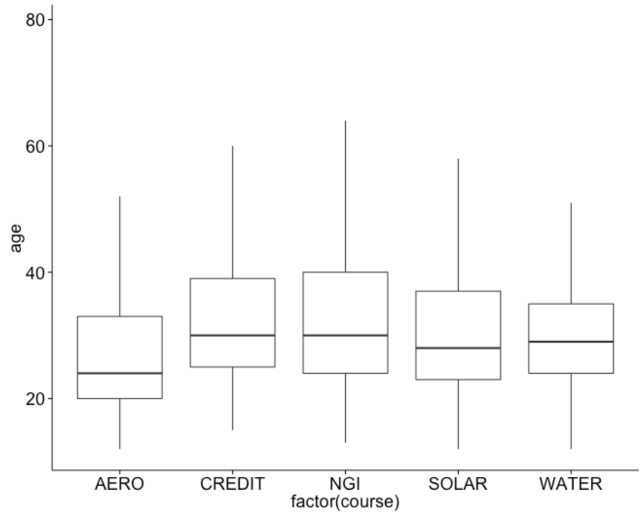

Figure 1 – Boxplots showing the age (median & spread) per course (all registered students).

To understand whether MOOC participants of different age demonstrate differences in performance that may indicative of varying learning needs and strategies, we have studied the patterns of grades distributions in relation to age (Figure 2). We compared performance across different age groups, removing from the analysed dataset the learners who have not started a single assessment task. Figure 2 exemplifies that for the participants of younger age, performance spikes around the grade of 0.6 (often a passing grade in the courses), as well as there is a stronger increase around the grade of 1.0 (perfect score). The plot for older participants has a more steady distribution, but clearly increases around the grades close to 1.0.

One of the ways of interpreting these patterns is to assume that there are varying attitudes that characterize these two sub-populations: 'a performance orientation' and a 'mastery orientation' (Elliot & Dweck 1988). In contrast to 'mastery orientation', people with a 'performance orientation' believe that success is the result of superior ability and of surpassing one's peers, and are often driven by a desire to outperform others and demonstrate their ability (Corwin and Harackiewicz 2002). The hypothesized *'performance orientation'* among younger students can explain the clear-marked spikes around 60% of the grade (pass) and towards 100% (perfect). On the other hand, older students may be more interested in learning than in receiving a particular grade or certificate, resulting in an observed more equal distribution of grades. A completely different way of interpreting this pattern could be that more mature learners are simply more prepared to engage with an educational provision that requires a self-directed and purposeful engagement. Within this line of reasoning, it could be assumed that the concentration of younger learners around 0.6 and 1 may represent two types of learners: those who would have succeeded anyway, and those who struggled with this kind of course, and scored lower not because they did not try harder, but because insufficient student support was provided.

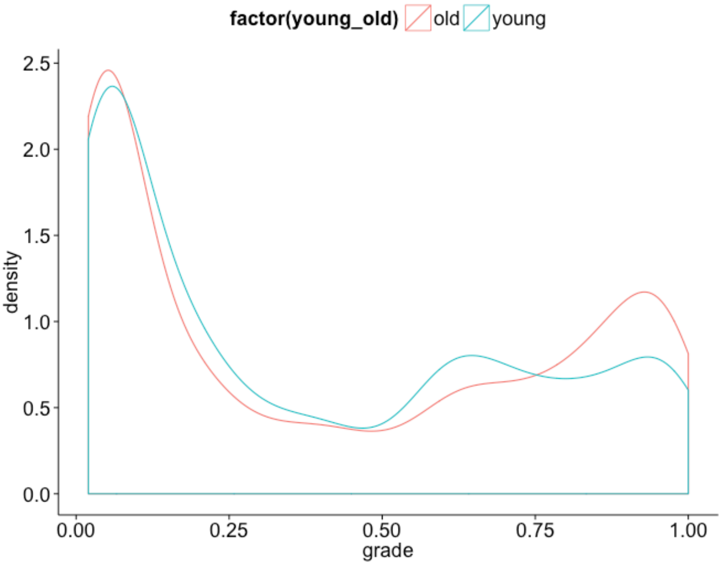

Figure 2 - Grade density plot (filter: grade>.01)

To gain some insights into whether these hypotheses are relevant, additional inquiry was done in the student motivations to take the course, as reported in pre-course surveys. One of the default answers in the pre-course surveys was *“I would like to get a certificate for successful completion”*. When compared the mean age between students who were motivated by a certificate, and those who were not, the age difference across all courses is significant (p=.000), with an average age difference of 3.9 years between those motivated by the certificate of completion and those who are not. This seems to support the interpretation that the certificate of completion seems to be a much more important driver for younger students than for older students.

Gender

The ratio of female students entering engineering courses is generally low (Jordan, 2013; MacLeod, 2015). This is not different in technical MOOCs, but we also noticed a higher disengagement from the activities for female students in all courses: the ratio of completing female students was much lower than the ratio of female students at the beginning of the course, shown in the table below.

Table 3 - Male-female student ratio start vs end of course (N = 65.596)

	ALL	AERO	CREDIT	NGI	SOLAR	WATER
Registered students (f)	19%	14%	21%	21%	15%	26%
Completing students (f)	15%	12%	17%	13%	12%	25%

When we compare the measured performance between female and male participants (figure 3), it is observed that female students receive lower grades than male students. A closer look reveals that female students across all courses are younger than male students. In line with that, we see fewer and fewer female students in the older age groups. Despite the younger average age of female students, we see no performance 'spike' around grade .55-.60 or 1.0 as we saw earlier, while the same pattern as descriptive of 'younger' students repeats here for male participants (figure 3).

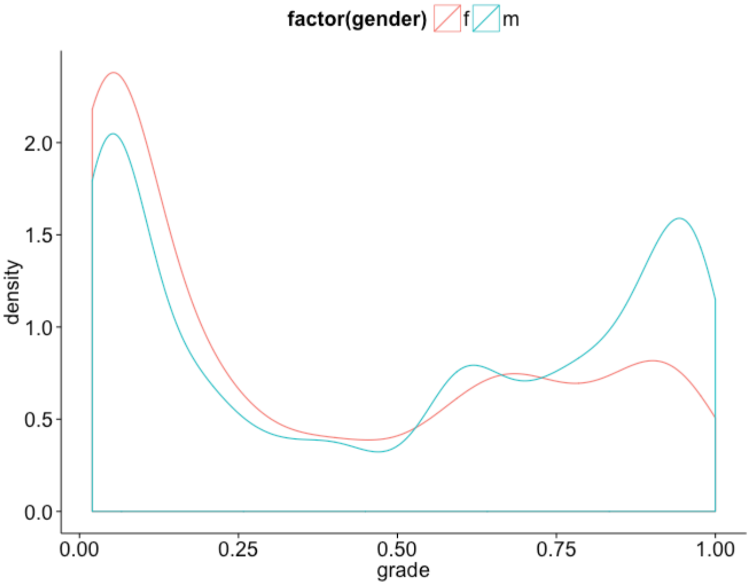

Figure 3 - Completion rate male vs female students (n=9713, filter: grade>.01)

The overall observed trend is that there is a low registration and participation rate of female students as shown in other technical MOOCs (Macleod et al, 2015). Additionally, there seem to be significant differences in performance between male and female students across all MOOCs.

Prior educational background

Figure 4 indicates the distribution of registered learners according to the level of their prior educational background. It can be seen that a large segments of the student body across all five MOOCs reported having a bachelor's degree. In comparison to other courses, the NGI and CREDIT MOOCs attracted more students with master's level of education, e.g. half of the students who registered for the CREDIT MOOC had at least a master degree.

Our analyses reveal that the completion rate is higher among higher-educated students than among lower educated students. On average, bachelor students comprise 40% in both completing students' population, as well as non-completing students' population. This balance shifts when it comes to the other levels of education: students with lower levels of prior education have a relatively lower percentage of completers versus non-completers.

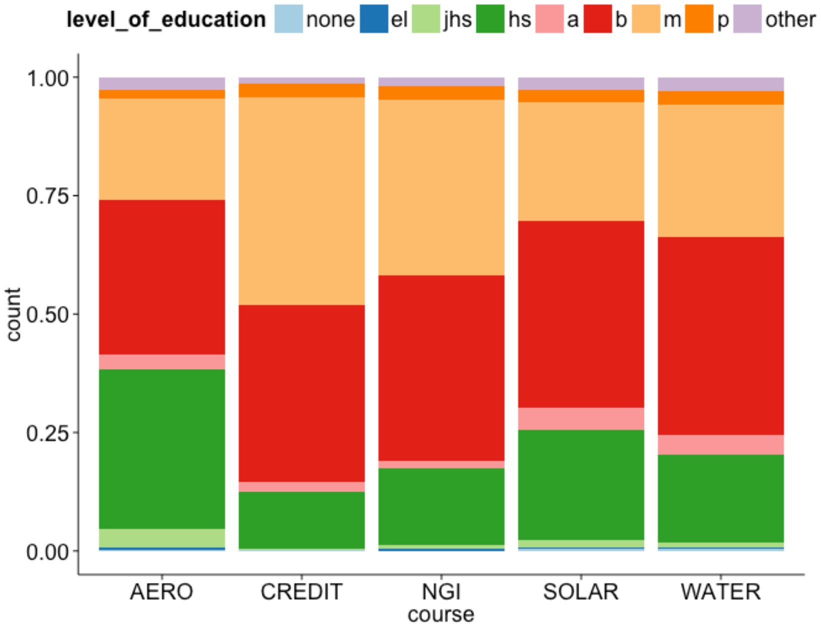

Figure 4 - Education levels for different courses for all registered students

In line with the above, we observe higher performance (grades) among students with a higher level of education (figure 5). Through a simple regression analysis, we examined a possible relation between level of education and performance across all courses. The results can be seen in the boxplots below, showing the grades on y-axis and variance of the most dominant levels of education: high-school (1), bachelor (2), and master's degree (3). The plot also contains the regression line, with an intercept of .34 and a slope of .07 (p=0.004).

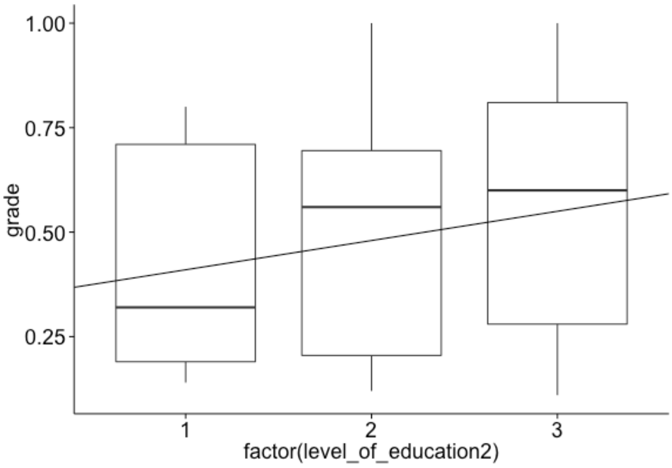

Figure 5 - Boxplot + regression line for grade ~ level of education (filter: grade>.10)

Prior experience in the topic and with online learning

Information about students' prior background in the topic of the course has been collected as well, with the question of research interest here being whether having a background is helpful and how many students have such a background. Most students indicate that they have no prior experience with the topic of the course, ranging from 50% (CREDIT and NGI) to 73% (SOLAR). As can be seen in table 4 prior background and grade are not related, but only for those students who have at least started the course and completed a few assignments (sub-set of the population with the grade above 0.1).

Remarkably, we do see a significant correlation – in every course! – between prior experience and grade when we take the entire student population of registered students into consideration (table 4). This may mean that those students, who have little to no experience in the topic, are much more likely to 'not start' the course, or disengage right at the beginning, than those who have some background in the topic. In addition, because we don't see any relationship between prior background and performance, it could signify that (other factors being equal) participation is more important than prior experience.

When looking at the entire dataset there is a significant performance increase with more prior experience, for all courses. This would mean that when students are more experienced they are more likely to continue or persevere during the course and that those who do not have prior experience more easily disengage from the course early on (table 4).

Table 4 - Correlation statistics for prior experience ~ grade (filter: all registered vs students with grade>.10)

	filter:	grade>.1	grade>.1	no filter	no filter
course		mean_grade	cor.stat	mean_grade	cor.stat
AERO	No prior experience	0.65	no	0.19	cor = .09
	Same/similar level experience	0.64		0.23	t = 3.3477, df = 1348
	More advanced experience	0.75		0.27	**p-value = 0.001**
CREDIT	No prior experience	0.72	no	0.16	cor=.08
	Same/similar level experience	0.67		0.19	t = 3.3505, df = 1604
	More advanced experience	0.73		0.29	**p-value = .001**
NGI	No prior experience	0.62	no	0.24	cor = .06
	Same/similar level experience	0.63		0.28	t = 1.9199, df = 1178
	More advanced experience	0.63		0.30	**p-value = 0.055**
SOLAR	No prior experience	0.68	no	0.20	cor = .13
	Same/similar level experience	0.71		0.29	t = 5.9084, df = 2026
	More advanced experience	0.69		0.22	**p-value = .000**
WATER	No prior experience	0.52	no	0.10	cor = .16
	Same/similar level experience	0.53		0.17	t = 5.4745, df = 1203
	More advanced experience	0.48		0.17	**p-value = .000**

Pre-course surveys that have been administered in the beginning of each course also included an inquiry about students' prior experience with online learning. Surprisingly, the difference in grades between students with and students without previous experience with online learning is quite large, and statistically significant. We have divided the sample into students with, and students without experience, the latter being students who have indicated to have finished more than one online course before. The student t-test shows a significant difference in average grade, being .65 for students without experience, and .69 (t-value = 2.8, df = 1853, p = .006) for students with experience.

Cultural background

Another demographic variable that we believed may help understand registered learners better was related to the cultural background that students come from. A vast majority of existing institutional reports only provide information about the country of origin of the participant. We intended to see a larger picture to gain insights into the degree of intercultural sensitivity required from the course. Cultural values shape learning behaviours and experience, and research on cultural differences and their effects on learners and learning environments points out how the same pedagogical methods and structure may not be equally effective for learners from varying cultural background (Hofstede, 1986; Sweeney, Weaven, & Herington, 2008). Learner's belonging to a cultural group has been derived based on the country clustering from the GLOBE Extension Study (Mensah & Chen, 2013), which accounts for (1) racial/ethnic distribution; (2) religious distribution; (3) geographic proximity of the countries; (4) major language distribution; and (5) colonial heritage. Figure 7 shows the distribution of the different cultural groups across the MOOCs.

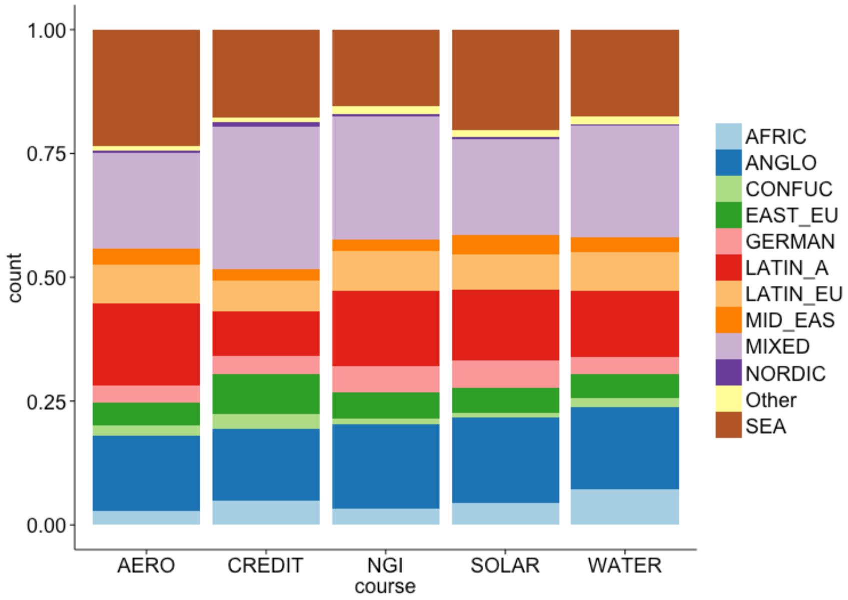

Figure 7 - Cultural clusters across MOOCs

Preferences for Individual or Collective Learning

Only a small percentage of the entire student body participated in the course discussions. The overview of social learning involvement by completing students shows that overall students with the intention to receive formal certification were more likely to visit and participate on the course forum.

When analysing the preferences of learners towards information sharing, engaging with other learners, forum participation and collaboration, we decided to consider the cultures from which the students come from. There are observed differences in reported preferences for the culture of learning with others. Such cultural groups as African, Middle Eastern or South East Asian report stronger preference towards working with another student. Students coming from countries belonging into Anglo, Germanic and Eastern European culture cluster report their preference of working alone (table 5).

Table 5 Cultural Preferences to Work Alone or Together in SolarX and WaterX MOOCs

Accumulated Culture Cluster	Preference to work alone, %		Preference to work together, %	
	WaterX	SolarX	WaterX	SolarX
African	38%	25%	57%	75%
English-speaking	54%	62%	41%	38%
Confucian	50%	58%	50%	42%
Eastern Europe	59%	64%	41%	36%
Germanic	76%	68%	24%	32%
Latin America	22%	43%	70%	57%
Latin Europe	53%	55%	47%	45%
Middle East	40%	39%	60%	60%
Nordic	0%	86%	100%	14%
South East Asia	40%	42%	58%	58%
Mixed	53%	55%	47%	45%
Total	47%	51%	50%	49%

4 Discussion and Conclusions

The aim of this paper was to take a critical look at who is the learner of the first generation of DelftX MOOCs. The data for this description were collected from the first five MOOCs; a mixed-method approach was used to look at the data from different angles and problematize demographic characteristics and their relationship to performance, and learning, in MOOCs.

First, we observe that students of different age groups demonstrate differing patterns in performance. We hypothesize that students taking and completing MOOCs, of 30 years old and younger, tend to be more motivated by clear markers of performance (certificate of completion). On the contrary students over 30 years old that complete MOOCs tend to be more interested in mastering the subject, or just learn relevant bits of the subject matter. Although such analysis needs to be replicated for more courses, we believe that the qualitative interviews with course participants can provide more insights as to whether the motivation attitudes for younger and older learners diverge.

Secondly, the number of female students is low in all courses; they are generally younger than male students; their overall performance (grades) is lower than male students. Both female students and students without prior experience are more likely to disengage from the course early on. Finally, despite the overwhelming presence of all continents and many diverse countries, most of the students taking DelftX MOOCs come from India and the US, and generally the South East Asian cluster (including India) and the Anglo cluster (including the US) are among four top cultural groups to complete a MOOC at Delft. However, we have found that these two groups differ in their preferences for learning with others. English speaking students, students of Germanic culture, and Eastern Europe tend to prefer to work alone, while students from South East Asia, Middle East and African cultures prefer to work together with others.

This analysis allowed us to pinpoint a sequence of characteristics that can be considered a start in profiling the learner in our MOOCs. Most importantly, the paper points us in several relevant research directions, such as i) the role of gender in MOOC participation and performance, ii) the variety of attitudes towards learning in relation to student demographics and performance, iii) the potential impact of assessment placement and design on less committed students, and iv) attitudes and preferences towards working with other students in relation to culture.

A bit of caution should be applied here though, because the term Massive is also to interpret as the massive variety of the student population and the kind of MOOCs, which makes it difficult to derive explicit conclusions despite the abundance of the sources. Reich states (2014) that due to the variety in MOOCs the numbers of MOOCs for analysis need to be much larger to come to general conclusions concerning teaching and learning. Therefore, it should be reiterated that the analysis reported here are to be used and interpreted with caution, since the MOOC context clearly differs from what Higher Education has experienced so far.

Distance education, of which MOOCs are a part, has had a tradition of serving non-traditional learners, i.e. the ones that are not the usual audience of on-campus bachelor level courses, and could be characterized as working adults in need of up-skilling. Our analysis shows the diversity and potential vulnerability of some groups of learners, if the pedagogical approaches do not accommodate to their diverse needs. In other words, if a MOOC provider focuses on delivering knowledge in rigid classroom like approaches, without certain learner-centeredness, such course may resemble their usual university bachelor provisions, and may not be suitable for a diversity of adult learners that subscribe to take it. We believe that approaching MOOC populations as adult learners, and treating MOOCs as provisions in adult education, rather than formal university education, allows embracing these diversity behind learner populations. It also allows building on the existing body of research and practice developed in andragogy. Despite of age, gender, culture, etc., adult learners are defined as individuals whose social roles are characteristic of adult status and who undertakes systematic and sustained learning activities for the purpose of bringing about changes in knowledge, attitudes, values and skills (Myers et al., 2014, p. 4). Such definition places emphasis on the social role of the adult, rather than persons or demographic, and is extended to the learners of younger age, whose major social role is not that of an adult, but who similarly to other adult learners face conflicting obligations and the need for self-directed learning skills.

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Active Learning – Opportunities and Challenges with MOOCs

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Abstract

This paper addresses Massive Open Online Courses, MOOCs, and how MOOCs can support active learning.

The international pace of development and interest in MOOCs is substantial. The number of MOOCs has increased dramatically in recent years. MOOCs is not an occasional activity, but is a web-based course form that is here to stay.

There are many different platforms available globally for MOOCs today and in many languages.There are both commercial and non-commercial online platforms offering MOOCs courses attracting millions of users all over the world.

Chalmers University of Technology has joined the MOOCs movement and is from 2014 a partner of the edX platform. The first MOOC that Chalmers University of Technology will offer (2015) is a course about the material graphene “Graphene science technology”.

Chalmers University of Technology conducts a strategic venture with MOOCs, opening for enhanced cooperation with other universities to achieve high quality in online web-based education, both on campus and at a distance.

From a higher education perspective, there are obvious advantages to universities to work with the MOOCs concept. MOOCs contribute to the development of pedagogy for online education –teaching and learning - and this can be used to improve the quality of traditional on-campus education and blended learning. Moreover, engaging teachers/researchers in the development of MOOCs, will support the building of skills for educational development and blended learning within the university. MOOCs also contribute to the development of technology in education. The technology level in a MOOC must be relatively high compared to “conventional” online courses.

MOOCs of good quality, pedagogically well-planned and with engaging learning resources should have the potential to support active learning.

This contribution to ALE 2015 workshop aims to start a discussion about how MOOCs can be used to support active learning in engineering education.

Key words – Active learning, Engineering education, MOOC´s, Massive open online courses, Teaching, Learning, Web-based learning, e-learning, Blended learning

1 Introduction

This paper addresses Massive Open Online Courses, MOOCs, (e.g. Open Education Working Group, 2015**)** and how MOOCs can support active learning.

The international pace of development and interest in MOOCs is substantial. The number of MOOCs has increased dramatically in recent years. The number of MOOCs is increasing rapidly. MOOCs is not an occasional activity, but is a web-based course form that is here to stay.

MOOCs are in general characterized by a large number of students per course and there is open admission without any fees for the participants.

Today MOOCs are given by a lot of universities around the world, including highly ranked universities such as Harvard, MIT, Stanford, University of Tokyo etc. The universities see a value in MOOCs for several reasons; recruitment of students, pedagogical development, spread of knowledge, international marketing, collaborations etc

There are many different platforms available globally for MOOCs today: Coursera, edX, Edraak, France Universite Numerique, Future Learn, Iversity, Open2Study, Udacity, Xuettan, Canvas etc. MOOCs are available today in many languages for example English, Spanish, French, Mandarin, German and Arabic. There are both commercial and non-commercial online courses. Below are examples of numbers of partners, courses and users of some MOOC platforms (Swedish institute for growth policy analysis, 2014, Swedish Institute, 2015):

- edX: about 35 partners, 375 MOOCs and 3 million users
- Coursera: about 115 partners, 900 MOOCs, 10 million users
- Udacity: about 10 partners (including Google), 50 MOOCs and 1.6 million users

Chalmers University of Technology has joined the MOOCs movement and is from 2014 a partner of the edX platform (edX, 2015). The first MOOC that Chalmers University of Technology will offer 2015 is a course about the material graphene "Graphene science technology".

Chalmers University of Technology conducts a strategic venture with MOOCs, opening for enhanced cooperation with other universities to achieve high quality in online web-based education, both on campus and at a distance.

Several other universities in Sweden and the Nordic countries are now offering MOOCs and explore the opportunities and challenges with MOOCs. A conference "MOOCs in Scandinavia" will be arranged in Stockholm 11 - 12 June 2015 (Karolinska Institutet, 2015).

MOOCs of good quality, pedagogically well-planned and with engaging learning resources should have the potential to support active learning.

The aim of this paper is to start a discussion about how MOOCs can be used to support active learning in engineering education.

Advantages and disadvantagess with MOOCs, use of MOOCs in higher education and a discussion of how MOOCs can be used to support active learning are addressed in this paper.

2 Advantages associated with the use of MOOCs

From a higher education perspective, there are clear benefits to universities to work with the MOOCs concept. Besides recruitment, spread of knowledge and marketing MOOCs contribute to the development of pedagogy for online education and can stimulate institutions to develop policies for e-learning.

The technology associated with MOOCs may be used to free up time for interactive exercises, group work, labs and problem solving on traditional on-campus courses. This can result in improved quality of traditional education on-campus and blended learning. Knowledge of how students learn will increase from studies on students´ learning online.

A MOOC is open with no barriers to entry or leave and there is no limitations in number of students. It is flexible in time, place and resources. A MOOC is often organized with video lectures, quizzes, dialogue, interactivity through questions and discussion forums with the aim to support building of socially constructed knowledge.

Participants participate in a MOOC of their own interests, motivation and needs. This gives the students possibility to choose between learning resources and to make own choices how to learn and engage. This encourages students to take responsibility for their own learning which supports active learning with student motivation. Voices from students, teacher and researchers can be present in a MOOC and can contribute to valuable interactivity and discussions.

Moreover, engaging teachers/researchers in the development of MOOCs, will support the building of skills for educational development and blended learning within the university. Taking part in the MOOCs development has the potential to improve the role of online instructor competencies.

MOOCs also contribute to the development of technology in education. The technology level in a MOOC must be relatively high compared to “conventional” online courses. The underlying web-based technology can change the pedagogic methods of on-campus education. MOOC-like courses may have the potential to complement or even replace traditional university courses.

MOOCs has also been reported as interesting for research communication, recruitment, offering open educational resources contributing to broad and lifelong learning among people, and as mentioned for marketing and branding.

Additional aspects on the impact of MOOCs is the possibility to support/foster international collaborations and cross-cultural issues.

The Swedish Institute (Swedish Institute, 2015) emphasizes the possibility of MOOCs to meet the problem with shortage of qualified teachers, which is the case in many countries today. The Swedish Institute is working with knowledge-building in developing countries and sees it as an important and interesting question how universities through the use of MOOCs can meet the enormous need for advanced education to students in developing countries.

This paper suggests that MOOCs of good quality, pedagogically well-planned and with engaging learning resources have the potential to support active learning.

3 Disadvantages associated with the use of MOOCs

There is a substantial level of support for MOOCs. However arguments against MOOCs have also been raised. The following disadvantages are frequently put forward:

The fact that a lot of resources are needed to produce, to build up, a MOOC and to manage it is seen as problematic. Significant production capacity is required and for development of the MOOC initial investments are needed. A considerable amount of capital is needed to create professional quality video, audio and other online educational materials. Substantial time allocation is needed by core staff, which means that a considerable amount of teachers´ resources and time is needed.

The questions of how to manage to give students suitable and sufficient support and to get valuable interactivity and dialogues in a MOOC are often discussed.

Examinations are regarded as complex in a MOOC and identifications of students over the internet demands extra efforts. The student identification is today often carried out using electronic

identification systems. Examinations need to be performed in a legally and fair manner. Also the assessment of course quality and quality assurance are often discussed.
There may be a need to break old lecturing habits and to overcome administrative and formal barriers for the implementation of MOOCs as an element of blended teaching and learning.

4 MOOCs in Higher education

A lot of universities already regard MOOC´s as an important learning resource and a way to promote themselves. Several prominent universities, for example Harvard, Kings College, Open University, MIT and Stanford have used MOOC:s for several years. Harvard and MIT offer edX courses (edX, 2015) non-profit and created by Harvard and MIT which brings higher education to students of all ages anywhere in the world via the internet with free MOOCs. University of California Irvine offers many of its´ courses as open educational resources. Another example is that some German universities offer open courses and ECTS credits for MOOC´s by the European MOOC consortium Iversity (Iversity, 2015).

New MOOC platforms that are being released are for example NovoEd from Stanford and Open25Study from Open Universities in Australia.

A web page (Open Culture, 2015) is showing more than 200 MOOCs that had their course start February 2015. From this web page you find more than 1000 free MOOCs in a lot of subjects including Engineering education. Other content you can find from this web page are free textbooks, free eBooks, free audio books, free movies etc. For more reading about MOOCs there is a systematic study of published literature 2008-2012 about MOOCs (Liyanagunawardena *et al*, 2013).

There are several organizations occupied with the possibilities of MOOC:s, and in a broader perspective blended learning, web-based learning, e-learning. For example the European commission launched a comprehensive initiative regarding open education 2013 which is going on and will continue (Opening up Education*,* 2015*)*. This initiative is intended to promote digital competence, the use of open learning resources and education and access to digital resources in both schools and universities.

The MOOC consortium OpenupEd is coordinated by the European Association of Distance Teaching Universities, EADTU, and is growing rapidly.

5 Discussion

In order to meet students´ ways to study and learn, the use of active learning has been discussed in a lot of studies (e.g. Prince, 2004).

Active learning refers to several models of instruction that focus the responsibility of learning to learners (e.g. Bonwell *et al*, 1991). In particular, students must engage in such higher-order thinking tasks as analysis, synthesis, and evaluation. Bonwell expresses this in the way that active learning engages students in doing things and thinking about the things they are doing (Bonwell *et al*, 1991). Bonwell suggested that learners work collaboratively, discuss materials, role-playing, debate, engage in case studies, take part in cooperative learning or produce short written exercises etc. They also put focus on *when* active learning exercises should be used during instruction. Numerous studies have shown that introducing active learning activities (such as simulations, games, contrasting cases, labs etc) before, rather than after lectures or readings, result in deeper learning, understanding and transfer.

To learn students must do more than just listen. They must read, write, discuss, or be engaged in solving problems. It relates to the three learning domains referred to as knowledge, skills and attitudes. This kind of learning behaviours can be thought as the goal of the learning process (e.g. Bloom, 1956).

Active learning is learning which engages and challenges students thinking preferably using real-life and imaginary situations. Curiosity, spontaneity, investigating, exploring, discussing and reflecting together with other are important components in active learning. Active learning stands in contrast to standard modes of instruction in which teachers do most of the talking and students are passive. Thus we might think of active learning as an approach to instruction in which students engage the material they study through reading, watching, listening, writing, discussing and reflecting. If we think of active learning in this way then it is natural to think of a MOOC as a possible resource for active learning.

The educational methods, technology used and web-based course moments in for example a MOOC need to be pedagogically well thought out to meet the students′ needs for active, engaging, interactive and collaborative learning. The use of appropriate educational methods, innovative educational technology and web-based learning has been discussed in many studies (e.g. Limniou *et al,* 2010).

A MOOC is open to everyone with the possibility to use a computer. No registration is needed. This fact means that you could encourage your students to join a MOOC in your own subject to awake interest, to start discussions and collaboration. It is *not* necessary to follow the whole MOOC – the students can choose to take part in what they find interesting without any obligations. This could be a way to share and reuse already produced learning resources of good quality.

Today some platforms offer MOOCs with flexible course start – courses “on demand” - where a student can start to study at a time of their own choice. This concept with on-demand courses instead of session-based courses have potential to build a global learner community. MOOCs could be one (small) element of a future blended educational program. A diversity of on/off line and on/off campus approaches could be used with regularly updated new educational technologies in order to support the students to meet the course objectives and competencies set as outcomes of a course. As a teacher you can encourage students to study selected parts of an existing MOOC as a way to get students interested in a subject and/or prepare for class in a blended learning course.

Students of today read fewer textbooks, use the web more in their studies and prefer to be active when they learn together with other students in real face-to-face meetings or frequently in virtual meetings with online communication and social communities on the web. By offering more resources and more varied learning resources the students can engage with the material in more ways and become more active.

From students point of view the possibility to take part in, build and share knowledge in a community is tempting and interesting. There is no doubt that the social aspects of online learning play an important role in student engagement.

Student motivation is necessary to get high quality in all learning. The importance of attitudes, personal goals, engagement and willingness to participate in a learning community is crucial. Learning and knowledge building take place when you reflect together others and use the knowledge to solve authentic problems.

From the connectivist perspective (e.g.Bell 2011) knowledge emerges as a result of connections. The connectivist principles of autonomy, diversity, openness and connectedness/interactivity have a bearing on the way students engage in a MOOC.

There is need for more research on factors that influence student learning in virtual learning environments e.g. a MOOC. How do students actually learn in such a virtual environment as a MOOC? Learning analytics is a growing research area that studies what students “do” in virtual environments.

According to above a MOOC of good quality, pedagogically well-planned and with engaging learning resources has potential to support active learning. If a student's interest and engagement can be captured at depth this is an important foundation for the student's continued learning; the students´ creativity and willingness to learn. If students´ interest and engagement can be captured this is an important foundation for the students´ continued learning, supporting the student creativity and willingness to learn. The key to successful studies is to offer effective learning environments with interactivity and collaboration supporting active learning.

At Chalmers University of Technology the engineering education teachers´ use of active learning and digital media in blended learning is continuously increasing. More and more teachers at Chalmers University of Technology are abandoning, or complement the traditional lectures and exercises for the benefit of blended learning

Chalmers University of Technology will continue to follow the development of MOOCs and how they can be used in e-learning and/or in blended learning at campus. There is obvious advantages following the development thus supporting and encouraging competence development about blended learning among teachers at Chalmers. This could also be seen as an important strategic development for the future.

6 Debate: Active learning - Opportunities and Challenges with MOOCs

The aim of this contribution to ALE 2015 workshop is to start a discussion about how MOOCs can be handled and used to support active learning in engineering education.

As expressed in this paper a MOOC of good quality, pedagogically well-planned and with engaging learning resources should have the potential to support active learning. The technology level in a MOOC is high, often with professional quality video, audio, video lectures, quizzes, self-tests, simulations, animations, discussion forums, project groups, problem solving, shared documents etc MOOCs –or parts of MOOCs - with no barriers to entry is suggested to be used to support active learning at campus, in blended learning or in purely online education. Opportunities and challenges with MOOCs for active learning need to be explored.

Maybe it is time for the ALE network to develop a MOOC to spread the ALE mission about the meaning of, and importance of active learning.

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Interdisciplinary Island of Rationality: A Promising Active Learning Strategy

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Abstract

Science, Technology, Engineering and Mathematics education is vital to the future of our countries and the future of our children. The teaching of Natural Sciences, Mathematics and Technology presented in the official documents of the Brazilian Curriculum Parameters proposes an education that values the student's intellectual curiosity in an emancipatory perspective, directing them to a growing autonomy in the learning process. In this context, the teacher, by choosing methodologies that enhance the active participation of the students, gives them the freedom to become responsible for their constructions, their commitment and their decision-making arguments. In order to educate young people to better deal with the context in which they are inserted and to alphabetizing them scientifically and technologically, Gerard Fourez proposed an interdisciplinary methodology, called "Interdisciplinary Island of Rationality (IIR)". The IIR can be a form of rapprochement between science and everyday life and an alternative for students to build a meaningful learning. This paper describes the construction of an IIR about "The electrical discharges in Brazil" carried out with a third year high school class in a public school in the city of Caxias do Sul, RS, Brazil, in the Physics classes. The main objectives of the IIR development was to promote the science and technology literacy, the autonomy and the meaningful learning of students through an active learning environment and to capacitate the teacher for the use of the methodology. The results show that the students involved with the IIR had a much better performance in the Physics classes than the students in the class who developed the same subject in a traditional way. In the literature, the IIR is not defined as an active learning strategy. However, the results obtained led us to consider the IIR as a promising active learning strategy suitable to STEM education and engineering education.

1 Introduction

Science, Technology, Engineering and Mathematics (STEM) education is vital to the future of our countries and **the future of our children, i.e.** the technological age in which they live, their best career options, and their key to wise decision (Driver *et al.*, 1994; Osborne, 2007; Sanders, 2009). The teaching of Natural Sciences, Mathematics and Technology presented in the official documents of the Brazilian Curriculum Parameters (PCNs) (BRAZIL, 1999) proposes an education that values the student's intellectual curiosity in an emancipatory perspective, directing them to a growing autonomy in the learning process. For Freire (1996), the construction of knowledge requires curiosity and critical reflection in a movement to overcome passivity.

We can also find in the Curriculum Guidelines for High School (OCEMs) (Brazil, 2006) that:

> The school, in defining its pedagogical project, should provide conditions for the student to know the basics of scientific research; to recognize science as a human activity constantly changing, due to the combination of historical, social, political, economic, cultural, religious and technological factors, and therefore, not neutral; to understand and to interpret the impact of scientific and technological development on society and on the environment (Brazil, 2006, p. 20).

For a science education to promote students' scientific and technological literacy it is necessary that the teachers' pedagogical practices be changed. The search for alternatives to provide a Science, Technology, Engineering and Mathematics (STEM) education to students and make them more critical and independent is a challenge for teachers. Encourage innovation in learning and teaching is not only a necessity, it is an imposition of educational historical moment. Action is needed to improve the curriculum and teaching practices through continuous teacher training, and promote, as a result, improvements in the quality of learning (Bell & Gilbert, 1996; Gatti, 2003; Tenreiro-Vieira & Vieira, 2005).

Education should promote in the individual the ability to relate scientific knowledge with the situations experienced by him in his daily life and also the ability to think about various alternatives for solving a problem (Songer & Linn, 1991; Campbell & Lubben, 2000; Nehring *et al*., 2002; Yore *et al*., 2007; Sadler, 2009; Zollman, 2012). Such competencies are exercised in the social and cultural spheres and are conditions for the exercise of citizenship in a democratic context.

The OCEMs (Brazil, 2006) also point out that:

> One should treat technology as a human activity in their practical and social aspects, in order to solve concrete problems. But this does not mean disregarding the scientific basis involved in the process of understanding and construction of technological products. The so-called metaphor of scientific and technological literacy points out clearly one of the major goals of science education in secondary education: that the students understand the predominance of technical and scientific aspects in making significant social decisions and conflicts generated by political negotiation (BRAZIL, 2006, p. 47).

For this we must consider the investigative competence of the student, the contextualization and the interdisciplinarity related to problem situations from the student's daily life. The need to make school science content endowed with meaning, to make it useful for student life, as well as to discuss the role of science and technology in contemporary society, has become a very important issue in the educational scenario in the last years (Fourez, 2002).

Thus, the teacher, by choosing methodologies that enhance the active participation of the students, gives them the freedom to become responsible for their constructions, their commitment and their decision-making arguments.

According to Fourez (1992), there is no particular problem or socio-technical controversy that can be resolved without the intervention of several specialists. In this context, Fourez (1997a, 1997b, 1997c) proposed that the school should focus, in teaching procedures, creating contextualized theoretical models, from the point of view of science, and the construction of interdisciplinary approaches through which the knowledge available are submitted to projects of action over the world. In order to educate young people to better deal with the context in which they are inserted, alphabetizing them scientifically and technologically, Fourez proposed an interdisciplinary methodology, which he called “Interdisciplinary Island of Rationality (IIR)”. This methodology "aims to produce an appropriate theoretical representation in a precise situation and in function of a particular project". The IIR can be a form of rapprochement between science and everyday life and an alternative for students to build a meaningful learning (Ausubel, 2000).

This paper describes the research on the building of an IIR about " the electrical discharges in Brazil " carried out with a third year high school class in a public school in the city of Caxias do Sul, RS, Brazil, in the Physics classes. The main objectives of the IIR development were:

- to promote the science and technology literacy, the autonomy and the meaningful learning of the students through an active learning environment;
- to capacitate the teacher for the use of the methodology;

- to verify the impact of the use of the IIR methodology on learning by high school students.

2 Interdisciplinarity

According to the PCNs (Brazil, 1999) and to the OCEMs (Brazil, 2006) the teaching of science is no longer focused solely on knowledge and will be oriented by building skills and abilities, articulated in the areas of representation and communication, research and understanding and socio-cultural context, having as guiding principles the interdisciplinarity and the contextualization itself. To facilitate the work in an interdisciplinary perspective, the subjects that have common teaching objects were grouped into three areas of expertise and their respective technologies: Languages and codes; Natural Sciences and Mathematics, and Human Sciences. The OCEMs (Brazil, 2006) bring about the interdisciplinary perspective that:

> The need to think in an interdisciplinary perspective arises from the contextualization as a teaching resource that serves to problematize the reality experienced by the student, extract it from its context and design it for analysis. That is, to build up a representation of the world to better understand it. This is a critical and analytical skill that cannot be reduced to mere pragmatic use of scientific knowledge. This critical analytical skill of the representation of the reality is not disciplinary, it does not fall within a single subject, since the aim of research is more complex (Brazil, 2006, p. 51).

Still, according to the National Curriculum Guidelines for High School (DCNEM) (Brazil, 1998a), interdisciplinarity serves to avoid the compartmentalization of knowledge and has an instrumental character when one thinks of the knowledge of the subjects to solve concrete problems or in the understanding of phenomena.

However, introducing interdisciplinary activities in the daily school routine is a Herculean task. The difficulty of working with interdisciplinary methodologies or techniques, in any level of education, has part of its roots in the disciplinary training of teachers. Even if there was some progress in the last decades, there is no incentive to future teachers to examine aspects of knowledge in a broader social context.

To offer an interdisciplinary training for future teachers of physics, chemistry and biology, for example, does not necessarily imply overload the disciplinary curriculum of undergraduate courses. Often, specific pedagogical actions may reduce the compartmentalized thinking of the future teachers. To Fourez, it would be enough to establish some interdisciplinary activities in the school curriculum, so that the students (of the K-12 education level) had a chance to, at least once in their lives, be faced with what he defines as knowledge for projects (Fourez *et al.*, 1993; Fourez 1997a, 1997b, 2002). This would enable them to develop interdisciplinary representations that integrate knowledge from different subject areas in order to gain autonomy in the selection and use of knowledge in many real situations. For this, teachers should then be able to implement interdisciplinary activities. However, this presupposes space in the undergraduate education curriculum to discuss, prepare, implement and evaluate such activities, or individual will of teachers already in service.

Thus, we could say that to promote interdisciplinarity in schools depends on intentional actions of the teacher through the planning of activities that foster collaboration and cooperation among the students. In order to rethink the process of teaching and learning in an interdisciplinary and contextualized perspective, the teacher must understand that he is the mediator between the content and the classroom, where the student builds his own knowledge in an active way aiming to build a meaningful learning. In this act of rethinking the process, the teacher needs to be aware that his training must be constant to facilitate this mediation.

In this context, a methodology that can help teachers introduce the development of interdisciplinary projects in basic education is the Interdisciplinary Rationality Islands (IIR) methodology proposed by Fourez (1992, 1997a, 1997b, 1997c). This methodology fits into the perspective of Scientific and Technological Literacy, which is characterized by the individual's ability to understand and/or invent theoretical representations of problems. The problems fall within multifaceted contexts, i.e., they are interdisciplinary problems with several possible approaches. Thus, the theoretical representations produced in this context are, in principle, interdisciplinary, since it is not possible for a real problem to be absorbed by a single subject without loss of meaning.

3 Interdisciplinary Island of Rationality

Many complex situations and systems, including the socio-technical controversies currently present in our societies, are hard to be approached in a pertinent way from a single disciplinary perspective. The fact is, drawing an adequate portrait of a complex situation or system requires deploying several perspectives and several disciplines (physics, chemistry, biology, ethics, law, sociology, history, philosophy, psychology, economics, politics, etc.). For example, this applies to controversies related to the use of embryonic stem cells, the **hacking into medical devices,** and the use of 3-D printing to create everything from architectural models to human organs. We can properly describe a complex situation, a system or a concept by building interdisciplinary islands of rationality (IIRs).

Gérard Fourez invented the IIR concept and has discussed it in various publications and venues (Fourez et al., 1993; Fourez, 1992, 1997a, 1997b, 1997c). IIRs have mainly been used in high school science courses, but they can also be used in other courses, because they rely on several disciplinary perspectives. The IIR methodology is particularly suitable to promote the individuals' science and technology literacy, since it helps to make connections between science, technology, and social progress. In other words, the IIR methodology can also be a powerful tool for STEM education.

According to Fourez, interdisciplinary islands of rationality consist of "one's representation of a specific situation, a representation that always implies a context and a plan that give the representation its meaning. Its objective is to allow the communication and the rational debates (in particular, concerning decision making)" (Fourez, 1997b, p. 221). The word "island" is used to invoke the idea of an amount of knowledge in the middle of an ocean of ignorance. It also serves to represent the need to choose some information elements from among the large number that exist in order to properly define a situation. Meanwhile the use of the word "rationality" underlines the fact that the creation of the representation allows for productive discussion, which is possible only if one makes sure to specify the meanings of the terms used and the models devised. In other words, it allows for a discussion of the situation which is not just a dialogue of the deaf.

Dealing with complex questions by means of the IIR approach in order to guide an action (buying a heating system, organizing a sales demonstration, to undergo a fertility treatment, to define a health bath, etc.) makes it possible to devise an informed representation of a situation, a system or a concept. The reason is that, on one hand, this approach orients the investigation according to specific needs, such as the general context in which the representation is being developed, students' interests, etc.); and, on the other hand, it systematically brings together various disciplines and individuals deemed to be specialists.

When building an IIR, specific issues will arise linked to some particular knowledge, which may or may not be answered, depending on the orientation of the project. The unknown domain to which these questions are related is called *black boxes*. In the context of IIR methodology, a black box is an object or representation whose general mode of action is known but the details of whose functioning are either unknown or not understood. This may be a material object, a procedure (transgenics, allergic reaction, etc.), or a representation (for example, representations of the ethical or economic issues). In short, black boxes raise questions that can be handled in greater depth in order to supplement or refine the situation's representation.

The decision to open or not these boxes, that is, to deepen or not certain knowledge, is up to the executive team, which may consist of professionals from a company, a group of teachers from a school, a group of students and teachers - or an individual. Opening black boxes means building models, usually linked to one subject, that contribute to the explanation of some aspect of the problematic situation under consideration.

In the academic context, the IIR methodology is thus to be seen as a *means* (and not an end) for arriving at a viable, relevant, and useful representation of a situation, system or concept. It makes it possible to identify the various aspects of a situation, system or concept, taking into account the action plan's target audience, the educational context, the material resources, the time available, the scope of the work planned, and the educational vision the IIR is a part of.

The IIR methodology has been studied by education researchers and applied successfully for some years now in some Brazilian high schools (Nehring *et al.*, 2002; Pinheiro & Pinho-Alves, 2005; Schmitz & Pinho-Alves, 2005; Lavaqui & Batista, 2007; Prestes & Silva, 2009; Regiani *et al.*, 2012; Richetti & Pinho-Alves, 2014) and elementary and high schools from other countries (Funkhouser & Deslich, 2000; Couture, 2005; Prud'Homme et al., 2006, Gagnon, 2010, Pouliot & Groleau, 2011; Bader *et al.*, 2013) with the aim of introducing interdisciplinary projects and scientifically and technologically literate the students.

4 The Stages of the Interdisciplinary Islands of Rationality Methodology

For building of an IIR, Fourez (1997a) indicates a sequence of stages and procedures suggested to facilitate and define the development of the work in the classroom. Fourez identifies eight stages for building an IIR, which, he said, do not have to necessarily be followed literally. They serve as a working scheme, in order to prevent it from becoming so comprehensive that it cannot reach the end and thereby jeopardize the attainment of the objectives proposed by the IIR. Although presented in a linear way, they are flexible and open. In some cases may be deleted and/or revisited as often as the team deems necessary. The team that is developing the Rationality Island is also the one who determines the time of each stage, according to the objectives, availability and needs.

The IIRs bring in the development of their stages a set of strategies and techniques that make the student more active in the teaching and learning process and that can collaborate with the occurrence of the students' meaningful learning. By means of the IR one can make the lessons more interactive, so moving away from traditional teaching, or a mechanical learning, in which students, generally, take a passive attitude in the classroom.

For the development of the methodology of the IIR, one creates a challenging environment. In the development of the IIR, students are taken as members of a "project team". Before starting building the IIR, the teacher presents the problem-situation and the execution schedule of the IIR. This stage (stage zero) is optional, but it is where the first questionings about the problem situation occur. The first stage (step one), called "the snapshot", consists of the survey questions that the team has about the problem-situation. The refinement of the issues raised, the definition of the way to search for the answers, the definition of the participants and the construction of rules and restrictions on the problem occurs in "the bird's eye view", which is the second stage.

Building on the decisions taken, the third stage (called "consultation with specialists") is where the consultation with people who can help to answer the questions of the team is carried out. In the fourth stage (called "going to the practice"), the opening of equipment, visits to places that are related to the situation, allows the group to stop thinking only theoretically and going to practice. With the maturation of the questions that must be answered to address the situation, the group moves to the next stage, stage five (called "detailed opening of some black boxes"), which is the time for content, the time to search subject-related principles, where experts from outside the group can be invited to assist it.

A moment of partial evaluation of the work occurs in the sixth stage (called "*schematization* of the desired situation"), in which the group holds a layout of the problematic-situation, trying to verify the improvements made and the necessary corrections. This allows the team to take the next step (stage seven called "opening black boxes without consulting experts"), which is to evaluate its ability of autonomy by the possibility of opening black boxes without consulting experts. Made the necessary corrections, the team goes to the elaboration of the synthesis of the rationality island (step eight called "the overview"), whereby the result of the activity is presented in the form of a text, poster, video, software, report or any other product, contemplating the problem proposed in stage zero.

The stages allow the work to be defined throughout the process and to reach a final result within the pre-defined contours, because by its very nature, projects tend to be excessively open and broad. Another important point to be highlighted is that a product must always be associated with the problematic-situation proposed. Thus, there is a context that limits the actions to be undertaken within the project. The type of product must be very clear at the beginning of the project, in order to prevent it from becoming so comprehensive that you cannot complete it. As previously mentioned, the stages, although presented in a linear way, are flexible and open, and in some cases may be deleted, extended and revisited.

5 Methodological route

The research developed in this paper is an applied research and in relation to its objectives is a descriptive research. As for the approach, this research is classified as qualitative research, as attempts to describe, understand and explain the complexity of interpretation, or description of the application of IIR methodology. Qualitative research aims to deepen the understanding of the phenomena that investigates from a careful analysis of such information and emphasizes the speech and writing of the participants with deeper understanding of the people involved.

Regarding the methodology for data collection, this research was a participatory action research, since one of the researchers responsible for the research was also the teacher of the students who developed the IIR. It was also a documentary research, as we seek evidence that there was a meaningful learning by the high school students from their initial questions and texts, as well as the material presentation of the teams, investigative printed texts, final essays, new questions and issues in the quarterly evaluation, that is, all the productions of the students developed during the building of the IIR.

As to the context, the research was developed in a public school in Caxias do Sul, a city in the northeastern region of the state of Rio Grande do Sul, Brazil. This school has about 900 students, distributed in the morning, afternoon and evening shifts. The shifts in the morning and evening serve approximately 550 high school students, while the afternoon shift serves approximately 350 students from elementary school.

An IIR about "The electrical discharges in Brazil" was developed in the discipline of physics, in the academic year of 2013, in order to promote the science and technology literacy, the autonomy and the meaningful learning of the students through an active learning environment, to qualify the teacher for the use of the methodology and to verify the impacts of the use of the IIR methodology on the learning of high school students.

The application of the "Interdisciplinary Island of Rationality" around the theme "The electrical discharges in Brazil"

The objective of this research was to evaluate the impacts of the use of the methodology "Interdisciplinary Islands Rationality" around the theme "The electrical discharges in Brazil" on the learning of high school students. The theme "The electrical discharges in Brazil" was chosen because the rays are natural electrical phenomena that cause an annual loss of 200 million dollars to our country in damage to the distribution and transmission lines, telephone networks, industries, telecommunications systems, private property and mainly in lives. The construction of the IIR on this theme aims, first, at the protection of human beings, and secondly to avoid material damage through knowledge and information, besides a better understanding of the electrical discharges from the physical-chemical, climatological, social, economic and environmental point of view and to provide a scientific and technological literacy to the students involved in the process.

The development of the IIR was carried out with a third year high school class in the last quarter of the school year. The school had two third-year classes, identified as 301 and 302, with about 30 students in each class. The class 301 was chosen to develop the methodology. The time used to develop the IIR was 25 class hours.

The class 302, which did not develop the IIR, had interactive expository lectures (Alves and Anastasiou, 2003) on the same subject during the same time. The teacher contextualized the subject of the lecture, in order to mobilize the student's mental structures to operate with any information he brings, linking them to the information that would be presented. In this case, the theme about the electrical discharges falls within the content of the physics course in the electrostatics chapter.

The development of the stages of the IIR

The theme "The electrical discharges in Brazil" was presented via the trailer of the movie "Back to the Future I, II and III" of about ten minutes duration (YouTube, 2015a) and a video that showed the death of a couple on a beach on the coast of the of São Paulo (YouTube, 2015b). Next, a brief slide show was performed with stories about electrical discharges in the country, in Rio Grande do Sul state and also in the city of Caxias do Sul. From the video and the slide show, discussions were initiated on myths and truths of the electrical discharges, since many science fiction films address the electrical discharges in a completely different way from reality, almost entirely fictional. This class was the development of the IIR step zero that was added to the process in order to present the proposal (Pinheiro & Pinho-Alves, 2005). This presentation of the proposal had the purpose of evaluating students' interest in the subject. Thus, the teacher presented the proposal, explaining what would be developed in that period and how the IIR would be built.

In the second lecture (step one of the IIR), a snapshot was made of the conceived situation. Students returned to the discussion on the subject with their classmates and developed questions on the theme. These questions were written by students on a sheet of paper. These records expressed the preconceptions and the initial doubts that have arisen about the situation presented in step zero. At this stage the teacher suggested to the students some topics so that they could proceed with the categorization of their questions. The suggested topics were: social, economic, physical, biological, geographical and historical aspects.

The students agreed with the suggestion of the teacher and divided up the questions into the six categories suggested. In stage two (the bird's eye view), the students by request of the teacher, brought for the class a little research on the subject to share and discuss in the large group. From the discussion about the research it was revealed that the interests were really distinct. Each student sought to frame his research in one of the previously defined aspects and thus took place the division of the work teams.

In stage three (consultation of specialists), students defined which specialists would be consulted directly and indirectly according to the needs and the interests of each team. For example, students who were working with the biological aspects requested the visit of a specialist in biology that could explain the nitrogen cycle and the nitrogen fixing on the ground by means of the electrical discharges, since they found it difficult to understand how this process happens. The other teams tried to consult specialists via informal conversations. In this context, school teachers from their own school and other educational institutions, such as SENAI (National Service of Industrial Education) and technical and vocational education institutions maintained by private companies were consulted.

In stage four (going to the practice), the specialist, whose visit was requested by the team that was working with the biological aspects, attended the school on the date and time combined. This expert is a instructor at the University of Caxias do Sul (UCS) and went to the school to explain to students about the nitrogen cycle and its fixation in the soil via the electrical discharges. The students actively participated in the dynamic, exposing their doubts, and asking many questions. For this activity students of the class 302 that were not developing the IIR were also invited.

In the stage five of the IIR, the detailed opening of some black boxes took place. For the development of this stage we used about 8 class hours. In this period, we tried to answer some questions by identifying them with the appropriate curriculum components in connecting disciplines and their respective areas of knowledge. We tried to deepen the content related to the questions concerning the black boxes. Many relationships were built in the area of natural sciences, more specifically in the discipline of physics. Concepts of electrostatic were developed, such as the electric charge, the electrostatic force (principle of attraction and repulsion), conductors and insulators of electricity, electrification processes, Coulomb's law, electric field, etc. Also in stage five, we used a series of reports from the "Fantastic", a television program by Rede Globo, which was broadcast for three consecutive Sunday nights in February and March 2013. This series of reports was done with the collaboration of the National Institute for Space Research (INPE) and addressed the electrical discharges in a way to warn the population, in order to decrease the number of accidents related to them. The reports are available on the G1 website (G1, 2013).

In the layout of desired situation, stage six of the building of the IIR, teams tried to use the investigative research, deepening the subject in question, by means of digital technologies such as the Internet. The teams had autonomy to be creative in building material to be presented to their classmates and to teacher. The in-depth investigation into the subject was guided by the teams defined by the categorization of questions. Each team had 10 minutes to present. Each team tried to be creative in the layout of its presentation using slides, photos, videos, stories and songs. One team created a song which referred to the rays. This step had total duration of 3 class hours.

In the seventh stage, we tried to open some black boxes without the help of specialists, that is, to deepen understanding of some issues without consulting experts. We sought to relate some black boxes to the presentations of the teams and to the investigations carried out by the students, using scientific journals, books and newspapers. This stage took place in school and lasted one class hour. We tried in this stage to stimulate again the discussion on the subject.

In the eighth and final stage, the overview, students answered a questionnaire in the form of a report on the activities undertaken or carried out in the implementation of the IIR. We found via these reports some erroneous preconceptions that have been reinforced, if compared with the initial texts of the same students. The reports also helped in the search for more evidence of the occurrence of meaningful learning by students. Also, as a way to search for evidence on the occurrence of a meaningful learning by the high school students, in the quarterly evaluation, three objective questions about the electrical discharges were included. Another objective for the inclusion of the questions was to check the students' knowledge of the subject on external evaluation situations, since the quarterly evaluation questions were similar to the National High School Exam questions (ENEM) (Brazil, 1998b).

6 Results and Discussion

During the development of the proposal we got a lot of data via annotations and discussions with students in the classroom. All the development stages of the IIR were carried out in a successful way. From the individual questions of the students and the categorization made (step one), it was possible to highlight some previous knowledge and observe the various aspects of the topic in question that generated interest of students and that guided the investigative survey performed outside the classroom by them. The students, by request of the teacher, brought a small record about electrical discharges, to be shared and discussed in the large group (step two).

Most of the records were made from research conducted using the internet, particularly Google. These initial records show that our students have different interests, some tried to read more, some less, some sought to do read scientific papers, while others just used the first option that Google presented. We had students who copied in full a particular text that was on the internet, without having at least the concern of the formatting, or to quote the author, when the guidance given by the teacher was reading and paraphrased writing in his own handwriting. We observed that some students tried to watch the news to be aware of what happens around us and around the world, while others seemed to be completely uninformed and disinterested.

Consultation with specialists consisted of a completely new experience for students (stages three and four). In particular, the visit of the biology instructor from UCS allowed us to have knowledge of various "problems" faced by students in the classroom. On the occasion, students reported that they found many difficulties in the study of biology. They attributed these difficulties, to the way the teacher led the classes. Students reported that biology classes were conducted with authoritarianism and no opening for questioning. Moreover, they comment that the teacher treated the subjects covered in class without the concern of relating them to the student's daily life and using an excess of technical terms that were difficult to understand. In these classes, the students were mere listeners in the teaching and learning process, because they said that neither understood why they had to study those biology subjects which had nothing to do with their daily lives.

At the detailed opening of the black boxes (stage five), some fundamental contents were developed to understand how the electrical discharges occur, what are their consequences and why we should take some precautions. Some experimental activities, texts on the electrical discharges produced by INPE and the series of reports exhibited by the TV show "Fantastic" from Rede Globo were used. These activities complement the study of electrical discharges in a physical, social and economic context and helped in the study of the questions that had not been answered.

In the layout of the desired situation (stage six) students were able to put into practice the study of electrical discharges during classes and further deepen their knowledge through investigative research. In this stage, the students, divided into teams, prepared a presentation on one of the aspects categorized in stage two. On the suggestion of the class, there was the draw of the themes and of the presentation order. The presentation took place one week after the orientation of the activity. The creativity of the teams regarding the material organized for presentations surprised the teacher. Most of the teams used slide shows produced in PowerPoint, images, photographs, videos, stories and songs. One team built a presentation with images and the voice of one of its components narrating the situation. The presentations of all teams are available on the website: www.ilhasderacionalidade.com.br. This website was developed as the end product of research presented in this paper. The development of the website aimed to show in a simple way the building of the IIR about the theme "The electrical discharges in Brazil". The purpose of this product would be to inspire other teachers to use the methodology, or to get to know the IIR methodology, their application stages and references that can assist in getting to know it. By means of the presentations of the teams and the written reports, it was possible to observe evidences of the occurrence of meaningful learning by the students. It was also evidenced in the students' speeches, during presentations and during the post-presentation discussion, the confrontation of their initial knowledge with new concepts presented. Thus, we observed evidences that students were able to reevaluate what they already knew and anchor in this prior knowledge to the new knowledge on electrical discharges.

More complex concepts, such as the ascending rays (from the ground to the cloud), descendants (from the cloud to the ground) and streamers (the functioning of a lightning rod), and that, in the initial questions, were virtually absent, were present in the presentations and written reports. The active participation of students in various stages of the IIR and their presentations and written reports were an indication that there were changes in their previously existing subsumers and, hence, the occurrence of progressive differentiation process preconized by Ausubel (2000).

An infographic and a booklet available at INPE's website were used for the further development of some questions without consulting specialists (INPE, 2013). In this stage (stage seven), some black boxes were opened and related to the presentations of the students.

In the eighth and final stage, students answered a questionnaire in the form of a report on the activities carried out in the implementation of the IIR. This report aimed to seek subsidies for the improvement of IIR methodology application. In question number one ("*What we studied about the electrical discharges helps us to understand the world we inhabit and the context of technological progress examined?*"), all students answered that the studies on electrical discharges helped them to understand better the world in which they live and the natural phenomena with its purposes and consequences. As for question number two ("*What did you understand about the issues and factors studied on the electrical discharges in Brazil?*"), most of the students answered that they understood why Brazil is the champion in lightning discharges and on the appropriate ways to protect themselves to prevent accidents. Some said they had been surprised by the amount of people who die every year due to electrical discharges and the heavy losses caused by lightning in the country. In question three ("*Do you believe that the study of natural phenomena (physical, chemical, biological) or socio-cultural, political and economic issues, of our daily life can be important to your autonomy in the scientific-technical world and in the society in general?*"), most students said they believe the study of natural phenomena such as lightning, using new methodologies, can be of great help to the development of their autonomy in the scientific-technical world and in the society in general. In question four ("*In which the obtained knowledge can help us to discuss more accurately when making decisions?*"), most of the students said that the obtained knowledge can assist a lot in decision making, for example, in relation to security measures to prevent damage and accidents with lightning discharges on days when occur during electrical storms. In conclusion to the report and as answer to question number five ("*In which the knowledge obtained about the electrical discharges gives us a representation of our world and of our history that allows us to better situate ourselves and provide a real possibility of communication with others?*"), the students answered that the knowledge obtained on the electrical discharges may facilitate communication with family and friends, in order to discuss and guide people about the care we must take, for example, in an electrical storms. The analysis of the written reports also allows us to conclude that it was evident the occurrence of an integrative reconciliation, as students demonstrated through the answers to questions, a reorganization in the concepts learned, generating new meanings and relating the concepts to each other (Ausubel, 2000).

Finally, we observed that the great majority of students from class 301 showed a greater willingness to learn and to be active in the learning process than the students from class 302 students, who have not built the IIR. The quarterly evaluation results also confirmed, in a quantitative manner, the effectiveness of IIR methodology. Most of the students from class 301 (79%), who developed the methodology, answered satisfactorily at least two of the three questions on electrical discharges present in the quarterly assessment. While in class 302, which has not developed the methodology, the number of students who got at least two of the three questions was much lower (45%)

7 Final Remarks

The methodology of the Interdisciplinary Islands Rationality allows us to get rid of a completely disciplinary education, based on the memorization of a set of information, often meaningless to the student. The building of the IIR gives the student the opportunity to become literate scientifically and technologically, developing a different view about science and technology, as well as their relation to society, and being able to express and position themselves front of topics related to them with responsibility and autonomy.

In what concerns STEM education, according to Jolly (2014), “STEM is more than just a grouping of subject areas. It is a movement to develop the deep mathematical and scientific underpinnings students need to be competitive in the 21st-century workforce”. She lists six characteristics of a great STEM lesson, and based on these six characteristics, we can say that the building of an IIR can make possible all of them. In the IIR reported in this paper, we are aware that the study of the electrical dischargers at this school level doesn't apply rigorous mathematical models, but focused on real-world issues and problems, involved deeply the students in hands-on inquiry and open-ended exploration, engaged students in productive teamwork, and applied science content the students were learning.

The methodology of the IIR is not a ready recipe. The teacher has to empower himself and develop sensitivity to recognize a problematic-situation that is appropriate to assist in the exploration of a syllabus content and in the scientific and technological literacy of his students. The steps of the IIR are nothing more than active learning strategies that allow students to be the main actors of their learning processes.

The building of an IIR on "The electrical discharges in Brazil," made the students to research, to study, to debate on and to understand this climate and atmospheric phenomenon from a social, economic, environmental, geographical, historical, technological and physical point of view, and also as something very present in their daily lives. The building of this IIR also allowed us to conclude that despite the IIR are not established in the literature as an active learning methodology, the results of this work and our experience with active learning strategies allows us to consider the IIR as a promising active learning methodology not only for basic education but also for higher education. In summary, the IIR was a great methodology to promote the science and technology literacy, the autonomy and the meaningful learning of the students through an active learning environment.

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The Responsibilities of Learning

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Abstract

Learning is deeper and more lasting when the motivation is intrinsic, when motivation comes from the learner. Learners get more involved if they have the chance to choose, and can regulate themselves with autonomy, choosing the learning task that best fits their current understanding of the subject matter. Involvement fosters responsibility, which is what it is required to spend effort on other more demanding, or less attractive tasks.

We propose the three following statements for debate:

1.- Learning is intrinsically active.
2.- For learning to happen, learners must take up the responsibility of deciding what, when and how to learn.
3.- For learning to progress, learners must take up the responsibility of deciding when to keep studying a given subject matter, and when to move on to the next subject.

Most "teaching" institutions co-opt students from the above 3 requirements. Let's give those responsibilities back to learners!

As an example, we present a learning experience that took place at first year of Telecommunication Engineering at UPC BarcelonaTech. The course was about computer programming. It was a small group of 8 students. They were given full self-assessment responsibility the very first day. The result was that they assumed their learning responsibility successfully.

1 Introduction

The approach presented in this paper was run in June 2014 at the course Computer Programming 2, from the first year of Telecommunication Engineering degree at UPC Barcelona Tech. Students were confronted with the fact that the teaching institution had so far co-opted them from their responsibilities and, in this course, those responsibilities were given back to them. So they were forced to assume them, almost for the first time in their studies.

In the first place, they had to realize that nobody could “learn for them”, no matter what teachers or other people did. So, in one way or another, learning required them to be active. Next, they were shown, with examples from their own experience, that it is really hard to learn something if you are not interested in it, or if you are not yet ready for it (i.e. you don’t have the required background). So you must be able to decide what, how and when to learn.

Finally, we believe that the mere existence of selective assessment biases student activity toward mark-oriented, reward-based strategies. Those strategies lead to the paradoxical fact of considering that you have succeeded if you passed the exam, even when you are conscious that you don't know much.

This paper discusses the above mentioned responsibilities, and shows the results of the UPC Barcelona Tech course.

2 Learning is intrinsically active

The act of learning is subjective. It is something that happens inside the learner's mind and/or body. So nobody can "learn for another person". You can only learn by yourself. Therefore, there must be some sort of inner *action* for learning to happen.

Learning requires motivation, understanding, formative feed-back, and practice. And each of these stages is active. Through motivation, which is an attitude, the learner actually decides to get involved in the process of learning. Understanding requires that the learner "opens up" a mental window, focusing on what it is to be learned, so that the knowledge gets in, and accommodates with what is already there. Feed-back requires making hypothesis and validating them. And practice, leads to assimilation and automation.

If the learner does not assume the responsibility of learning, the above active processes won't happen.

In many institutions it is quite common to believe that learning takes place when the teacher lectures. Therefore, that is what most teachers do. Just lecture. And in this way, teachers often deprive learners from their responsibility. Yet, in the learner-subject-teacher triangle, the teacher is precisely the only one that is *dispensable*.

In conferences such as this one, when we talk about "active learning", we mean *active* activities designed to foster or facilitate some of the above stages of learning. Unfortunately, most often those activities are still designed by teachers, and not by students themselves, thus still depriving them from their autonomy.

Yet, learning is active, no matter what.

3 For learning to happen, learners must take up the responsibility of deciding what, when and how to learn

In many teaching institutions students sit and teachers have them attend pre-designed activities (either active or frontal). Usually, all students must go through exactly the same activities. Courses have closed programs, and degrees have a small proportion of elective subjects. Within a given subject matter, teachers assume the responsibility of deciding the sequentialization of the syllabus, the pace and timing of the matter, the form of presentation, the kind of exercises and activities that students must go through, and so on.

Some teachers and institutions even believe that this *must* be so for the sake of *equity*: because all students *must* be treated in the same way.

Understanding takes place when new information combines with what we already now and forms new concepts, either building on previous concepts or replacing them. Learning cannot happen in isolation, disconnected from previous knowledge. And learning cannot happen if learners are not ready, either because they are not attentive at the current moment, or because they have not yet assimilated the required previous knowledge, or because their previous knowledge is wrong, and the new information does not fit in.

Each student in a room is in a different point in their process of learning. A certain activity at a certain time will only benefit those students (if any) who are at the appropriate process of learning for that particular activity and in the right mood to engage in the activity. Having them all do the current activity at the same time is simply not efficient.

Moreover, *each student has his own learning style*. Some learn preferably from graphical information, others from definitions, others from examples, others from gestures, and so on. Once more, having them all do the same activity is simply not efficient.

If it made sense to speak of *items* of learning, then we can say that the learner is the only person who knows *what* to learn or which item to learn next: s/he simply must proceed with the item that "lets itself be learned" next. That is, the item for which the previous information is mature. Just like picking up and putting together the pieces of a puzzle.

Likewise, the learner is the only person who knows *when* to learn that item. Trying to learn it too early fails, because the previous information is not ready. The latest moment for an item to be learned, is when it becomes a requirement for the next item. And the fact of needing this item, is one of the major motivations for learning, because learning then makes sense.

Finally, *how* to learn an item depends strongly on the learning style of the learner. So the learner is the one who must learn to know the sources of information and learning activities that best suit him/her at each moment.

In a deeper sense, if people along their all learning career (in schools, colleges and universities), seldom get a chance to stop and focus on what they need, on what they have to do to get it, and on what they need to learn to do it, then they lose contact with their inner being, and they don't know anymore what they truly want. Then, they have to organise their lives according to mainstream criteria. That is why they often choose to study a career which is, supposedly, more likely to provide a good job. Rather than finding out their own *vocation*.

From this standpoint, people should be encouraged to decide on their learning goals and practical objectives, and to follow their own learning strategies. The problem is that most teachers and institutions do not seem to believe that 18 year old students are mature enough for that. Yet, babies and small children learn in an spontaneous way.

The surprising fact is that, when learning takes place out of learning institutions, most of us learn in the ways described above. That is, autonomously.

4 For learning to progress, learners must take up the responsibility of deciding when to keep studying a given subject matter, and when to move on to the next subject

Selective assessment is quite often counter-productive. That is, it does not help to improve learning. Let us consider exams for instance, as they are the most common strategy for selective assessment.

First of all, exams bias the focus from learning to passing the exam. Most students know that passing the exam does not often mean that they have learned. But yet, after passing the exam, nobody complains that they would like to keep learning or that they don't know enough. On the other side, most students know that knowing the subject well enough is not a guarantee for passing the exam. There can be many reasons for failing, other than not knowing the subject, such as not feeling well on the day or the exam, or misunderstanding what is being asked, or making mistakes on things that you new, which make you fail on a whole problem, and so on.

Students who fail while knowing something are forced to repeat the course from scratch. They are never asked to take it from where they reached the previous term. And students who passed while not knowing enough, are never given a second (free) chance to take the course again, that is, a second chance to learn. At most, they are given the chance to take a second exam.

Second, exams are considered to be *objective*, because all students have to answer the same questions. Here comes again the concept of *equity*. *All* students should be measured with the *same* test. But other than the test itself, there is nothing objective in an exam. Students are different from each other, teachers who mark exams mark differently, students feel differently on the day of the exam, some may me sick, some may be more focused than others. Some may feel nervous.

Third, the teacher judges what is written without knowing the *intention* of the student, and mistakes are confused with misunderstandings. Usually, students have to guess what the teacher expects them to answer, and exams are often designed with only a valid solution: the one expected by the teacher. Sometimes students guess the right answer, without really understanding why.

Moreover, some teachers seem to believe that students should be particularly brilliant and creative, precisely on the day of the exam, rather than showing their knowledge on the main concepts of the subject.

Finally, nobody ever asks the students what is the way in which they would like to show what they know (a picture, a definition, a piece of code, etc.), even though students have their preferred ways of expressing themselves

As a result, institutional learning is often about learning how to answer exams. And those students with that skill are the once who have most chances. Many students learn mechanically to solve the kind of exams that teachers usually ask, and private academies teach students explicitly how to pass exams from a particular teacher. Given the syllabus, almost all students know what is going to appear in the exam, and the exam itself becomes the learning objective. The most precious learning material is an exam from the previous term, with the teacher's "correct" solution and institutions collect them as something that students have the right to have.

Measuring student knowledge is an aberration in the first place. *Knowledge can not be measured*. Only learners themselves can have an idea of what they really know and what they know not, and this is not always so. Knowing what you know, by itself, it is knowing a lot. But nobody can get into you mind. Then, knowledge is measured in terms of behavioural (usually written) tests that students are obliged to solve. And institutions take over the responsibility of deciding and accredit if students know enough.

Then, since students want their degree, and the rule is passing those exams, everything counts. Institutions, then, write regulations in order to rule out *fraudulent behaviour* from students. Thus, fraudulent behaviour is considered wrong because of the fact that *rules should not be broken* (righteousness). When the actual problem with faking in exams is that *the student misses the opportunity to learn*.

Exams (and numerical assessment in general) are an extreme case of *reductionism*. A 3 or 4 pages text written by the student must be reduced into a two-figure mark. How is that possible? Then teachers, always for the sake of equity, create correction *algorithms* from which to derive marks.

Since the responsibility for learning has been co-opted from students, both students and teachers externalise their faults. When failing, teachers say that students don't work and don't know enough, students blame their teachers because the exam was so difficult or out of scope.

If you like skiing, whose is the responsibility of improving your skill? Who does it benefit? Would you stop practicing because someone says you are doing quite well? Would you fake that you are doing well?

5 A practical example: the course at UPC Barcelona Tech

In first year Computer Programming 2, in UPC Barcelona Tech we had a group of 8 students who had failed the term with a mark above 3/10 (5/10 would pass the course). We posed the above questions to them: who has the right to tell you what to do to learn? Whose responsibility is it to arrange and serialize your learning activities? Whose responsibility is it to decide if you know enough to pass the course? How should you show what you know? and so on.

So we decided to give them a “free-ticket”, and to allow them to set their marks themselves. They were explicitly given the chance to set themselves a good mark, and forget about the course, right the very first day. But nobody left, they all stayed and realized that learning was not only their responsibility, but most of all, they realized that learning was in their benefit.

So they had a few meetings together and decided to learn programming by writing a small program by themselves. Each of them helped the others, and the teachers were there to help them along the project. All of them managed to write a small, yet illustrative program, and they all showed their satisfaction of having learned, and having learned by themselves.

6 Conclusions

Having teachers and institutions decide what students should know is one of the major difficulties for active and autonomous learning. Teaching is then forced to be the same for them all, and they all must show their performance against a standard test. Students are therefore deprived of their responsibility to decide what to learn, and when to stop learning a particular subject.

In our institutions, equity stands over justice. Yet, as the saying goes, *there is no major injustice than treating different people in the same way*.

Introducing Generic Skills In A First-Year Engineering Course

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Abstract

New curriculum of Computer Science Engineering at the University of Concepción, first applied in 2011, which is based on competences and learning outcomes, includes two courses in the first year: Taller de Ingeniería I and Taller de Ingeniería II, both with the next two main objectives:

- Bringing students to engineering and, in particular, to the context of the computer engineering, and
- Introduce, at conceptual and cognitive levels, generic skills declared in our new curriculum.

In this work, we are going to present aspects of definition, implementation and results of the course Taller de Ingeniería II during the last three years (2012-2014). We refer in particular to:

- Definition of the course, which is based on Creativity, Innovation and Entrepreneurship concepts
- Methodologies, since it considers only active learning methods
- Evaluation using rubrics to assess performance in activities aimed at strengthening critical thinking, teamwork, communication and information analysis skills, among others.
- Logistics, since the nature of the course requires the availability of a team multidisciplinary support.
- Results, as it has lots of observable material.
- Changes to be introduced in the future, due Faculty of Engineering at the University of Concepción will apply a similar experience with freshmen in all their 13 engineering majors.

1 Introduction

Most of engineering students at the University of Concepción have, in their first year, just courses of Calculus, Algebra, Physics and/or Chemistry. These courses are extremely difficult and does not allow students visualize what they will do in their future profession. This situation have produced a lack of motivation in students, which resulted in a retention rate of only 60%.

To mitigate the impact of this situation, at the Computer Science Department have created a new curriculum, which is based on competences and learning outcomes, that incorporates two new courses in the first year: Taller de Ingeniería I, a freshmen seminar that introduces students to areas of emphasis of computer science through presentations by academics and outside speakers, emphasizes career opportunities, professional ethics and practices, history of the profession, and resources for academic success; and Taller de Ingeniería II, where first-year students are faced with teamwork, preparation of technical reports, process design and solving real engineering design problems. In this paper we describe the main aspects of the definition and implementation of this second course, besides complementing information about results of its application in the past three years.

Our proposal was inspired in a similar experience carried out at University of Colorado (ITLL, 2015) with their freshmen and second-year engineering students whose activities and main concepts associated are reported in (Abarca *et al.,* 2000).

In the next chapter you will find aspects of the definition of the course Taller de Ingeniería II. In Chapter 3 we presents a description of the activities, the ways to evaluate them and some observable results about them. In Chapter 4 is shown some general observed results about the course and our students.

Taller de Ingeniería II

The main goal of our second introduction course is motivate students to get involved in his major by searching for solutions to problems with engineering approach. In this sense, the competences we expect our students to develop in this course are:

- Application of mathematics principles, engineering sciences and computer science to problems of engineering
- Identification of user's needs, from which conceive, designs and implements solutions that meet the specifications.
- Develop team work skills to solve problems in a collaborative way, especially in a multidisciplinary team
- Understand, manage and communicate effectively in the work environments delimited by the professional and ethical responsibility.
- Engage in continuous self-learning processes enabling it to adapt to the evolution of the theory and technology

Learning outcomes

Competencies are general descriptions of the skills we expect our students to develop in their university career. Then it need to specify more precisely the technical and generic skills we expect students to develop in the course, these are the learning outcomes. Thus, at the end of the course students must be able of:

- Propose solutions to problems with engineering approach
- Effectively communicate the solutions to the problems in oral and written form
- Work as a (multidisciplinary) team to solve problems
- Analyse problems using the most appropriate techniques in accordance with the proposed objectives
- Define the problems and their causes with sufficient breadth to generate feasible alternatives of solution.
- Select, between different alternatives, an optimal solution to a problem.

The last three learning outcome encompass aspects of the engineering design stage.

To be specific, we have determined that the learning outcomes of the course can be reached with a list of activities to help us develop in students the following summary list of skills:

- **Information seeking and analysis skills** (IS&A): Professionals and students can possess some tools and technical knowledge to solve their problems but almost always it will be necessary to resort to new sources of information that provide new knowledge about the problem to be solved. The ability to do this efficiently and effectively is essential in an engineer.
- **Teamwork Skills** (TWS) Many of the problems faced by engineers require the collaboration of many people of different specialities, therefore, to develop team work skills is fundamental to an engineer.

- **Communication Skills** (CS): Communication skills are not only a useful tool for engineers, the singular is that in those determine the success of the projects, from the stage of convinced investors to clear specification of the design to its implementation and operation.
- **Design Skills** (DS): Design is the creation of a plan or convention for the construction of an object or a system. More formally design has been defined as a specification of an object, manifested by an agent, intended to accomplish goals, in a particular environment, using a set of primitive components, satisfying a set of requirements, subject to constraints. An engineer or engineering student must learn how to design in earlier stage of their formation.

Activities

We have though in 6 activities that allow our student reach the skills reported before, these activities are;

Mystery Artifact Challenge (MAC), Teamwork Activity (TWA), Requirement Specification Activity (RSA), Interest Group Activity (IGA), Design Activity (DA) and Final Project Activity (FPA).

In the next table we report how the different activities developed in the course Taller de Ingeniería II contribute to the skills that we want to foster in our students. Just as reference, for example, MAC contribute to develop information seeking and analysis, teamwork and communications skills,

Activities/Learning Outcomes	IS&AS	TWS	CS	DS
MAC	X	X	X	
TWA		X		
RSA		X	X	X
IGA	X	X	X	
DA		X	X	X
FPA	X	X	X	X

2 A Brief Description of Activities

In the next section we are going to describe some of the activities developed in the Taller de Ingeniería II course.

Mystery Artifact Challenge

This exercise is used as an introduction to the reverse engineering process. It provides an initial opportunity for team members to work together to solve an open-ended problem.

Our mystery artifact challenge, is an activity inspired in a similar one described in (Abarca et al., 2000). In this activity students are organized in teams, each of them are given an artifact upon which, after a thorough investigation, must answer the following questions: what is the artifact?, how it is work?, which is its function?, etc. Some artifact that we have used in past are an arithmetic machine from 1800s, a stem of a diesel engine injector needle, an electric transformer, a piece and circuits from a trackball, etc.

The MAC takes two weeks, the first is used to *explain the exercise, to submit the artifacts, students* to make consultations on the assigned artifacts and to stablish hypothesis and to plan the information seeking (see figure 1). In the second week, all teams must make a presentation regarding the assigned device.

This activity assesses teamwork (stated by the Professor and his assistants in the room) more a self-assessment and evaluation between peers by the students themselves. Communication skills are assessed during the presentation of the mysterious object. For teamwork and communication skills we use rubrics that we allow assess communication skills for both one and the other

Although it is not the objective of the activity, over 90% of the artifacts have been positively recognized.

Figure 1. Students in a MAC activity

Teamwork activity

Teamwork is a collaboration effort carried out between members of a working group in order to achieve common goals. When there is not teamwork, members of a group have difficulty completing their tasks effectively and often struggle with no clear objective. On the other hand, teamworks catapult its members to competition as a result of his character cohesive. Teamwork is an important aspect of any successful organization.

This is an activity of two classes, one hour one in which associated concepts as leadership, integration, cooperation, contribution, etc., are exposed and explained and another three hours class in which students participates in 5 or 6 outdoor games as a way to promote teamwork performed by different groups. Some of these games have been called Trasvasijar (to pour into another container), Minefield, Collectors Treasury, Crossing the pond, River Crossing, Electric Fence and Air Collectors. As a reference, the River Crossing game is described in the next:

> **Objetive**: To help one family composed by a father (80Kg), a mother (80Kg), twin brothers (40Kg each), a baby and a small pet dog to cross a river with a raft with 80 Kg as maximum capacity.
>
> **Instructions**: In teams of 7-9 members, each group will be provided with a sheet of paper and a pencil. In a maximum of five minutes the groups should designate roles (parent, child 1 child 2 baby and pet). These roles must be made by the members of each team in a visible area of your body. At the same time, each team must plan and write clear and precise and feasible for all family members to cross the river plan. Consider that the raft should not charge more than 80Kg and that neither the baby nor the pet can be alone anywhere.
>
> As each team has its plan should deliver a moderator, who will determine if the plan is readable (that is) and feasible or should do it again.

When all plans are delivered or expiration of the time for planning teams will be able to execute your plan, getting the win the team that has delivered its first feasible plan.

Learning: This activity shows what constitutes a feasible solution to a problem of limited resources and how team members must assume different roles at different times to keep within capacity of the resource (in this case the raft). Finally, we demonstrate the effects of pressure to deliver something before the competition, which is the day to day business. Often the first company that serves the requirements of a market which is victorious. Also respond before all but evil can bring negative consequences

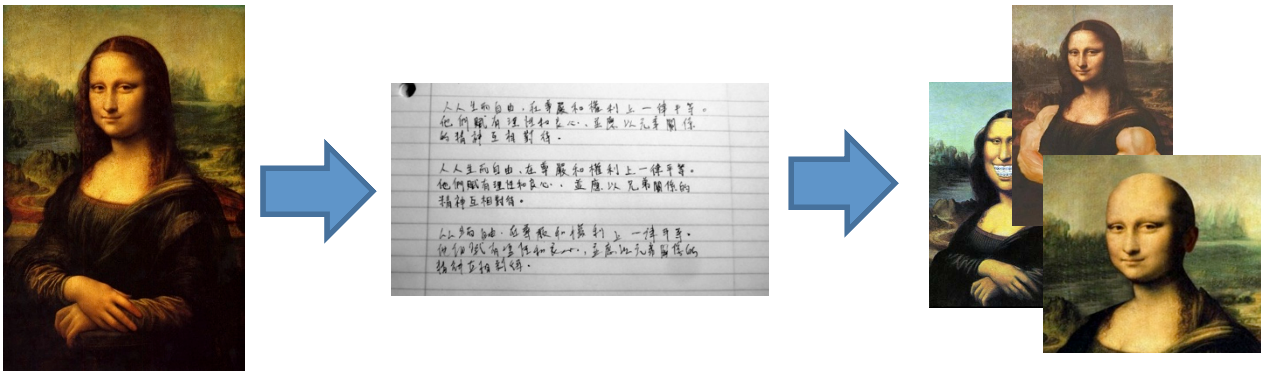
Figure 2. Students participating in different teamwork activities

Requirement Specification Activity

Software Engineering (SE) is an engineering discipline concerning all aspects of software production. Software engineers adopt a systematic approach to carry out its work and use tools and techniques required to solve the problem posed, according to restrictions development and resources available. Requirement specification is a SE stage in which customers and engineers fix or determine, precisely, needs or desires of users on each part of the information system to automate. The success in the development of this stage determines the time and effort of total project development, also reduces the cost of debugging and associated risks.

The requirements specification is not without difficulties, one of them has to do with communication between engineers (technical language) and customers (own language problem). To show how the lack of a common language between engineers and clients phenomenon can affect to a SE project, we have created the following activity: The students, organized in groups of 5 students receive an image (picture) that will have to describe as fully as possible, creating a system to specify them if necessary. Once after a predetermined time limit or having all the teams finished with the descriptions will be exchanged for each team play, based on the description that has been responsible for a drawing.

To end the activity photographs will be compared with reproductions produced by the teams, this comparison constituting a part of the assessment work equipment produced by each team.



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他們賦有理性和良心，並應以兄弟關係的
精神互相對待。

DESIGN DESCRIPTION RESULTS

Figure 3. Requirement Specification Activity

Interest Group Activity

Individuals or groups of individuals can affect or to be affected by a company, government or other organization. In response, they can legitimately make demands on the organization, generating dependencies that are dynamic in time, as individuals or groups of individuals pursuing their own interests and often these are conflicting.

This phenomenon is typical in relations between business owners and their customers, while the former seeking better prices to maximize profitability the second ones want lower prices and higher quality.

In Chile, a problem that has always involved conflict of interest has occurred against the installation of any power generation system. In this scenario, companies, the government, the inhabitants of the area affected by the installation of central power generation, political, environmental organizations, consumers and other stakeholders face many demands or interests.

In this context, the work done by students in the course is given a quota national problem (in the last two years has been selected Chilean Educational Reform), determine:

How did the problem begin?

Who are the stakeholders?

What everyone thinks? What affects them?

What are the balances between them? What interest groups have more power and what that kind of power?

Is it possible to reconcile the wishes of the different interest groups?

etc.

The research must involve finding technical information, data media, expert opinions, interviews with representatives of interest groups and the very position of the team regarding the problem. All information collected should be summarized in a report and defend positions on each team (group dynamics).

3.5 Final Project

The last 6-8 weeks of the course are aimed at the realization of the final project. This involves automating a process or the creation of a mechanism using Arduino. The kits have used a programmable microcontroller Arduino language (similar to C language) and a set of sensors and actuators. The timeline for this project is as follows: in weeks 1 and 2 induction kit is made, with demonstrations of their use and basic training in electronics and programming circuitry. In parallel, each team consisting of 6-8 students must conceive a project that can be used in these kits. In the third week the proposal must be fully defined and each team must report in the specification document the problem to solve. Below and to the penultimate week the teams are free to design, implement and document the history of your project. Finally, in the last week each team must make a presentation of their project in front of their fellow students and other invited guests (teachers, senior pupils, etc.).

Figure 4. Students at the Final Project Activity

3 Conclusions and Future Work

Although not conclusive that is due to the impact of introductory courses described, career managers have observed a substantial improvement in the retention rate, which has risen to almost 80%. Further study on the reasons that have improved this indicator is pending.

In terms of logistics, completing the course Taller de Ingeniería II has required increasing the number of tutors (senior pupils who collaborate with the course) not only in number but included specialties, i.e., today we collaborate with the course tutors who come from areas such as electronics, information, education and psychology.

Finally, the success of these courses has been recognized in the Faculty of Engineering of the University of Concepción, so much so that since 2015 has started a similar course will be aimed at students in the 13 engineering specialities taught in this Faculty, favouring in the first instance to 120 students and waiting extend the offer to 1000 freshmen students.

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Papers and extended abstracts from the Poster presentation

Peer and Self-Assessment of Teamwork Collaboration Competencies

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Abstract

The ability to collaborate in teams is a central learning objective in a course for students enrolled in the elective 6th semester Civil Engineering Program. Therefore, methods for project management and team collaboration were facilitated through a designated course. The teamwork collaboration competencies of each student are, however, very difficult to assess for external supervisors not being part of the team. As a consequence, a model for peer and self-assessment of this competence was included as a central part of the course assessment.

Each team of 4 persons had a facilitated process of making an Agreement of Collaboration (AC) for the project, including listing of values, norms and rules defining their mutual understanding of *good teamwork behavior*. The AC was discussed with the supervisors and finally signed by each member of the team.

At the completion of the project period each team member was asked to assess (grade and motivate) their own and their team mates' compliance with the AC during the project period. The grading process was confidential. The peer assessment contributed to 50 % of the final course grade.

The result of the assessment shows that no students gave higher grades to themselves than the average grade they received from their team mates. There was only a little difference in team mates' grading of a given fellow team mate. Students expressed that the work with the AC was useful for the teamwork process, and that the peer assessment process had a positive effect on their own and the team's joint performance.

1 Introduction

At Aarhus University School of Engineering (ASE) a 6th semester elective package of courses and a project (totaling 30 ECTS-credits) in Wastewater Engineering is offered to Danish and international students (Maribo & Nielsen, 2002). The semester includes 15 ECTS-credits of courses primarily in the first 7 weeks of the semester, and a 15 ECTS-credit team based project, primarily in the last 7 weeks of the semester. The objective of one course (CCCP of 5 ECTS) is to enable the students to become effective team workers in a cross-cultural project based learning (PBL) environment. In half of the CCCP course, students work with theories and methods for planning and managing a project, and methods for how to use the potential of a team and become an effective learner and performer in this setting. The CCCP course addresses central challenges of PBL as described in e.g. Holgaard et al (2014) and Dahl et al (2012), such as ice-breaking and adaptation, management of time and resources, use of a team role model for insight in team potential (Belbin, 2004), goal-setting, sharing of expectations, communication and conflict management. One central learning objective is to set common standards for the team collaboration in an operational way in an Agreement of Collaboration (AC), and to demonstrate ability to collaborate according to the set standard, and during the project period to experiment with ways to improve collaboration in the team.

In a number of years the assessment of the students' achievements in the CCCP course has been on a pass/fail basis. The condition for getting a pass was minimum 80 % participation in learning activities and a qualified process report with reflections on the team process. Two years ago it was decided that students should be given an individual grade as part of the course assessment.

So the challenge in the CCCP course was how the central collaboration ability could be assessed (graded). And how this assessment could be done in accordance with the concept of constructive alignment as introduced by Biggs (2003), so the assessment method would be aligned with and motivate the learning, in this case support the team collaboration.

Motivated by the work reported by Farreras & Bofill (2012), in which a process where students themselves define the criteria for good teamwork collaboration, and define criteria for a future self-assessment of their teamwork, it was decided to use a similar approach. The idea is that only the one that wears the shoe knows where it hurts. Or in this case: only the members of a team are able to assess how well each member of the team has been collaborating in the team. Outsiders, such as staff, will only have a limited and inadequate view of what has been going on in the group, and an outsider, who has not been defining the criteria for good teamwork collaboration, would also potentially have a different understanding of this than those inside the team.

It was decided that the assessment of the collaboration competencies was to be made as a peer assessment on the basis of the team's own definition of "good teamwork behavior", defined in an Agreement of Collaboration (AC). The specific meaning of good teamwork behavior was left to the teams themselves to define. In facilitated sessions the teams should make an Agreement of Collaboration (AC) stating the team overall values and objectives, norms, and specific rules for the collaboration. This work included sharing of expectations and experiences, and discussions on issues such as: how are decisions made, delegation of work and quality assurance, meeting culture and other issues. The AC defined the team's understanding of good teamwork behavior, and was to be agreed upon and signed by all team members.

The assumption is that this approach has several advantages from having a general premade definition of good teamwork behavior and having external (staff) facilitators assessing the team member's performance:

a) The process of making the AC would enable the students to share and reflect on values, norms and rules that would be central to them as basis for their teamwork. This should be an important help in getting the team off on a god start and be a tool for improving the collaboration in the team. This is supported by PBL literature, e.g. Kolmos *et al* (2008) and Holgaard *et al* (2014).
b) Definition of good teamwork behavior may differ from team to team, and the process of defining it is important in understanding it and committing to comply with it, as reported by Farreras & Bofill (2012).
c) Defining the criteria for the assessment themselves will make the peer assessment a meaningful and reasonable tool for assessing the collaboration competence.
d) Knowing that individual performance in the teams will become assessed, will encourage students to more commitment to the team and compliance with the AC.
e) In relation to the collaboration process, the supervisor can be used more openly to assist in finding ways to improve the collaboration, since he/she is not at the same time assessing the student's performance in the team.
f) Having the students use the Danish ECTS 7-point grading scale should make them more confident with the meaning of this scale.

It was decided to evaluate the peer assessment process by an anonymous questionnaire at the end of the semester, addressing the students' perception of the accomplishment of the objectives described in the above assumptions a), c) and d). It has not been the objective to assess the validity of the students' peer assessment of the collaboration competencies as such.

2 The peer and self-assessment process

At the beginning of the semester students were presented with the method for the peer assessment of the CCCP course, including the requirement to the Process Report and the peer assessment form.

The peer (team mate) assessment was performed after the students had handed in their project report, but – for practical reasons - before the project exam. It was made clear to the students that the assessment form received from each student would be treated with confidentiality. No information from the students' assessment of team mates would be disclosed to fellow students or third parties, unless in a processed and anonymized form. If students would choose voluntarily to share information on their mutual assessment of each other, they could choose to do so.

With reference to the team AC and defined standards for *good team mate behavior* students were asked to give a grade - and optionally to motivate their grade with a few comments – to:

1. The team performance as a whole ("…rating of your team's overall ability to collaborate in the project period")
2. Assessment of each fellow team mate individually ("..your rating [of team mates] should be based on your evaluation of your team mates' ability to comply with the collaboration standards stated in your AC")
3. Self-assessment ("My own performance in relation to the standards set in the AC")

Students were informed that in case "large discrepancies between assessments of a specific team member appear, I will take a short individual talk with the persons involved to clarify the matter". Receiving the team mate assessments I did not find it necessary to do so.

Furthermore, all teams handed in a short Process Report with reflections on the project process and enclosures such as AC (with reflections on the usability of this), team role analysis and team profile, Gant chart for the project, scheme for QA, timetable, samples of minutes from project meetings. This report was mandatory, and besides being a learning experience for the students, it also served as background information in case of large discrepancies in the peer assessment.

Following the peer assessment and after the project exam, students have been asked to evaluate and comment on how the work with the AC and the team mate assessment has influenced their performance in their team.

3 AC as a tool and students' perception of the usability of this

Initiated by a class discussion on what characterizes good team behavior and sharing of mutual experiences and expectations to teamwork, each team drafted an AC including values, norms and rules for the collaboration. The AC was qualified through discussions, and efforts were made to identify observable indicators for behavior that would indicate compliance or non-compliance with team values (box 1). The AC was signed by all team members, thereby committing each other to follow the AC.

Values and norms:

- “We work for a high grade report”
- “All team members must help each other in order to reduce… stress”
- “Be polite and ready to be criticized”
- “Take initiative”
- “Liability: All team members agree to follow through with commitments and take responsibility for their work and behaviour.”
- “Be prepared”

Rules:

- “Chairman on rotational basis, one week at a time. The chairman must organize e.g. meetings, the topics to prepare.”
- “All team members should be present and participate in the project meetings…”
- “All group members must come prepared to all meetings and work sessions, having done what they are required to do before certain deadlines.”

Box 1. Example of values, norms and rules from team ACs.

Reflections in the Process Report on the usability of the AC point to the AC being a valuable tool for the teams. The following are some characteristic statements:

- “In my opinion the AC was very useful at the beginning of the project work…”
- “To be honest no one looked at the AC after we made it… looking back we can see that all respected it and followed the rules.”
- “…probably because the AC was written before we started with the project, it didn’t apply 100% to the actual working situation and was a bit too theoretical. Maybe such an AC should be revised from time to time… Nevertheless, we would establish for further collaboration such a learning agreement … since it absolutely did help us.”

Directly asked (with 4 possible choices of answers) the usefulness of the AC was confirmed by the students (Fig 1).

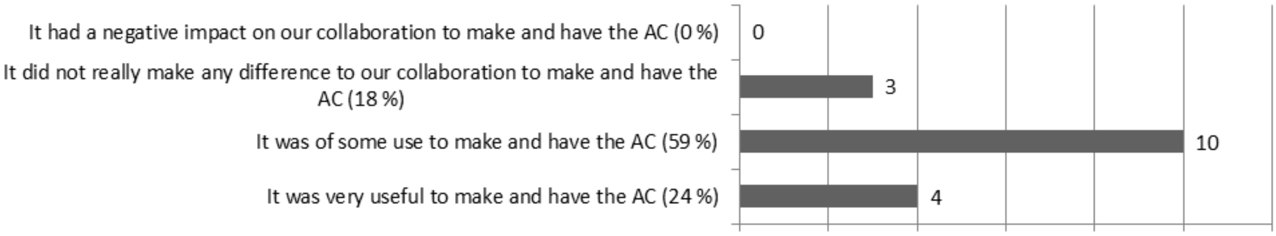

Figure 1. Students’ response to the question “How useful did you find the AC for your collaboration during the project period?” (17 students out of totally 24 responded).

4 Peer assessment results and the students’ evaluation of the process

The peer and self-assessment showed some interesting results:

- All students gave fellow team members grades from average and up (i.e. 7, 10 and 12 on the Danish scale. The Danish grading scale is a 7-point scale with the following grades: 12(A), 10(B), 7(C), 4(D), 02(E), 00(Fx) and -3(F). Letters in parentheses are the equivalent ECTS grades).
- No students self-assessed their own grades higher that the average peer assessment.
- Variation between peer assessments of the same fellow student was not higher than +/- one (1) grade level.

Examples of four groups' assessment of each other can be seen in table 3.

Table 3: Result of peer and self-assessment from four teams. *A, B…P*: students. Grade in (): self-assessment. FG: given final grade point, average of peer assessments. TR: student assessment of the team's overall performance. ECTS conversion: 12=A; 10=B; 7=C; 4=D; 02=E; 00=Fx; -3=F.

Team 1		Assessed student				
		A	*B*	*C*	*D*	TR
Assessing student	*A*	(10)	10	10	12	12
	B	12	(10)	10	12	7
	C	10	10	(10)	10	10
	D	10	10	7	(10)	10
	FG	10	10	10	12	

Team 2		Assessed student				
		E	*F*	*G*	*H*	TR
Assessing student	*E*	(4)	12	12	12	10
	F	7	(12)	12	12	12
	G	7	12	(12)	12	10
	H	7	12	12	(12)	12
	FG	7	12	12	12	

Team 3		Assessed student				
		I	*J*	*K*	*L*	TR
Assessing student	*I*	(7)	10	10	7	10
	J	10	(10)	12	7	10
	K	10	10	(12)	7	10
	L	12	12	12	(7)	12
	FG	10	10	12	7	

Team 4		Assessed student				
		M	*N*	*O*	*P*	TR
Assessing student	*M*	(7)	10	10	12	12
	N	10	(10)	10	12	12
	O	10	10	(10)	10	12
	P	10	10	7	(10)	12
	FG	10	10	10	12	

The assessments in the four teams shown in table 3 are characteristic examples of the pattern in the team mate assessment. Students E and L are generally rated low compared to team average. Comments from the two teams and the two students in question reveal a joint understanding of the reason, and this is confirmed by the self-assessment of the two respective students. Team 2 shows full agreement in the peer assessment, and Teams 1, 3 and 4 show minor variations in the assessment, but generally the team mate assessment is consistent and relatively high.

The process reports reveal that all teams were functioning without major conflicts. Teams rated their performance as team from middle to very high.

After the end of the semester the students were individually asked how the knowledge about the final peer assessment element influenced their own and the overall team performance (figure 4).

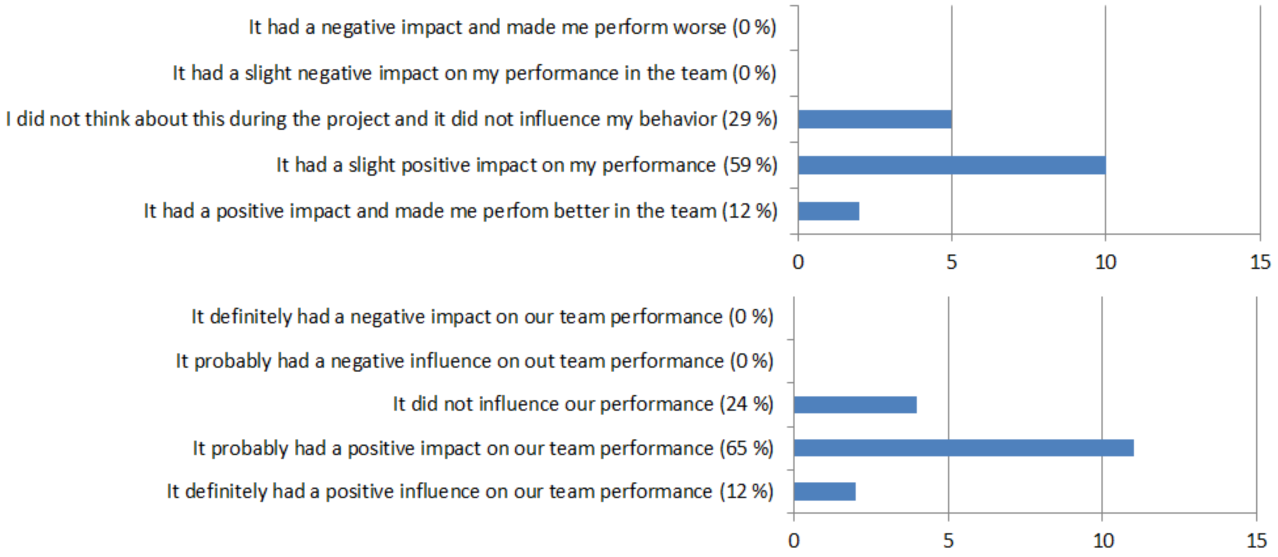

Figure 4. Answers to questions regarding the peer assessment process: A) How did it influence your own performance in the team that you knew this would be evaluated by your team mates at the end of the semester? B) How do you think it influenced your team's performance that you had to assess each other at the end of the project? (17 students out of totally 24 responded).

It is notable that all respondents indicate a neutral to positive effect of the assessment on their personal performance in the team, and even stronger positive effect on their team's performance. Most students' comments were positive to the peer assessment element, but also slightly negative comments were given, e.g.: *"I do believe it pushes some people to do better. It depends on the character of the person. I also think it is a bit delicate sometimes to give a mark to your team mates. I, personally, am not a big fan of it."*

5 Conclusion

Using an AC is by students seen as a positive instrument to support collaboration and team performance. Students' comments point to the fact that the effect of the AC probably could be higher, if it was discussed and revised half way in the project period and not just in the beginning.

The peer assessment of fellow teammates' performances is by students seen as a supportive assessment tool. No self-assessment is higher than the joint team's peer assessment of a given student. This indicates a tendency to be nice to your team mates. This is probably the case in teams that have been able to function and manage problems and challenges. There are only small variations between peer assessments of the same team member, and between the average of peer assessments and the self-assessment of a given student. Based on this it is fair to conclude that the assessment model seems to be in accordance with the set objectives. Whether the peer assessment as quality control of the students' compliance with the collaboration learning requirement as instrument is precise can be questioned, but since these standards are set by teams, and the fulfillment is experienced primarily by the team, the peer assessment must be the most reasonable approach. The peer grading seems to result in grades on the high side. The students' response indicates that the assessment fulfills other purposes such as providing feedback, and it aligns with the learning objective, by stimulating their own and the team's performance. This was one of the key reasons to introduce the CCCP course, so the assessment process appears to support the learning objective.

The use of comments given to motivate the grading is important, in particular if big variations between self-assessment and peer assessment appear, and if big variations in the assessment of one particular student appear in a team. The Process Report can also be an important tool to understand discrepancies and therefore be useful in the final assessment of the individual students.

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Autonomous learning combining research and engineering projects

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Extended Abstract

Stating the contents of Advanced Audio-visual Systems is not an obvious task, as the related technology is in a continuous changing process. Stating a stable set of contents for this course will make it to become obsolete shortly. Advance Audio-visual Systems is a last year course in Sound and Image in Telecommunication Engineering degree, so the design of this course has not to be compulsory content-centred. The course is organized giving students a great level of autonomy, based on the development of different projects, focusing in the type of work more than in the content itself. The main goal behind this approach can be summarized in two lines. On the one hand, students can focus their work on their own area of interest, resulting in a high level of motivation. On the other hand, promoting a realistic engineering environment implies that many engineering skills are developed. When presenting a course based in these main ideas, some questions appear unavoidably. If the student can choose the contents to work in, will his/her learning be incomplete? Is it 'fear' to assess and grade students who have been working in different contents? The answer of this questions will depend on the confident one is in PBL and other active learning strategies. Being used to work with active learning schemes, is easy to answer these two questions with No and Yes respectively. Contents are, in my opinion, in a second plane, behind getting other engineering skills, as having the ability of being able to autonomously follow and adapt to technology evolution. Assessment issues will disappear when content is no longer the central aspect of the course.

The benefits of working in PBL environment are well known, but the specific results will highly depend on project details. The specific skills worked when developing a project with a high level of practical implementation will differ from the ones when performing a project based mainly in literature review and theoretical maths. Combining the outcomes of different project types with the general PBL benefits it will be possible to define a custom set of goals. The expected results of the course include, a high level of engagement, responsibility, state of the art audio-visual technology knowledge, teamwork and communication skills. Besides, as students are not used to have decision-making possibilities, the perspective of being autonomous is a new challenge for them, being another engagement factor.

The final course structure is constructed under a three projects scaffold. Each team will have to develop three different types of projects. One is based on a difficult research problem with a final stage of proposing, programming and testing a working algorithm. The second is a case study or bibliographic review centred in state-of-the-art technological developments. The third one pretends to solve a practical engineering project. All three projects allow the students enough freedom to fit their work with their own concerns.

The average results are impressive, both in terms of student's implications and concerning the quality of the projects developed. There are groups showing a lower performance, but the general results present a high level. Students' opinion is also encouraging referring course approach and their own work as well. As a sample, this is an excerpt of one student's opinion: "*I will like to thank you your effort of taking into account students' opinion. (...) Speaking on behalf of my classmates I can say that this is one of the most attractive courses in the whole degree. (...) I have been aware of having a very complete and useful learning process and well-focussed to real working environment*".

Design and implementation of a simulation game for the acquisition of skills and competencies in the process of execution of Continuous Improvement projects

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Abstract

The application of simulation games in an industrial environment is a powerful tool to improve the learning process. This tool lets the assimilation of knowledge in an organization's members, which certainly leads to acquire and strengthen their skills. Simulated games, offer the participants the possibility to develop their potential and they can be trained properly to perform their productive tasks. This paper reports the application of a very basic simulation game, in an industrial environment practice, where it simulates an industrial cutting process. To carried out the simulation game has been used an adapted version of the Six Sigma methodology, called DMAIC - 7P (Define, Measure, Analyze, Improve, Consolidate, Standardize and Reflect), these methodology is a systematic approach to improving the product or process to meet customer requirements. With these simulation games participants are given the opportunity to implement their potential and develop their production and quality management activities, allowing them to have a clear vision how to manage the resources that are available and help them develop communication, creativity, negotiation and problem solving skills.

KEYWORDS**:** Training people, simulation game, continuous improvement, six sigma

1 Introduction: Simulation game in industrial environments

Nowadays the answer to the companies need for growing to become more competitive and adapt to the current global context, is to adjust to the demands and requirements of customers, controlling and setting production processes. For this reason the application of simulation games becomes a valuable resource to generate a change in companies, creating an appropriate atmosphere for to learning, creativity and where practical knowledge and decision making is transferred.

A game is an activity that involves a set of decisions made by the players and is focused on achieving the objectives that are developed, in a specific context (Abt, 1970). Players are involved in an artificial conflict with defined rules and measurable results (Salen, 2004). Targets and rules are defined and different ideas followed-up (Parlett, 1999).

Games represent an essential element in human culture which helps the learning process. According to Huizinga, games should have six fundamental characteristics (Huizinga ,1971):

1. Optional (playing is optional and not required),
2. Set in space and time
3. Has an uncertain development
4. Unproductive
5. Ruled

6. It is a simulation (it is a representation of a real-life event).

A simulation game is defined as the process of designing a model that represents a real system. It covers a set of experiments in order to understand how the system works. And evaluate various strategies to deploy it (Shannon, 1975). For this, the game should be adapted to people needs and the context in which they are developed (Dávila, 2002).

The games are focused on learning processes and skill acquisitions, and their application have benefitted many organizations, being the military the first to address and benefit those resources (Salen 2004). Another area in which simulation games are used it is the astronauts training for their missions. Simulation games are also usually used in the training of pilots.

There are different industrial sectors such as, steel engineering industries, textiles, manufacturing, among many others; and although each company is completely different in its processes, raw materials, staff and other resources, this simulation games can be adapted to each of them. Therefore the applications of simulation games in industrial environments include different areas (Álvarez, 2006):

- Environmental impact analysis
- Analysis and design of manufacturing systems
- Analysis and design of communication systems
- Evaluation of the design of public service delivery agencies
- Analysis of land, sea or air transport systems
- Analysis of networks and computer systems
- Analysis of the production system in a factory
- Training of industrial operators
- Planning of production in food industries
- Financial analysis of economic systems
- Evaluation of tactical or military defense systems

The traditional approach to teaching manufacturing processes is by classroom lectures, in which students passively receive information from the instructor and do not have opportunities to develop first-hand experience of the application of manufacturing techniques (Fang, 2009).

Simulation games in industries are a great learning tool, as they represent a model of the real working environment with which the worker to perform his duties will face. Those games can be created to suit each industry only needs to analyse the specific features you want to represent in the simulation, clearly establish the goals to be achieved, to develop such dynamic and finally choose the right seeks to develop mechanism. Although some sectors have used the simulation as a tool in the development of skills for some years, the productive sectors and labor are still far behind in this aspect , for although some companies are already benefiting from the application of simulation games to train effectively to colleagues in technical aspects, communicative, teamwork, among others; most organizations still unaware of the potential that these tools have to help foster the development of their staff and thus, contribute to achieving the objectives of the company (Pather, 2009).

2 Designing a simulation game

The field of simulation games is extremely extensive as it encompasses from areas focused on worker behavior and their response to certain situations, to areas where human intervention is practically nil (Spitz, 2004).

DeKanter (2004) proposes to design a simulation game should take into account the following principles:

- Intentionality. Design with a clear and precise objective.
- Contextualizing. Join the learning activities for an easy understanding of the game.
- Manipulation. Design the learning environment to promote understanding.
- Collaboration. Motivate the participants to take ownership of the game and the process of solving the problem.
- Communication. Promote the exchange of ideas and alternative viewpoints between the players.
- Reflection. Promoting a critical analysis of the learned topics.

Carry out a game design involves an extensive process, which must be aligned with the learning objectives proposed; from conception of the didactic model that seeks to use, the determination of the physical and human elements necessary for its implementation, setting specific skills that are to be developed in participants, rules, procedures, methods of measurement and evaluation of results.

3 Research questions

The aim of this paper is showing to train efficiently people in acquiring skills in the field of problem solving in industrial environments by playing a simulation game.

To do that, this paper reports the application of a very basic simulation game, in an industrial environment practice. The game has been developed to help manufacturing industries in the training of its staff in the acquisition of knowledge and skills for the orderly resolution of problems in production processes, using the simulation game adapted from the Six Sigma methodology and that we are going to call DMAIC - 7P (Eguren,2012). We`ll use this to develop skills in the production environment and make people more efficient, competitive and able to take the best decisions in the organization.

The application of this simulation game in organizations like training and learning strategy helps improving workers performance through the acquisition of knowledge and skills that helps the resolution of problems in production processes.

The use of this game also intended to include workers in their work routines resolution problems skills in order to be able to use a structured and systematic one when facing everyday problems. All this will increase the level of efficiency of the production process and the process of problem solving.

4 Methodology/Approach –

The methodology used is based on the “case study research” (Yin 2003), particularly appropriate to the development of theories oriented to explain how and why organizations operate (Coughlan, Coghlan 2002). In this case the game conductor has taken an active role in the implementation and monitoring the game. This has allowed the identification of the different aspects and skills to improve or promote the game participants.

The game has been developed in the following stages:

- First, it has been conducted a preliminary analysis of the theoretical framework where have been identified, the necessary skills to develop projects to address continuous improvement implementing Six Sigma methodology.
- Second the aspects to consider, for the development and implementation of simulation games in industrial processes have been identified. For this simulation we`ll use DMAIC-7P methodology to achieve the objectives set to the game. This will help participants acquire the necessary skills to solve the production environment problems quickly and concisely.

- Then, a practical simulation game has been developed, which simulates an industrial cutting process. This game has been tested in an auxiliary enterprise of the automotive industry to train people in "Continuous Improvement Process".

5 The simulation game

The game simulates a cutting process in a company dedicated to cutting elements for the electronics industry, which has the need to increase the level of product`s quality. The customer requires a level of machine capacity of Cmk> 1.66 and process capability of Cpk> 1.33. To achieve these objectives the management of the company has launched an improvement program based on Six Sigma methodology (Pyzdek, 2003). For this it has been defined an improvement team that will work using this methodology and the appropriate templates to support. The work of that working team will focus on reducing variability and to identifying the factors that affect this in the cutting process.

The production line includes steps from cutting to controlling of the material, which are distributed in the following workstations (WS):

WS1: Take raw material: What simulates an extra flat toothpick
WS 2: Mark the cutting length: it is cut to a length of 30 ± 0.5 mm. For marking a measuring ruler is use for that purpose.
WS 3: Cut a side: scissors are used.
WS 4: Measure: A caliper gauge is used.

The game is played in seven different phases that are explained at the beginning and end of every session. It is during the explanation session that the students get to develop the teamwork and problem solving skills while exploring and experiencing. The seven phases to carried out the simulation game have been adapted from the Six Sigma methodology, that we are going to call DMAIC - 7P from now on (Define, Measure, Analyze, Improve, Cconsolidate, Standardize and Reflect). Each step of DMAIC-7P, define arguments and routines that are necessary to use in each of the phases and the possibilities that are offered by the game to acquire the knowledge to be gained in the real production environment. That offers a systematic approach to improving the product or process to meet customer requirements (Eguren, 2012).

Phase1: Define

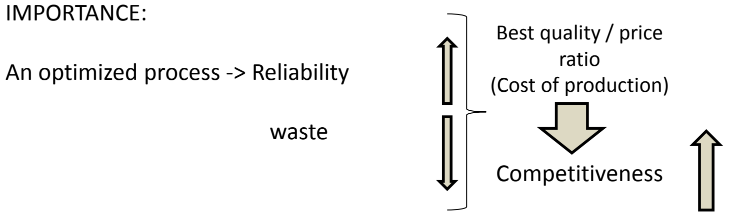
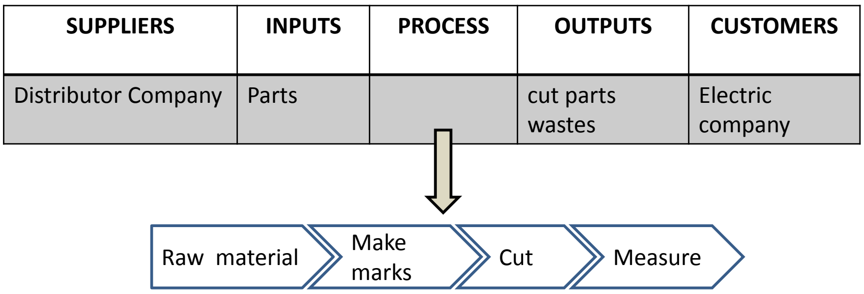
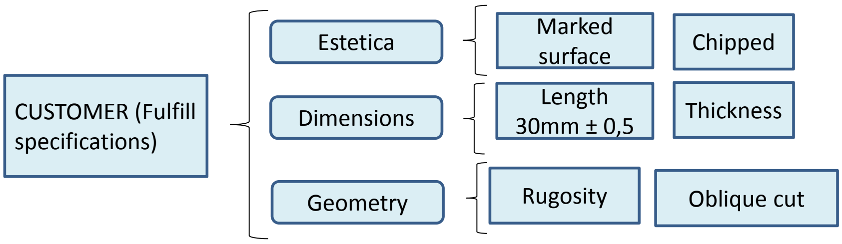
During this phase the working team will develop skills which are related to the definition and implementation of the project address. The team should be able to delimit the environment where the project will be developed as well as the inputs and outputs involved in the process, suppliers and customers who are affected by the improvement. The economical and the financial impact will also be something to be account. Finally they must identify the Critical to Quality (CTQ) characteristics and define a metric for each of them, in order to know the starting value and the value to be achieved with the objectives, to quantify the benefits that that the project represents.

The teams will be made up of of no more than 4 people and we will have to take into account finding different profiles in order to acquire the necessary (see Figure 1).

Figure 1: Work team carrying out the simulation

Each team will receive a kit of work, composed of flat toothpick, a ruler, a thick marker pen, a pen, scissors and a caliper gauge. To support this phase we can use different tools / methods such as, project scope, critical to quality, Gantt chart, financial impact, high level process map (SIPOC), affinity diagram, Kanon model, requirements/voice of customer (VOC), and analysis of interested parties. Table 1 shows a summary of the results obtained in Phase 1 (Define) of the simulation.

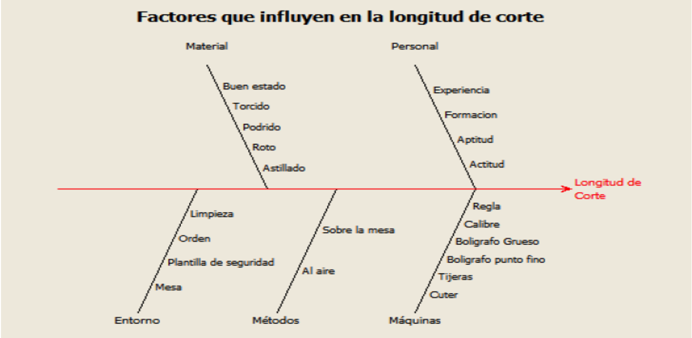
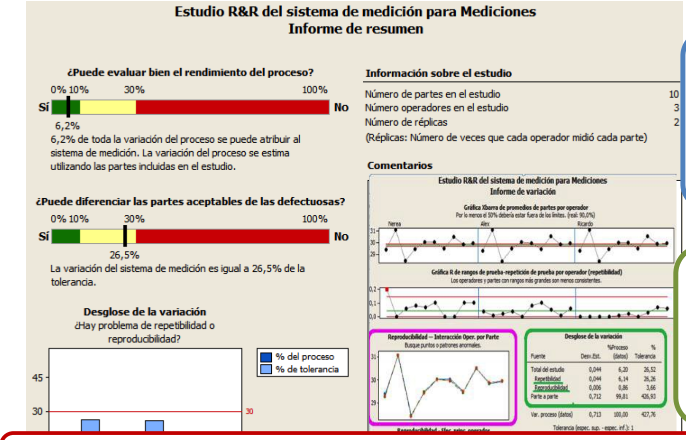
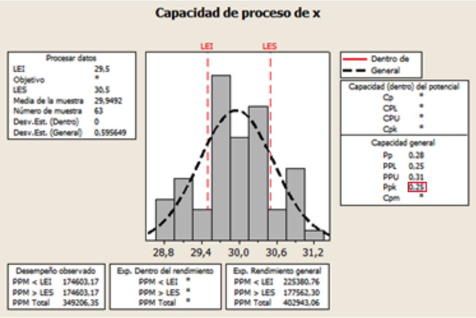
Table 4: Results obtained in Phase 1 of the simulation

<table>
<tr><th colspan="2">PHASE 1 :DEFINE</th></tr>
<tr><td>ACTIVITIES DEVELOPED</td><td>METHODS AND TOOLS USED</td></tr>
<tr><td>DESCRIBE THE PROBLEM AND THE IMPORTANCE OF PROJECT</td><td>PROBLEM: High variability and not get to the capabilities requested by the client.
IMPORTANCE:
 </td></tr>
<tr><td>DEFINE A HIGH LEVEL PROCESS MAP (SIPOC)</td><td> </td></tr>
<tr><td>VOICE OF CUSTOMER</td><td> </td></tr>
<tr><td>IMPACT ON BUSINESS</td><td>- Increased reliability
- Less wastage.
- Best price / quality ratio</td></tr>
<tr><td>EXECUTION OF COMMITMENTS</td><td>Actors involved:
- The department of accounting and finance, for possible investments need to be made when make the improvements.
- Department of raw material purchases
- Maintenance personnel and operators, for possible changes in the production line or possible training courses</td></tr>
</table>

Phase 2: Measure

The objective of this phase is to define the measurement system, through which the starting point is measured, to identify improvement opportunities for improvement. It must develop the ability to ask relevant questions about inputs and outputs of the process check forms for data collection and establish stratification factors needed, identifying and facilitating their analysis, to understand the reasons of process variability and quantifiable way related to the CTQ. To support this phase we can use different tools / methods such as, flow chart, Pareto chart, defective unit produced, stratification, chart of relations, cause effect matrix, Ishikawa diagram, 5 why. Table 2 shows a summary of the results obtained in Phase 2 (Measure) of the simulation.

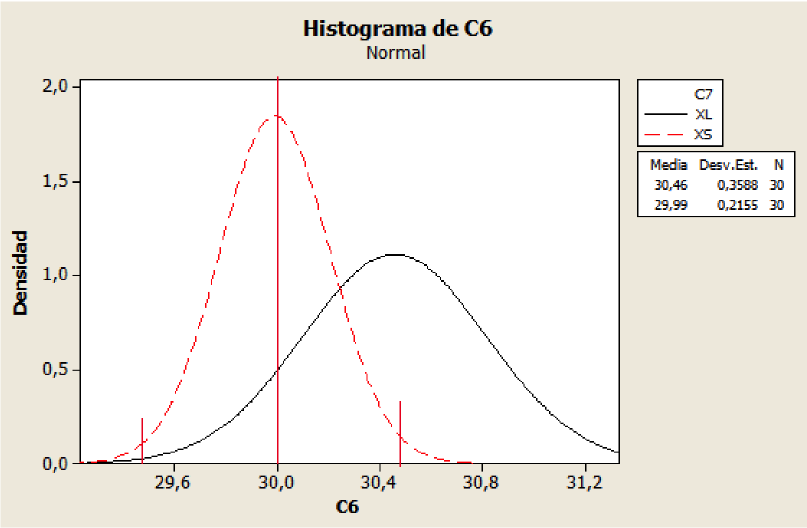
Table 5: Results obtained in Phase 2 of the simulation

PHASE 2 : MEASURE	
IDENTIFY THE "X" FACTORS OF PROCESS THAT INFLUENCES IN THE LENGTH OF CUT	
VALIDATE THE MEASUREMENT SYSTEM	**Estudio R&R del sistema de medición para Mediciones** **Informe de resumen** **¿Puede evaluar bien el rendimiento del proceso?** 6,2% de toda la variación del proceso se puede atribuir al sistema de medición. La variación del proceso se estima utilizando las partes incluidas en el estudio. **¿Puede diferenciar las partes aceptables de las defectuosas?** La variación del sistema de medición es igual a 26,5% de la tolerancia. **Desglose de la variación** ¿Hay problema de repetibilidad o reproducibilidad? **Información sobre el estudio** Número de partes en el estudio 10 Número operadores en el estudio 3 Número de réplicas 2 (Réplicas: Número de veces que cada operador midió cada parte) **Comentarios** The measurement system is valid because it is in the range between 10% and 30%. The repeatability is 26.26%. Reproducibility value is 3.66%. Most of the measurements are very similar
IDENTIFY THE STARTING POINT	 • The person does not influence the measurement process. On the other hand it is appreciated that the measurement system has some variability. • The type of tool used influences the process (Thick market pen, scissors) • The person influences in the marking cut length phase.

Phase 3: Analyse

The objective of this phase is to find the main causes to take a problem and not just the symptoms (effects). The abilities to generate hypotheses are developed in this phase, to identify the root cause of the problem. To support this phase we can use different tools / methods such as, trends chart, histogram, measurement system analysis (MSA), process capability (CP), hypothesis testing, and box plot chat. Table 3 shows a summary of the results obtained in Phase 3 (Analyse) of the simulation.

Table 3: Results obtained in Phase 3 (Analyse) of the simulation

PHASE 3: ANALYZE	
CAUSES THAT GENERATE THE VARIABILITY OF PRODUCT	The thickness of the thick market pen. Has been analyzed influence of the thickness of the thick market pen using a 0.5mm pencil. Influence of the person, in the cutting length marking phase. The operator will mark that in previous processes has obtained better results. The cutting tool: scissors or cutter. Have been analyzed outputs using sharp scissors.   
CHECK HIPOTESIS	
IDENTIFY X`S (OUTPUTS) VITAL	Vital X are: 1) The thickness of the pen tip, for its lack of precision when marking stick. 2) The operator marking the stick. The result varies greatly depending on the operator doing the marking stick. 3) The cutting tool. The results are different depending if you used scissors or a cutter to cut.

Phase 4: Improve

The objective of this phase is to select and test the improvements that can reduce the variation of the problem. The implementation is also planned. Finally, changes will be established and made in operating conditions. To address this stage can be used different tools / methods such as, design of experiments (DOE), Gant chart, failure mode and effects analysis (AMFE), anti-error systems (Poka-Yoke), matrix impact/effort, matrix of priorities. Table 4 shows a summary of the results obtained in Phase 4 (Improve) of the simulation.

Table 6: Results obtained in Phase 4 of the simulation

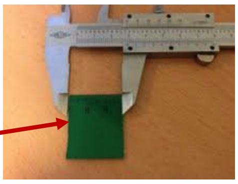
<table>
<tr><th colspan="2">PHASE 4: IMPROVE</th></tr>
<tr><td>SELECTION OF IMPROVEMENT</td><td>To assure the correct marking, will be used as poka-yoke, a piece of rule, cut to the appropriate length. Will correct the influence in the variability of output due to the operator on the marking phase.
- This piece of rule, measure 29 mm to compensate for the thickness of the pencil tip (0.5mm).
- For marking, a pencil 0.5 mm is used for greater precision.
- Use of good quality scissors that allow us to accurately cut is made.</td></tr>
<tr><td>ASSESSING RISKS OF PILOT TEST</td><td>

- The poka-yoke that is used to mark, must be supported with enough strength and firmness so that it will not move while you are marking.
- When making the cut, the operator must pay attention and put the blades of the scissors just above the pencil marks, for cutting adequately

</td></tr>
<tr><td>PILOT TEST</td><td>

There has been a 10 minute test with the implanted improvement.

The poka-yoke measured 29 mm to compensate for the thickness of the tip of the pencil.



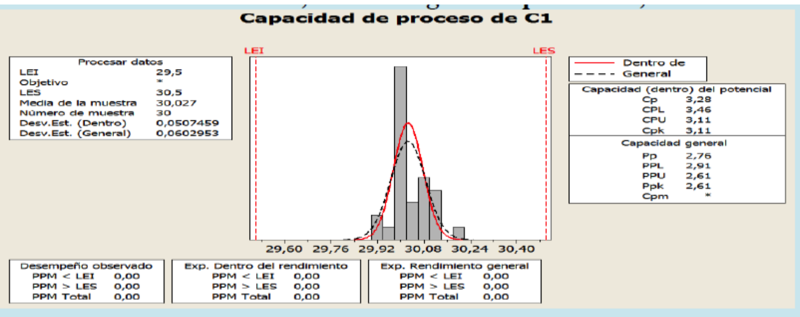
</td></tr>
</table>

Phase 5: Consolidate

In this phase, the team must inspect that the improvement is sustained over time. Once completed the improvement plan, the effectiveness of the actions that have been implemented are evaluated, and the results quantified, checking and evaluating. Them address this stage can be used different tools / methods shown before. Table 5 shows a summary of the results obtained in Phase 5 of the simulation.

Table 7: Results obtained in Phase 5 of the simulation

<table>
<tr><th colspan="2">PHASE 5: CONSOLIDATE</th></tr>
<tr><td>CHECK RESULTS</td><td>



The new CPk obtained is 3.11, is greater than 1.66

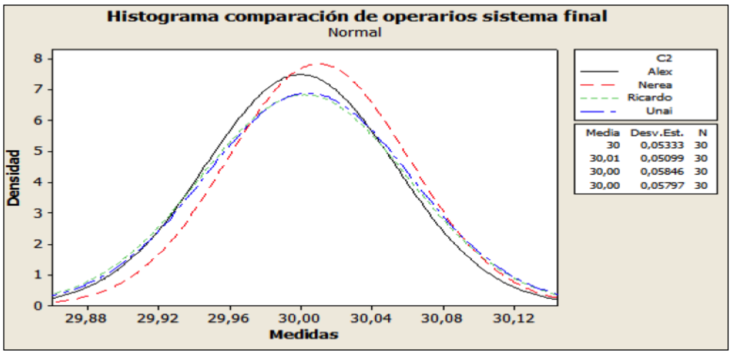
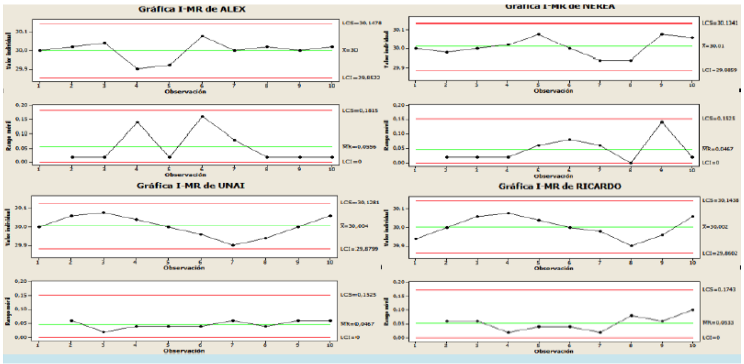
.

</td></tr>
</table>

Phase 6: Standardize

In this phase the team should ensure that the consolidated improvements become a standard of work, managing to maintain the objectives achieved over time. To do this, processes must be redefined in detail. The team should standardize the improvements to prevent recurrence of the problem. The team must also develop the new management system applied in the improved process for being able to follow it. It should collect operational requirements, graphics management to use, measures and responses to problems. To support this phase we can use different tools / methods such as, definition and process management, visual controls, registration data, statistical process control (SPC), definition of audit plan. Table 6 shows a summary of the results obtained in Phase 6 (standardize) of the simulation.

Table 8: Results obtained in Phase 6 of the simulation

PHASE 6: STANDARDIZE	
STANDARDIZE	• Train operators to perform the correct use of the new tools. • Proper calibration of the scissors and measurement tool (gauge), so there is no variation between the different production lines.
MONITORING SYSTEM DESIGN	To test the standards, the following results of a test are analyzed: • The levels of output after short X sticks • The level of implementation of the tasks designed for the new process 
PILOT TEST OF STANDARDIZATION AND MONITORING	Process monitoring with 4 workers.  Has been tested with the new process four different operators and have been observed with all the established results are obtained. So the process is standardized

Phase 7: Reflection

The objective of this phase is to show the results of the simulation and reflect on what they learned both individually and as group. The team must make an assessment of the goals achieved, exploitation of knowledge, and new knowledge acquired. We will have to make sure that the improvements are shared by the organization. Table 7 shows a summary of the results obtained in Phase 7 (reflection) of the simulation.

Table 9: Results obtained in Phase 7 of the simulation

PHASE 7: REFLECTION	
QUANTIFYING RESULTS	Comparing the two processes we see an improvement, our CPk now is 3.11, being the starting of 0.28. Initial Productivity: 25 pcs / 10min Productivity improvement after 43 pieces / 10min Improvement achieved: 72%
QUANTIFYING LESSONS LEARNED	They have used concepts learned in other subjects, such as Poka-Yokes and machine capacity ratios. What has helped you understand the practical use of them.

6 Conclusions

Student Feedback reflect, that the application of simulation game in the process of industrial court, has been valid to understand the theory and acquiring skills, related to the techniques of quality assurance in industrial processes to apply it in a real environment, specifically in; standard methods of continuous improvement, statistical tools, Poka-Yokes and standardization systems.

Routines have been carried out are oriented towards the use of a scientific approach, the statistical thought process and proof-based communication, both during the cause analysis phase and in the phase for planning and implementing solutions which have a high impact on the root cause of the problems.

The key element is defining the quantity of data which is needed and the way to obtain it. It is also necessary to develop the skill for planning an experimenting in order to obtain the maximum information with the minimum experimental effort, without forgetting the way to analyze this. The game also enhances team interaction and problem-solving

While the simulation game doesn`t replace actual practice, in the case presented, it represents an effective solution for staff training, and lets participants take an active role in the development of the game, which helps in the learning process. This game is a learning tool that can be applied to any company as a training tool.

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Design and implementation of an Evaluation System for a Continuous Improvement Model in an automotive supplier company

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Abstract

This paper shows the design and implementation of Key Performance Indicators (KPI) to assess the effectiveness, efficiency and developed learning, in executing the improvement projects resolution process, applying Six Sigma methodology, in an auxiliary company of automotive sector. In the application, it was found as key factors: the commitment of the leadership, the culture or habits in the company, effort dedicated to team work and the involvement of the tutor or coach.

Keywords: Improvement Projects Resolution Process (IPRP), Six Sigma, Key Performance Indicators (KPI) of the Continuous Improvement Process.

1 Introduction

In recent years, owing to the globalization of the economy, the increasingly prevailing role of new technology and changes to the productive model, industrial sectors have been experiencing great changes in all spheres of action, which along with the background of the current financial crisis, have generated an environment which is characterised by strong competition, which in turn forces companies to constantly adapt to market conditions which are hard to foresee. Due to this, organizations today have a constant need to reduce production costs, improve quality, reduce wastage in production lines and increase manufacturing output in order to both achieve and maintain competitiveness (Bhuiyan, Baghel et al. 2006). In this context, employing the Continuous Improvement Process (CIP) albeit not sufficient on its own, becomes a basic resource to generate a long term competitive advantage (Carpinetti, Buosi et al. 2003).

The Continuous Improvement Process (CIP) may be defined as "the process to constantly and gradually improve the different areas of a company, seeking increased corporate productivity and competitiveness (Sainz de Vicuña 2002)". Further to this definition, more definitions may be added according to the goals sought or the approach to reaching them: "gradually improving the processes by progressive innovation" (Brunet, New 2003), or "strengthening creativity and learning in order to develop an environment for growth" (Delbridge, Barton 2002).

The implementation of a CIP is a process of change through changing routines and behaviours of all involved, so a key factor for its implementation is the management and monitoring of both the level of implementation as the evolution of the CIP. There are authors (Dabhilkar, Bengtsson et al. 2007, Bateman 2005) raised the importance of a proper management and monitoring of CIP. According to Bessant (Bessant, Caffyn et al. 2001) , the process of managing and monitoring the CIP should be a cyclical process in which you have to first make a diagnosis through appropriate auditing tools to identify the strengths and weaknesses of CIP, further improvements need to implement in order to reinforce the behaviours where have found weaknesses or introduce new behaviours, and finally would require an overhaul and repeat the cycle.

Schroeder raises (Schroeder, Bates et al. 2002) using more objective indicators to measure the results of the CIP. Poses set specific goals based on performance indicators, as these are helpful to make the change more tangible in terms of individual performance and organizational performance, to monitor results, encourage people to progress in their environment (Hyland, Mellor et al. 2007, Bessant, Caffyn 1997, Moran, Avergun 1997).

In order to make a more accurate measurement of the level and evolution of the CIP it is necessary to identify and define key performance indicators. Bahamon (Bahamón 2006) and Wu and Chen (Wu, Chen 2006) raises the achieved objectives related to the level of resources used, "efficiency". Moreover, several authors that link the success of CIP with the level of the objectives achieved in different natures, ie the "efficiency", in areas such as productivity, quality or service (Terziovski, Sohal 2000, Bhuiyan, Baghel et al. 2006, Garcia-Sabater, Martin-Garcia 2009). Hyland (Hyland, Decker et al. 2008) , raises the need to develop a dynamic of learning to learn, or learning to improve in an efficient and effective approach that allows increasingly larger problems and more complicated, so measuring the level of learning achieved is another indicator consider.

2 Research Questions

Despite the importance of process performance measurement and monitoring of CIP, it was noted that this is an unusual practice (Greenbaum, Kaplan et al. 1988) but highly recommended, as it allows companies to detect if the CIP is getting the objectives, diagnose the causes that can explain how they are working and can help identify possible alternatives to improve the situation (Bond 1999).

The present study shows the process of designing and implementing a system for performance evaluation of the implementation of the Improvement Projects Resolution Process (IPRP) following Six Sigma methodology called PRPM-IKASHOBER (Eguren, Pozueta et al. 2012), based on performance indicators, effectiveness, efficiency and developed learning.

The MPRP-IKASHOBER has been used as a method of training of staff from different factories of an auxiliary company of the automotive industry in solving quality problems. This is why the PRPM-IKASHOBER has been tested in real productive environment projects where we find these trained people developing their tasks.

In this document we can have a look at the indicators to follow up the knowledge that the staff have acquired after the use of PRPM-IKASHOBER. The study of these indicators has identified key issues and skills to develop, to implement the PRPM-IKASHOBER in an effective and efficient way developing on organization that learning to learn.

3 Research methodology

The used methodology is based on the "case study research" (Yin 2003), particularly appropriate to the development of theories oriented to explain how and why the organizations operate. In this case, a researcher is a none independent observer, but a participates in the process. Unlike other research methodologies, it is concerned with creating organizational change and simultaneously studying the process involved.

In this case the researchers have taken active part in the implementation and monitoring of various projects. The phases of the methodology used in the research project are: First, the process is defined, which will apply the evaluation system, which corresponds to the IPRP using Six Sigma methodology called PRPM-IKASHOBER. Subsequently, it is proceeded to identify issues and consider methods, to develop and implement a system for evaluating the performance of an IPRP. Then, the evaluation system has been developed, and to conclude it has been applied in an auxiliary enterprise of the automotive sector.

4 Characteristics of the process applied

The process where the rating system has been used belongs to the Improvement Projects Resolution Process using Six Sigma called PRPM-IKASHOBER (Eguren, Pozueta et al. 2012). The PRPM-IKASHOBER has been set up as a process within the CIP which creates value in an organization and for this end of stages and phases has been identified, this structure is shown in Figure 1.

Stage 1: Planning

Initially the committee promoting PRPM-IKASHOBER will identify indications and behaviour which ensure support from Management and from those responsible for the different Organization areas for PRPM-IKASHOBER (Wu, Chen 2006, Jorgensen, Kofoed 2004).

Having set up the PRPM-IKASHOBER, the Lead team, working with the line managers of the different areas of the Organization, will go on to analyse the critical processes so as to identify the Improvement Projects which have the suitable features to be worked on in this improvement process, as well as the people with the suitable profiles to form part of the teams. The operating method followed is based on the Six Sigma DMAIC methodology. It consists of five phases (Define-Measure-Analyse-Improve-Control) (Pande, Neuman et al. 2007). In this research project, it has been considered opportune to amend the methodology addressed to propose it using the following seven phases:

Phase F1: Define: In this phase you must ensure that the project impacts in strategic areas of the company.

Phase F2: Measure: Deep initial diagnosis: drawing on validated metrics and rigorously defined defect/opportunities.

Phase F3: Analyse: Identification of the few X variables, the root causes of the problem in a rigorous way, confirmed by experimental evidence.

Phase F4: Deploy: Evaluation of the selected improvement ideas in a controlled and rigorous pilot testing experience, and monitoring of side effects and other elements that help to modify the ideas.

Phase F5: Consolidate: Check that the improvement is sustained over time, measuring an indicator agreed with all parties concerned.

Phase F6: Standardise: Validation of the operative according to the standard.

Phase F7: Reflection: Closure of the project.

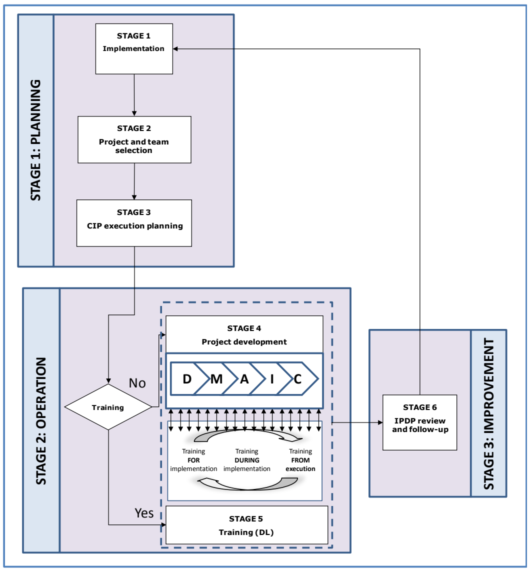


Figure 25: PRPM-IKASHOBER Phases (Own study)

Stage 2: Operations

In the operating stages of the PRPM-IKASHOBER two possible plans of action or phases, to take place in parallel, are considered. The first is that relating to the actual project implementation, where the Team deploys the skills linked to the problem-solving process and teamwork skills with the aim to successfully achieve the project goals.

The second concerns that of training the Team leaders by implementing projects using Dynamic Learning (DL) (Baird, Griffin 2006). In this phase the Research team will come into play and will observe and act on the team-project pair with the aim to implement the CI projects effectively and efficiently.

Stage 3: Improvement

In the PRPM-IKASHOBER Improvement stage, the members of the Lead team will periodically review and assess the level of accomplishment of the established goals (Dabhilkar, Bengtsson et al. 2007, Bateman 2005) for the PRPM-IKASHOBER, based on criteria for effectiveness and efficiency.

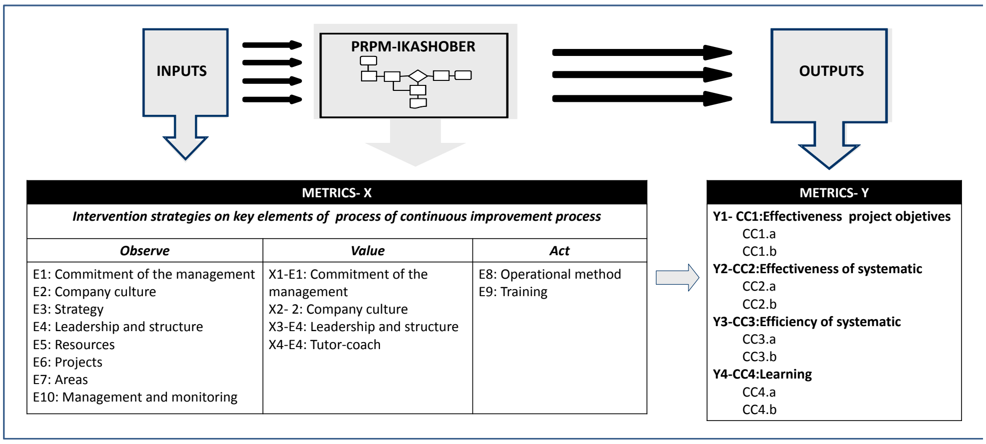
5 Description of the Evaluation System

As posed Grütter (Grütter, Field et al. 2002) , and given that the assessment process evolves as CIP is being established, it has developed an evaluation system adapted to compose and check that hypothesis by association between outcomes and compliance level factors.

For this purpose it has been given that the PRPM-IKASHOBER must act according to the same guidelines as any process of the organization, and it has been followed the structure shown in Figure 2. As seen in Figure 2, factors, E1: Commitment of the management, E2: Company culture, E3: Strategy, E4: Leadership and structure, E5: Resources, E6: Projects, E7: Areas and E10: Management and monitoring have been observed. Moreover, factors X1:E1: Commitment of the management, X2:E2: Company culture, X3:E4: Leadership and structure and X4: E4: Tutor coach has been valued. And to conclude the research team has acted on E8: Operational method and E9: Training

Furthermore, as process outputs are the metrics Y `s, that correspond to different performance measurements PRPM-IKASHOBER that will be performed according to targets addressed. These metrics correspond to, Y1-CC1: Effectiveness project objectives, Y2-CC2: Effectiveness of systematic, Y3- CC3: Efficiency of systematic and Y4-CC4: Learning.

Here are the features of each element valued:



METRICS- X		
Intervention strategies on key elements of process of continuous improvement process		
Observe	*Value*	*Act*
E1: Commitment of the management E2: Company culture E3: Strategy E4: Leadership and structure E5: Resources E6: Projects E7: Areas E10: Management and monitoring	X1-E1: Commitment of the management X2- 2: Company culture X3-E4: Leadership and structure X4-E4: Tutor-coach	E8: Operational method E9: Training

METRICS- Y

Y1- CC1:Effectiveness project objetives
CC1.a
CC1.b
Y2-CC2:Effectiveness of systematic
CC2.a
CC2.b
Y3-CC3:Efficiency of systematic
CC3.a
CC3.b
Y4-CC4:Learning
CC4.a
CC4.b

Figure 2: Evaluation System Structure

Outputs of PRPM-IKASHOBER valued

Y1-CC1: Effectiveness project objectives: This indicator measured the results of % fulfilment of project objectives for each project in each of the seven phases of the operating method. Moreover, it has also been used two indicators related to Y1, by which evaluates and compares the evolution of PRPM-IKASHOBER each cycle. The displayed indicators for Y1 are, CC1.a: % of projects that meet or exceed the target set and CC1.b: Mean % compliance of projects that meet or exceed the targets.

Y2-CC2: Effectiveness of systematic: It measured along the systematic and using the appropriate tools, projects achieve the objectives addressed related to systematic PRPM-IKASHOBER for each phases of the operating method. The displayed indicators for Y2 are, CC2.a: % of projects that exceed efficiency level 3 and CC2.b: Mean of projects that exceed level 3 of effectiveness.

Y3- CC3: Efficiency of systematic: It measures whether the projects achieve the objectives set for each phases of the operating method on schedule and using the resources programmed. The displayed indicators for Y3 are, CC3.a: % of projects that exceed the efficiency level 3 and CC3.b: Mean of projects that exceed level 3 in efficiency.

Y4-CC4: Learning: This indicator measures whether the team gains expertise on the process / product that works and knowledge of the method, the systematic and tools that help you learn. The team applies what it learns, measure the level of knowledge acquired for each of the phases of operating method. The displayed indicators for Y4 are, CC4.a: % of projects that exceed the learning level 3 and CC4.b: Mean of projects that exceed level 3 in learning.

They are also are rated the following X metric:

X1-E1: Commitment of the management: This indicator shows whether the support of the direction is clear, if the team has the resources and necessary means and has sufficient autonomy. X2-E2: Company Culture: This indicator shows if they develop new work habits in the organization to enhance competitiveness.

X3:E4: Leadership and structure: This indicator measures, whether the leadership and the team have clear objectives, shares, follows rules, it is distributed and respected roles.

X4: E4: Tutor coach: This indicator measures whether the tutor / coach has the knowledge, skills, time and resources to guide the leader and the team, in order to achieve the objectives effectively and efficiently.

System for data collection

The assessment of the elements X1-E1: Commitment of the management, X2-E2: Company Culture, X3:E4: Leadership and structure, X4: E4: Tutor coach, Y2: Effectiveness of systematic, Y3: Efficiency systematics and Y4: Learning is each phase, was performed in each operating method phase, according 1 to 4 Lykert scale (Taylor-Powell, Renner 2000), where, 1 is Completely out of the required level, 2 is not reached the required level, 3 is getting the required level and 4 is the required level is exceeded. Moreover, the assessment of Y1: Effectiveness of project objectives, results from analysing the results of the objectives of each project in each of the phases of operating method. This has allowed us to observe the evolution of the PRPM-IKASHOBER progressively as each phase of operating method has been running. The process of data collection was as follows:

Rating all attendees of the presentations made by the leaders to present the results of each phase of the project. In this case, when making presentations have filled in all attendees questionnaires related to aspects of Y2- effectiveness of systematic and Y3-efficiency of systematic. The fulfilment of a questionnaire from the Champions, leaders, promoter team members and researchers. The assessment is performed for each project after each phase of the operating method, and to this end a questionnaire specifically designed for each stage, the people who have to fill in to receive e-mail, via online. To finish the assessment, we analysed the level of compliance of the use of operating method and improvement tools, development of training and education process.

6 Implementation of the evaluation system

The model has been implemented and improved by implementing improvement projects in different plants from an industrial company in the automotive auxiliary sector belonging to Mondragon cooperative group. The aforementioned group is the largest business group in the Basque Autonomous Community and the seventh in Spain. The following paragraphs show the characteristics of the different plants where the model has been implemented:

Plant A: It is a medium sized manufacturing plant employing about 400 people dedicated to machining cast iron brake discs. This plant is a premier supplier in the automotive industry. Over the past four years they have applied dynamic structured problem solving by improvement teams. In this plant, we have made these projects: P1: Improved levels of noise and jump in parts and P2: Increased capacity in the measurement line.

Plant B: It is a medium sized manufacturing plant which employs about 500 people engaged in the elaboration of suspension parts for cars. This plant is equal to plant A concerning to the implementation of quality systems and CI dynamics is identical to that on plant A. In this plant we have made these projects: P3: Study of the effects caused by heat treatment in casting, P4: Reduction of sink marks defective, P10: rework reduction in coating parts and P11: Improve the mould of the fusion process.

Plant C: This is a medium sized manufacturing plant employing about 300 people who produce aluminium callipers. The plant dynamics does not consider any structure to address the activities of CI. In this plant we made these projects: P12: Reduction broken parts.

Plant D: It is a medium sized plant (about 200 people) that manufactures high-pressure injected aluminium cylinder head covers. This plant is identical to plant A plant from the point of view of implementation of quality systems, it is usual to joint dynamic teams with Kaizen Improvement. In this plant we made these projects: P5: Reduction of defective injection process breechblock and P6: Reducing internal and external defective cylinder head cover.

Plant F: It is a research canter that supports the research and industrialisation projects of the different plants described in the preceding paragraphs where they work 50 employees. This plant, concerning to quality systems, it is identical to plant A: they are very familiarised with the research, experimentation and teamwork, but they do not have any standardized model. In this plant we have made these projects: P9: Savings in raw material in the fusion process.

7 Application results

Analysis of fulfilment project objectives

In Figure 3 "% achievement of objectives" in the different phases of the operating method for each project addressed, we can see that the projects have covered only 6 of them (P3, P5, P6, P9, P10 and P11) reached and / or exceeded the targets set after having finished the seven phases of the operating method.

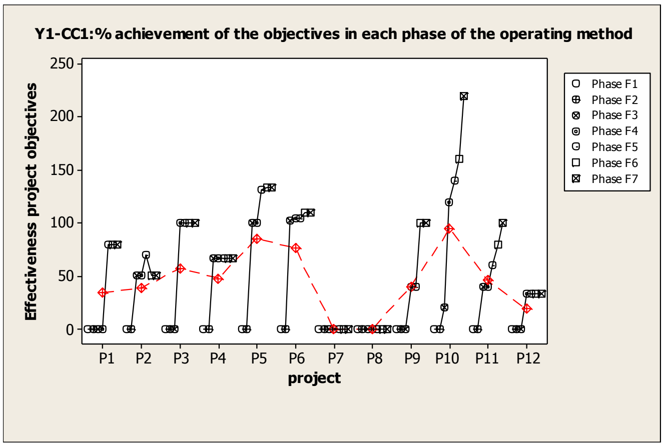


Figure 3: % achievement of the objectives in each phase of the operating method

Highlighting positively P10 where project goals are exceeded from Phase 4, widely surpassing 220% up to about the end of Phase 7. Moreover, it is noteworthy from a negative standpoint P8 and P7 project, in which evolution has not been observed in the results related to the objectives. Confirming that due to different problems, these projects were closed in vain. Another project with low level results is P12, which has fallen to 30% of the targets, which shows that there has been evolution of this indicator from Phase 4.

It also shows that, except P7 and P8 projects, all projects have begun to obtain improved results from the implementation of Phase 3: Analyse. On the other hand, we can see that in the P3, P5, P6, P9, P10 and P11 is where the results have been achieved, and it has been from Phase 4: Implement, showing evidence of the importance of the proper implementation of these two phases in order to achieve the targets set in the projects.

Figure 4 shows the level of compliance with the indicators, CC1.a:% of projects that reach or exceed the target and CC1.b: Mean % of completion of projects that meet or exceed goals. It can be seen that at the end of Phase 7 operating method, only the 50% of the projects have achieved the results at or above the targets set. It also shows that the average in which these projects have exceeded in 127% in Phase 7: Reflect.

Concerning to the evolution of the indicators over the method of operation, it can be seen that the indicator is steadily CC1 with a positive trend throughout the execution of each operational phase of the method. However, for the indicator CC1b shows that in Phase 6 breaks standardize its upward trend to regain it in

Step 7: Reflect. This shows evidence of weaknesses at the standardization process when projects enhancements discussed.

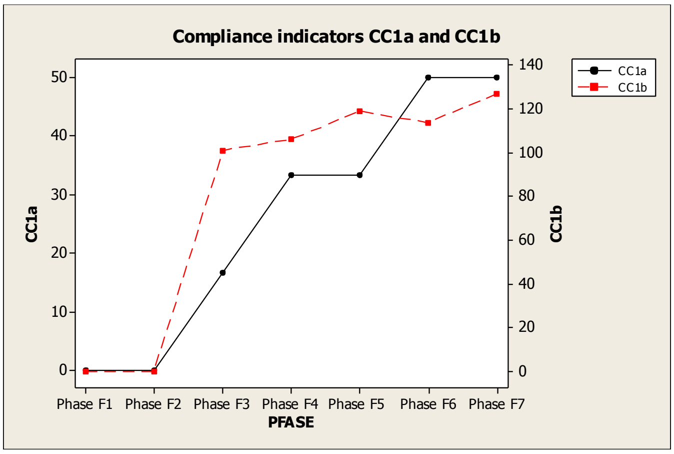


Figure 26: % Compliance indicators CC1a and CC1b

Fulfillment of the systematic

Figure 5 shows the level of compliance with the indicators, CC2.a:% of projects that exceed efficiency level 3, CC3.a:% of projects that exceed the efficiency target of the method and CC4.a: % projects exceeding level 3 learning. In all of them you can see an irregular evolution of % projects reaching target levels throughout the execution of the various operating phases of the method, it is observed mainly low levels in the indicator CC3a: Efficiency for the phases F3: Analyse, F4: Implement, F5: Consolidate and F6: Standardise, where only between the 10 and the 40% of projects exceed target levels, where evidence shows that projects have been delayed in executing the different stages and have not been addressed following the schedule set.

Regarding the indicator CC2a Effectiveness of implementation, the results show a level slightly above the previous indicator, and can be observed weaknesses in the phases F4: Implement and F6: Standardise, where it only have exceeded targets by 20% and 30% of projects, respectively. This shows signs that in phases F4: Implement and F6: Standardise, many projects have not developed the activities and routines of a solid form and following established guidelines.

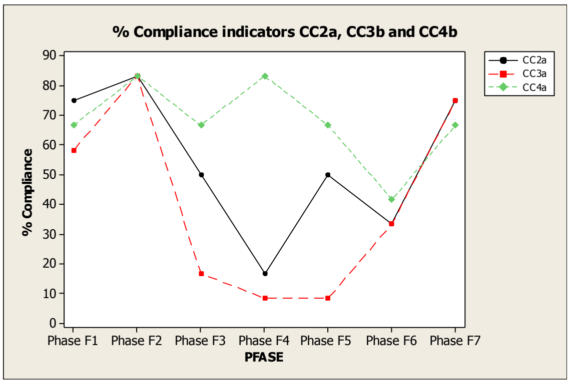


Figure 27: % Compliance indicators CC2a, CC3b and CC4b

The results of the third indicator analysed CC4a: Learning, have been much better. It can be seen that the levels for phases F1: Define, F2: Measure, F3: Analyse and F7: Reflect, have been acceptable, low levels are observed in phases F5: Consolidate and F6: Standardize, showing signs that there weaknesses in practices related to the consolidation of the results and the standardisation of the improvements.

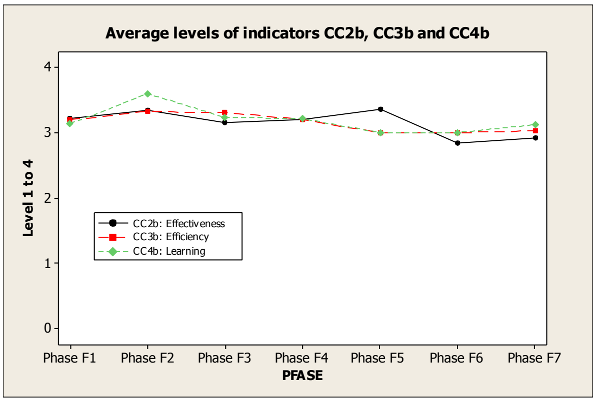


Figure 28: Average levels of indicators CC2b, CC3b and CC4b

To conclude, Figure 6 shows the results of the indicators CC2.b: Media projects exceeding level 3, CC3.b: Average of projects exceeding level 3 efficiency and CC4.b: Rating average project exceeding level 3 learning. Averages for these indicators have remained at similar levels although it looks there is a slight decrease for the valuations of phases F6: Standardise and F7: Reflect.

Levels of compliance related to the departures of the PRPM-IKASHOBER

Figure 7 shows the levels of compliance related to the departures of the PRPM-IKASHOBER systematic, Y2-CC2: Effectiveness of systematic, Y3-CC3: Efficiency and Y4-CC4: Learning. It can be seen that the projects have behaved and have evolved differently in the level of implementation of each phase of the operating method and each indicator. They are describes the behaviors observes for each indicator below.

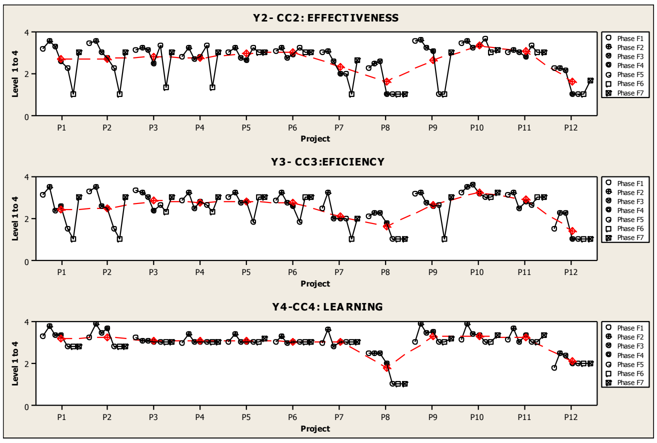


Figure 29: Levels of compliance the systematic for each project

Y2-CC2: Effectiveness of systematic: we can see by this indicator that weaknesses have been observed when all phase of the operating method in P12 and P8 projects have been executed. Which have not reached at any time the level 3 marked endpoint reference, it also shows that in the project P8 there has been no progress in the last four stages of the operational method, as this project has been stopped from Phase 3. P7 has been another project with low levels of compliance. The draft shows that the indicator has had a negative trend when executing phases F3: Analyse, F4: Deploy, F5: Consolidate and F6: Standardise the operating method, from which it has been traced to when executing Phase 7: Reflection.

Moreover, it can be seen that in most projects undertaken (P1, P2, P3, P4, P8 and P7) phase is weaker than from the standpoint of effectiveness of the scheme is Phase 6: Standardise , indicating that the team leaders have problems or weaknesses in executing this phase.

For projects that have had a positive trend in the indicator of effectiveness of systematic highlights, P5, P6, P11 and P10 in which we can see that the performance levels for each stage of the method have been operating within the objectives.

Related to respect the implementation of the phases of operating method, it is clear that a general behavior of projects in the early stages of the implementation of the operational method, F1: Define F2: Measure and F3: Analyse, it has been positive, showing a trend change when phases run F4: Implement, F5: Consolidate and F6: Standardize, and producing a turning point of the trend in Phase 6: Standardise, from which the results effectiveness of systematic re-traced.

Y3-CC3: Efficiency systematic: Regarding the efficiency of systematics, it should be noticed that the same patterns are repeteated as those shown in the indicator Y2-CC2: Effectiveness systematic. We need to highlight certain peculiarities in P4 and P3, which it shows that they have run all phases of operating method efficiently, but as for Phase 6: standardise, it has not been effectively implemented. This indicates that no standardisation robust systems have been developed in the two cases. By contrast, P6 and P5, in Phase 4: Implementation has not run efficiently, despite have reached the level of efficiency of systematics for these projects, it has been necessary to use more resources than initially planned.

Y4-CC4: Learning: Concerning to the learning levels achieved in each case, in Figure 7 we can see that in all cases except P7 and P12, they are achieved learning levels have been high. Although he had difficulty getting the results or the methodology applied in an effective or efficient way, leaders have acquired skills that previously did not have.

8 Conclusions

In the present research paper it has been designed and implemented a system to assess the effectiveness, efficiency and learning developed when implementing the PRPM-IKASHOBER. This system can assess the model continuously in each phase of the implementation of the improvement process, and to analyse the evolution of the PRPM-IKASHOBER over the years. It can also allow you to see teamwork, culture, organizational aspects and performance of the tutor.

Difficulties have been observed though the application of the system related to CI key elements, E1: Management, E4: Leadership and structure and E6: projects. In this sense, it has not been enough compliance with the guidelines referred to the actions of senior management and has been found to comply with the roles of middle managers is vital. Leaders must develop the ability to interact seamlessly with their superiors and manage the team and to communicate and share the results of the projects.

Weaknesses have been observed when executing improvements and develop robust systems standardisation. These weaknesses create large risks of leaving unfinished projects because once found improvement ideas for the team, it is not expected to consolidate the results and they are not designed performance standards.

All this has allowed us to implement a corrective action quickly so that the projects undertaken have a higher level of success. The developed tool can also serve as a reference for application in other industry sectors.

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Identification of diversity - A key to learning improvement

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Abstract

To disseminate knowledge in the most effective way, it has to be directed and adjusted to fit the receiver. In relation to lectures and supervision of student projects, this means that the lecture needs to have a basic knowledge about, both the typical student and in particular the diversities amongst the students.

Here is a short description of the averages engineering student at Aarhus University School of Engineering, based on survey results, general statistics and fundamental ideologies in the Danish educational system. Combined with reflection of the results from two different experiments of using personality test as a way to work with the diversities, the diversities amongst the students can become an asset in the learning environment.

Whether the knowledge about the students are going to be collected in a formal or informal way, it requires time and focus if it has to be more than the lectures gut feelings.

1 Introduction

An active learning environment, challenges the students and lectures interpersonal competencies. This is particularly clear in group based project work, simply because the relation between students and lecture are closer and often more personal.

As supervising lecture you will see groups that fight like cats and dogs, some get through with a helping hand and some are able to deliver results far above their individual level of skills. The challenge as supervisor is to: Identify groups in trouble, create an environment where the students are able to work with potential problems and provide the students with tools to work with interpersonal relations in a professional way.

In this work, knowledge about the students' different personalities and competencies are crucial, actually so important that each lecture, as a minimum, has a private set of intuitive categories to describe the students, and how to work with the different groups. However, this does not provide the students with any knowledge that can improve their abilities to work in a group.

To tackle this shortages, different experiments of implementing traditional personality type testing, have been conducted at Aarhus University School of Engineering. The experiments are inspired by normal recruiting procedures in many companies.

A fast and professional way to gain information, about some personal preferences and ways to react, is to use a form of personality test when recruiting a new employee. Such tests might provide the individual student; with useful knowledge about the students own preferences and the diversities amongst their fellow students and thereby increasing their interpersonal competencies.

2 The typical student

Before tackling the diversity amongst the students, here is a short description of the typical student based on statistics and the fundamental ideologies of the Danish educational system.

At Aarhus University School of Engineering the average student is a 22.1 year old male. He has a degree from high school, business-college or technical-college. He has a strong interest in technologies and problem solving and he likes to build things. But, 16.2% of the students are female, 12% of the students do not have a high school - or college degree, and 9% of the students have at least one child. (Haase, 2014)

From a statistical point of view it can therefore be concluded that the general student population can be described as a relatively homogeneous. This picture of homogeneity is also seen in the students' educational foundation. All Danish students have been through primary school, a school founded in the philosophy of professor Kristian Kroman, meaning a schooling system striving to create a harmonious and versatile development of the children's body and soul. As he was cited by Axel Sneum in 1947:

"It is not enough the pupils learn to listen; they must first and foremost learn to see. It is not enough the pupils learn to remember, they must first and foremost learn to think. It is not enough the pupils learn to slave, they must first and foremost learn to work". (Sneum, 1947)

Today the philosophies of Kroman are manifested in the preamble of the primary school stating that:

The goal is to promote a versatile development of the pupils, - a development, where the individual pupil have the experiences of being in control over his or hers own learning environment.

The versatile development is seen as the means to give the pupils a desire to learn, and a desire to exploit his or hers learning potential.

Desire is fundamental to develop and learn. (emu, 2014)

Meaning that the students are raised to be seen and respected as individual. Individuals that can control and set personal goals, based on personal desire, without necessarily needing to reach the same goals as other.

In spite of this, it is not an intuitive reflection, that fellow students can have the same goal, but not the same preferences to work environment, work methodologies or information sharing.

This is the challenges and reason to focus on student diversity. But the question is; how to describe the diversities when statistics and educational background gives the picture of a uniform group of students.

3 The diversity described from a lectures point of view

One way to describe the different types of students is "the list" any lecture (and student) can write based on a combination of experiences and intuition. Here is an example of such a personal set of student types.

The perfectionist
Only top results are accepted as satisfying.
This is far from realistic expectations for all the students in this group.

The craftsman
A student with practical experiences from the "real world".
This student has a tendency to be challenged on the theoretical level.

The working bee
Work, work, work!
Not necessarily the biggest talent, but hard work often pays off!

The eighth wonder of the world!
A very confident and attention seeking student. Often the tallnt do not compliment the confidence...

The student with other responsibilities
The student with family and children. They have a life beside studying, that put restrictions on the possible time to study.

The laid back student
This is actually two types of students. The very talented few to whom the subjects are easy and logic and the student who has not realized that talent and charm is not enough.

Mommy's little boy (girl)
An insecure and quiet student, with a tendency of not taking the responsibility of own learning and failures.

This might give the lecture, who wrote the list, a tool to describe which challenges that can be expected to develop during a group based project work, and even some ideas of how to guide the students. But it can never be much more than a qualified guess. It is and will always be a personal interpretation often made on a very thin base of information.

More importantly such a set of categories does not provide the student with any tools that can help them to understand and respect their fellow students' preferences, in particular if these preferences divert from the students own.

4 Describing the diversity trough personality testing

Another way to describe the diversities between the students are inspired by normal recruiting practice in the private sector, where a potential candidate will be asked to take a personality test.

In two very different experiments of using personality tests at Aarhus University School of Engineering the personality tests are in both cases based on Dr. Carl G. Jung (1875-1961) personality profiling theories from year 1921.

The two experiments have been conducted on very different scales and implementation methods.

4.1 The informal, small scale experiment

This experiment was conducted as an optional challenge to a project at 3. semester where one of the learning goal is "to be able to work in a group". The following describes the results gained in a project group of three students.

When the project started one of the students had the feeling of being a burden to the rest of the group. The students were advised to take a JTI (Jung Type Indicator). A free version available on www.jobindex.dk was used. Afterwards the results were discussed in a supervising session.

As seen in Figure 1, it was clear that there were both similarities and significant differences between the group member's preferences.

Figure 1: Plot of the tree students JTI test

Despite it was a very simple experiment, it gave the students an insight to themselves and tools to start understanding there fellow students.

Here is a short excerpt from the students own reflection note:

Taking the test, made us understand that all humans are different, and that it is important to respect these differences. As an example, some needs a bit of time by them self to think and reflect before being able to make a decision.

Taking the test was very good, because it focused on the differences in the group and put words on subject that normally is hard to talk about.

Jess, Kristian and Siv.

4.2 The formal way – systematical, big scale testing

The following is based on an interview with Head of Education, Helle Wivel.

Since year 2008 all students at the Department of Mechanical Engineering, has been offered the chance to take an Insights Discovery personality profiling test. The test is conducted during the first week of studying. Afterwards the students are offered a feedback consultation both as individuals and as a group. If needed the students are allowed extra consultation for instant in case of conflict handling.

The result of the test is also used when setting the groups in the first two semesters. The first group is set with the intension to create the ideal group, where all the personality types are represented. The second group are mixed, aiming to challenge the students personalities, forcing them to work outside there intuitive preferences.

With this use of the type test, the personality profile seems to become an active used toolbox for the student in many different situations. From tackling a lack of progress in a project, to being able to talk about and even joke with personal preferences; "you know I'm yellow, so I would prefer if we could put in some fun time…"

It is also seen that those few students, who for one reason or another did not take the test, when first offered, asks to be allowed to take it later on, often just before they have to start their internship on the fifth semester.

It has been an investment to enroll personality type testing in this scale, but it is an investment that pays off. Not in a level that can be measured in the grades, but since personality type testing was enrolled, the number of undefined dropouts have been significantly reduced. In other words providing the students with tools to work with their interpersonal competencies increases the students abilities to complete their study.

5 Conclusion

Gaining useful knowledge about the diversities of the students is easier said than done. From traditional statistics the students is defined as a relatively uniform population.

In the meantime, a group of students are not a uniform population, who all want the same and learn in the same way. If students were a uniform mass, it would not be possible to write any intuition and experience based "list", which divides the students into different categories, with different types of challenges.

Personality type testing can provide some knowledge, about the diversities seen between the students. This knowledge can be used actively, by both the lecture and the students. From comparable input information, the interpersonal diversities become visible. Hereby it becomes easier to talk about differences in personal preferences; "are we different?" is no longer a question, it is therefore possible to start asking "how do we handle our differences?"

All in all identification of the diversities amongst the students might not lead directly to better grads or a higher level of learning. But it will definitely reduce or remove learning obstacles related to group based project work, simply because the student are given a tool to work with their interpersonal competencies.

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SET (Skills Evolution Tool)

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Abstract

To **promote equality**, **social cohesion and active citizenship**, one of the objectives of the **Bruges Communiqué** 2020, ensures that VET suppliers, as indicated in the statement itself, not only provide the students with specific technical skills but also other more extensive skills, including general skills which enable them to manage their professional careers and play an active role in society.

To us professional competence is one that includes both generic skills and technical competencies. With this interpretation we respond to the challenges of competitiveness, innovation, etc..

The above-mentioned **generic skills** can be very varied, but in our case, in the Basque Country, we have organized them into three groups of different skills:

- Team work
- Learn to learn
- Critical and creative thinking

The basic tool for change in the classroom is based on the use of **active and collaborative teaching methodologies**.

Implementing these active methodologies requires, in turn, continuing to create **new learning scenarios** where the implementation of progressive collaborative learning is gradually introduced. Which means:

- Changing the current **structures** of VET institutions, particularly in relation to the teaching-learning process: Teamworking, modifying school timetables, boosting digital learning as well as knowledge of languages, Incorporate companies as co-responsible bodies for student learning
- **Conditioning spaces**, classrooms, workshops and furniture, providing greater transparency to teaching.
- Fostering **leadership for learning** by the VET management teams.
- **Training teachers** in generic competencies in education, the use of ICTs and raising awareness and helping them, giving them a toolbox to undertake new roles with a new mindset.
- **Collaborating with local businesses**, capturing feasible projects to be undertaken by students.
- Adapting students training, **personalizing learning**, turning them into protagonists.
- Experimenting and **disseminating practices** in relation to the experience with active collaborative methodologies, establishing phases of implementation in schools according to each school's culture, and creating networking at schools.

Pilot experiments to date indicate, on the one hand that students are more motivated, have a greater capacity for work, but also that this kind of competence, since in it is in constant evolution, is very **difficult to assess**.

This is, as in other experiences, the biggest concern and difficulty: Because in the end, teachers need **new evaluation systems**. New systems appropriate to new assessment scenarios.

This is why our interest in this regard has been focused on evaluation.

We believe that having good assessment systems is the best way to accelerate the implementation of active learning methodologies that facilitate the acquisition of technical and transferable skills:

- Because by changing the evaluation we change the way of teaching, planning and organization of learning.
- Because teachers will adapt methodologies to the kind of tests or exams to what students have to take.

A significant development in this regard has been the **SET tool** (techniques and transversal **S**kills **E**volution **T**ool) that have been developed, since it facilitates the evaluation process through the use of ICTs.

This tool is helping us in experimenting with new methodologies, but also increases the need to validate its performance and features, which are:

- During assessment, the emphasis is placed on **the evolution of skill sets**, not in qualification. Evaluation = Evolution. Being in constant evolution, the feedback given to students on their learning is essential, not the marks awarded.
- Assessing competencies becomes **a shared process,** teamwork: of teachers and students.
- **Self-assessment** of students is implicit in the act of evaluation.
- Much **flexibility** is required due to the variety of specialties, experiences and attitudes in relation to numbers, headings, people, etc..
- It needs to be user friendly **flexible** and easy tool

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Perspectives of using learning assignments in course assessment

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Abstract

In this work, students' activation via learning assignments is presented. The continuous course assessment based on learning assignments was observed to be effective in activating the students to work constantly throughout the course. This paper shows three cases representing different forms of activating assignments. It was observed that the students who completed courses with learning assignments achieved high grades. Challenges in continuous assessment deal both with creating meaningful exercises and assessment of the assignments with the available teaching resources. We see that guiding the students to constructively align their learning can be supported by providing them an active role in their learning process.

1 Introduction

Active learning can be defined various ways (Prince, 2004). One way is to include only the activities that take place in class rooms in order to enhance engagement to learning process. In this study we have selected a broader idea and decided to look at learning activities carried out between lectures in form of learning assignments. These assignments determine the course grading and they consist of pre-formulated substance knowledge questions and also learning log.

Learning that is activated all the way during courses can increase students' deep learning. One way of enhancing active learning process is to give students learning tasks to activate them to study independently between lectures. In this concept teacher's role is to guide and mentor the learning process by assessing and giving feedback to the student during the whole course while students are completing the learning tasks. When these tasks are affecting the assessment of the whole course, a concept of continuous assessment is applied. Continuous assessment has been observed to enhance the students' learning, motivate them to work harder and result in better grades. (e.g. Trotter, 2006; Cole and Spence, 2012; Tuunala and Pulkkinen, 2015)

In this study, three case studies are introduced which describe the application of continuous assessment as a tool to activate students in Aalto University School of Chemical Technology (Aalto CHEM). The cases include two Bachelor level courses and one Master level course.

2 Research objectives

The aim of this paper is to study how to engage students to work continuously throughout the course to result in deep learning and how to manage teaching resources to support high quality in learning. As a result, we discuss the means of active, continuous course assessment in motivating the students towards acting as professional learners. Motivation plays a key role in learning and it is important to consider various ways in order to enhance continuous motivation to support the students' activities towards deep learning. (Barron and Harackeiwiz, 2000; Hidi, 2000). Three different cases were studied to see how these continuous assessment methods affect both students' and teachers' work.

3 Methodology

The first case is a compulsory course which is annually taken by ca. 200 students. The majority of the students is 2nd year students aiming at the degree of Bachelor of Science (Technology). At this course it is possible to choose either learning assignments or a conventional exam. The learning assignments include learning logs and defined questions on the studied content. In the end of the course there is an oral exam in groups of 4-5 students. All the work is assessed by the teacher and students get at least group feedback of everything they do. The final grades of students were compared in the end of the course.

As the second case we have a Bachelor level course where the assessment is based on eleven weekly individual learning assignments and five lab works including reporting in groups. The assignments are quizzes in virtual learning environment (Moodle). Using automated quizzes makes it possible to run these assignments for group of 130 students yearly. The laboratory exercises are assessed by the reporting.

The third example is a Master level course. Typically about 60 students take the course annually. The assessment of the course is based on ten weekly assignments and exam is not an option. In the assignments the students are given a topic which is related to the lecture topic, but they have to find material for the topic, evaluate the validity of the sources and complete a report of couple of pages.

4 Results

The results are based on students' feedback and teachers' observation in cases 2 and 3. For case 1 the learning assignment makers and exam takers results were analysed based on the information of the course grades between years 2009 and 2013.

Case 1

The average grades of the students in case 1 were calculated for both groups of students, those who chose the learning assignments and those who took the exam. As clearly seen in Figure 1, the students who took the learning assignments succeeded markedly better that those who took the traditional exam. In interpretation of the data we left the zero-result in the exams out and compared the final grades. In exam ca. 10 % of the students failed and some students took the exam several times that increased the work load for both these students and teachers. All the assignment makers passed the course at one trial.

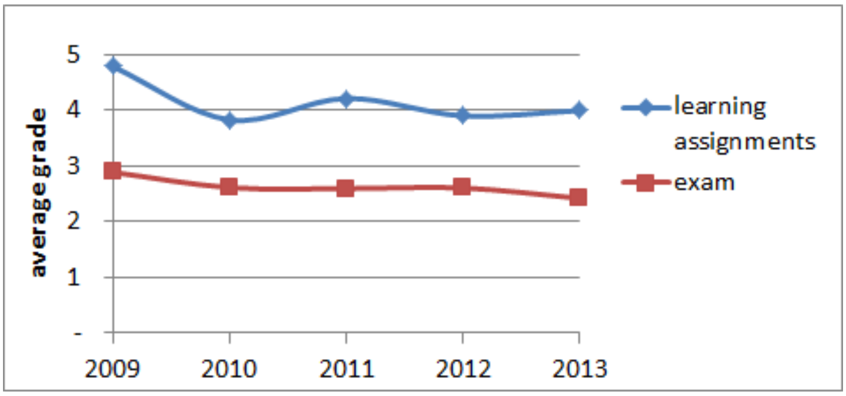

Figure 30: Average grade of students who take learning assignments compared to those who take the exam.

The students appreciated the possibility to select their own way to complete the course. We had to restrict the amount of assignment makers to 15-40 students annually depending on the teacher resources. This was not regarded as a problem as all who wanted to participate in continuous assessment were able to do it.

Case 2

The course presented as case 2 is a new course in Bachelor's program. The idea has been to support students' learning processes also by applying continuous assessment methods. Based on the experience the biggest challenge has been to produce quizzes that would be difficult enough to really challenge students. The possibility to fill the test was restricted to three trials and each trial reduced 20 % of the maximum points. Students were very quickly able to set a system where right answers were spread amongst them and almost everyone got maximum points. Lectures were giving hints for the assignments at lectures but as the assignments were too easy the amount of students attending the lectures decreased gradually throughout the whole course. In feedback students claim that the assignments are too easy and thus they did not motivate learning. Of course students appreciated the high grades they obtained.

Case 3

The course in case 3 has been organised in a similar manner since the start of the course, thus comparison to the course with conventional exam with similar content is not available. However, feedback has been gathered extensively since the beginning of the course in year 2010.

The commitment of the students to this course is very high. The average grade over the years has been 3.9 which is relatively high. Mainly all students who have started to make the assignments have completed the course during one semester.

The assignments include questions which require an essay-type answer. In one assignment there are typically several smaller questions or issues which should be included in the answer. In all assignments the students have to search some material themselves and thus they are activated to study the topic based on their own interests and background and strengthen the knowledge which they regard as the most important in building their own expertise. In most of the assignments at least part of the answer can be concentrated on the student's own field of study. The emphasis of the assignments is to teach the students to find the most essential content of the material they find and report that in "engineering language". This is also one of the essential learning outcomes of the course. Feedback is given on each assignment and also format of the report is commented and the students' performance has been observed to improve during the course.

During the course the students also learn to build new information on the knowledge they have acquired during the course. This is observed as citations to earlier assignments. This observation is very important in terms of students' ability to build the new information on their existing knowledge according to constructivist theory of learning.

5 Conclusions

The feedback of all our cases indicates that the students appreciate continuous assessment. They were motivated to be active during the whole course in order to ease their schedule during the official assessment period.

The value of active assignments compared to traditional exam is the enhancing of deep learning when students are actively involved during the whole course which is also confirmed in the students' feedback. Another benefit is that learning takes place evenly throughout the course and it's not concentrated on the assessment period. Furthermore, this way of assessment provides the teacher to get on-line feedback of students' learning and the difficult issues can be reviewed if needed. The essay type assignment is suitable for courses having limited number of students to ensure constructive feedback and automatically corrected quizzed were observed suitable for course with large amount of students.

In continuous assessment the course content is divided into smaller parts. Students are more motivated to concentrate in narrow unities and thus they master these topics more easily than large sets which should be studied for an exam. This encourages the students to deeper understanding of the topics and better results in learning. However, it would be extremely interesting to be able to meet these groups after one year to see how the learning strategies affect their long term memorising and ability to use the concepts learned.

From the point of view of course development active learning rises questions about teaching recourses. How many assignments can one teacher handle? Students expect and value continuous feedback which makes them improve their performance but what is the quality of feedback with large amount of students? With several teachers available the workload can be shared but it has been observed that each individual applys the assesment criteria in a slightly different way. A good way to unify the grading when multiple teachers are involved could be to use e.g. Rubyrik style matrix with ready-made evaluation phrasing. The results of this study give the responsible teacher of the course valuable tools for negotiating the adequate personnel resources for ensuring the quality learning at the course. After all, the main target should be in supporting the students to constructively align their learning by providing them a possibility to more active role in their learning process.

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Software Tools to Support Project-Based Learning of Control Systems

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Abstract

At Universidad del Valle, Colombia, the methodology of Project-Based Learning PBL is used in courses in the control systems area of the Electronic Engineering program. In this approach, starting from a problem, students independently address the concepts, modeling and analyze mathematically the system object of the problem, conceive and design solutions, and use the technology to implement the solution, all this in the framework of a control project. To employ this methodology, is required to use software tools to support mathematical modeling, analysis and control system design, and the use of control and communication technology; for this purpose exist commercial software resources and academic laboratories for experimentation, but these are very expensive. This paper presents software tools to support the PBL of control systems, implemented with free software, accessible by Internet with animated interfaces and interactivity capabilities. The developed software has three tools: Interactive Animations, Analysis Tool of Control Systems HASC, and an Analysis Tool of Proportional Integral and Derivative PID controller HAPID. The interactive animations are aimed to facilitate learning of most important concepts of control systems theory. HASC application performs the mathematical support for the analysis and design of control systems. HAPID application supports the analysis and design of PID controller and the learning of diverse operation functions and fault detection in control loops. As development tools are used the free software *Easy Java Simulations* to design the graphical user interfaces and the *Scilab* as the mathematical calculation engine. The paper also presents several didactic strategies that illustrate how to use the software tools in a PBL methodology of control systems, showing that the developed software tools, offer a learning environment, which encourages the active learning and the development of transversal skills like self-learning, decision making and problem solving.

Keywords: Control Education; Project-Based Learning; Interactive Animations; ICT in education.

1 Introduction

A control system is a set of interconnected dynamic elements that perform an action with feedback, to achieve a given goal. The stimuli and system responses are called signals or variables. Reference signal is a stimulus applied to the control system to produce a desired response. Output signal is the obtained response, which may be different of the desired signal. Disturbance signal is an input that adversely affects the output signal. The elements of the control system are: plant, actuator, controller and measuring block. Plant is the object of control, actuator amplifies the power of output controller signal to the levels of input variable to the plant, which is manipulated by the controller with the aim that plant output variable behaves according to a desired reference, and measuring block allows do measurement of output signal, through sensors or transducers.

In engineering, the control theory is applied with the purpose to control variables, usually of industrial type, with the aim of automate a task for increase production or improve the quality of a service or product. To implement a control system is necessary obtain the plant model, analyze their dynamic and design the control strategy. Plant modeling, is the procedure that allows obtaining a mathematical representation of the system by means of physical laws and differential equations; analysis allows observe and evaluate the dynamic behavior of control system; and design of the control strategy, consists in select the appropriate controller that allows obtain the desired system behavior. (Ortiz et al. 2011), (Fernández-Samacá et al. 2012)

In the professional field, the practice of engineering is performed by projects, being the PBL an appropriate methodology to educate new engineers professionals. This methodology encourages the active learning, since students access to concepts in a self-learning way, and use the analysis and technology according to project requirements for the problem solution.

At Universidad del Valle, the PBL methodology is used in the control systems courses area of the Electronic Engineering program. The methodology starts defining a problem with three elements: a context, a variable and a control objective. To solve the problem, is required to develop a control project, which is executed in four phases during the semester. The phases correspond to: identification of the different elements in a typical control loop, mathematical modeling of system, analysis of system response in time and frequency domains, and the design and implementation of PID controller. (Fernandez-Samaca 2010)

In PBL the topics are learned according to project development, which requires to use software tools to support mathematical modeling, analysis and control system design, and to use of control and communication technology; for this purpose there are commercial software resources and academic laboratories for experimentation, but they are expensive. This paper presents software tools to support the PBL of control systems, implemented with free software, accessible by Internet with animated interfaces and interactivity capabilities. The developed software has three tools: Interactive Animations, Analysis Tool of Control Systems (HASC, by its initials in Spanish), and an Analysis Tool of PID controller (HAPID, by its initials in Spanish).

This paper is organized as follows: section 2 shows the interactive animations focused on facilitate learning of the most important concepts of control systems theory, like feedback, mathematical modeling, time and frequency domain analysis, stability, compensation, reconstruction of signals, control structures, controllability and observability. Section 3 presents the HASC application that supports the mathematical calculations in analysis and design of control systems. Section 4 presents the HAPID application as support tool for analysis and design of PID controller and learning several operation functions and fault detection in control loops. Each section presents a didactic strategy, where are described different types of activities to be performed by students in each developed application. Section 5 presents the assessment of the software tools, through surveys with an assessment scale of 1-5, 1 = no compliance and 5 = excellent level of compliance. Finally, section 6 presents some concluding remarks of work.

As development tools are used the free software *Easy Java Simulations* (Esquembre 2005), (Esquembre 2010), to design the graphical user interfaces and the *Scilab* (Scilab Enterprises 2012), as the mathematical calculation engine. The applications are embedded in an HTML document as *Java Applets* and are available (in Spanish) on the website: http://eieela.univalle.edu.co/ludicas_animadas/menu_ludicas.html.

2 Interactive Animations

A didactic strategy to facilitate the learning is 'playing'; according to (Gonzalez et al. 2011), it is considered as an effective tool to promote the active learning and to construct knowledge. Learning by playing allows simulating a reality; the game, in which the 'play' activity is centered, results a good scenario to err and learn from mistakes. In (Mondeja González et al. 2010), authors consider that characteristics like spontaneity, competition and participation make the play-activities a good alternative to encourage students in the learning process and reflect about the subject issues, motivating students to the field.

In control courses at Universidad del Valle, tutor organizes student groups and proposes them to develop Hand-On activities with the aim of introducing the concept of the topic and facilitate their understanding (Samacá & Ramirez 2011). However, for develop it, must be taken into account limitations like: physical space, additional materials, number of students, time; and depending of concept to teach, the activity can be complex and difficult to develop; furthermore, since these Hand-On activities are developed in student groups, are limited like self-learning activity. In order to avoid these limitations, were developed interactive animations intended to the same goals of Hands-On sessions presented in (Samacá & Ramirez 2011): '*facilitating the comprehension of the control concepts*'. (Ramirez-Ramirez et al. 2013)

It consists of 15 interactive animations, accessible by Internet, easy to use and understand which facilitate assimilation of control concepts in topics like: feedback, mathematical modeling, time and frequency domain analysis, stability, compensation, reconstruction of signals, control structures, controllability and observability.

Generalities

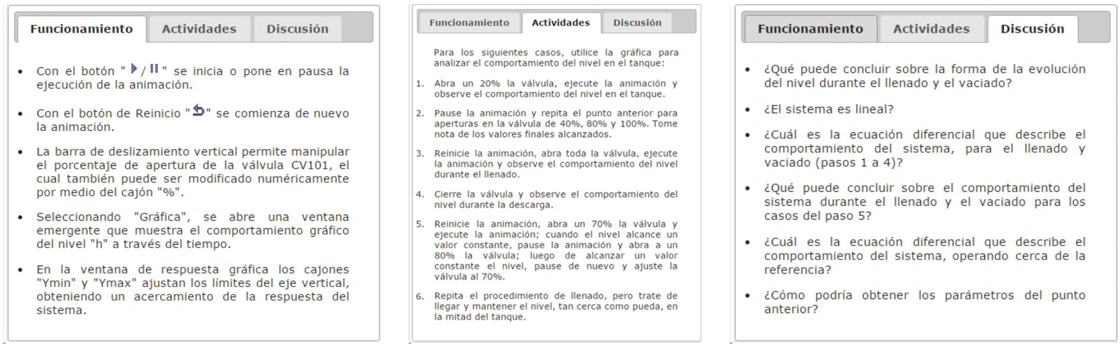
The interactive animations have a graphical user interface composed by:

- Groups of simple dynamic objects as: wheels, pivots, plane surfaces, valves, level tanks, masses, springs, ropes and pulleys.
- Interaction elements as: action buttons, sliders, radio buttons, boxes for entering and displaying variables values, and registration windows to show graphic behaviors.

For a proper operation and concept learning, each interactive animation contains four aspects:

- Description: Introduces and describes the general behavior of interactive animation.
- Operation: Describes the function of each element of graphical user interface of animation.
- Activities: Establishes the instructions necessary to obtain behaviors.
- Discussion: Establishes discussion questions to analyze behaviors.

The aspects of operation, activities and discussion are organized in a view by tabs, allowing the student to consult every aspect when needed. The Figure 2 shows an example of the content and organization of these aspects, corresponding to the interactive animation called 'Valve and Tank'.



- Con el botón " ▶/⏸ " se inicia o pone en pausa la ejecución de la animación.
- Con el botón de Reinicio "↶" se comienza de nuevo la animación.
- La barra de deslizamiento vertical permite manipular el porcentaje de apertura de la válvula CV101, el cual también puede ser modificado numéricamente por medio del cajón "%".
- Seleccionando "Gráfica", se abre una ventana emergente que muestra el comportamiento gráfico del nivel "h" a través del tiempo.
- En la ventana de respuesta gráfica los cajones "Ymin" y "Ymax" ajustan los límites del eje vertical, obteniendo un acercamiento de la respuesta del sistema.

Para los siguientes casos, utilice la gráfica para analizar el comportamiento del nivel en el tanque:

1. Abra un 20% la válvula, ejecute la animación y observe el comportamiento del nivel en el tanque.
2. Pause la animación y repita el punto anterior para aperturas en la válvula de 40%, 80% y 100%. Tome nota de los valores finales alcanzados.
3. Reinicie la animación, abra toda la válvula, ejecute la animación y observe el comportamiento del nivel durante el llenado.
4. Cierre la válvula y observe el comportamiento del nivel durante la descarga.
5. Reinicie la animación, abra un 70% la válvula y ejecute la animación; cuando el nivel alcance un valor constante, pause la animación y abra a un 80% la válvula; luego de alcanzar un valor constante el nivel, pause de nuevo y ajuste la válvula al 70%.
6. Repita el procedimiento de llenado, pero trate de llegar y mantener el nivel, tan cerca como pueda, en la mitad del tanque.

- ¿Qué puede concluir sobre la forma de la evolución del nivel durante el llenado y el vaciado?
- ¿El sistema es lineal?
- ¿Cuál es la ecuación diferencial que describe el comportamiento del sistema, para el llenado y vaciado (pasos 1 a 4)?
- ¿Qué puede concluir sobre el comportamiento del sistema durante el llenado y el vaciado para los casos del paso 5?
- ¿Cuál es la ecuación diferencial que describe el comportamiento del sistema, operando cerca de la referencia?
- ¿Cómo podría obtener los parámetros del punto anterior?

Figure 2: View by tabs of the aspects, Operation, Activities and Discussion.

Didactic strategy

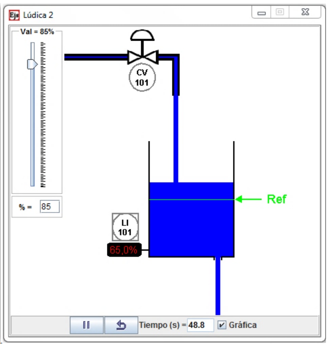
The interactive animations are used as preliminary stage to study the topics and with the purpose of introduce and facilitate understanding of the concepts; students enter to the web page that contains the applications, select the interactive animation of interest, understand its operation, develop the activities and perform the discussion.

The following example shows the use of the interactive animation ‘Valve and Tank’ to understand the concept of mathematical modeling of a system. The concept of modeling consist in determine a mathematical model that describes the dynamic behavior of a system, which is usually represented by differential equations. Description of the animation is:

> *This animation shows the level behavior (in percentage) in a tank, which have constant area section of 3m^2, and turbulent flow in discharge equal to:*
>
> $$q_o(t) = k\sqrt{h(t)}$$
>
> *The level evolution through time is plotted in the registration window. The animation has the following instruments (standard ANSI / ISA 5.1):*
>
> - *CV101: Control Valve*
> - *LI101: Level Indicator*

Figure 3: Description of the interactive animation ‘Valve and Tank’.

This interactive animation has two windows, one to set the parameters and another to observe the system behavior. In the first window (interactive window), the user can observe how the tank is filled and empty interacting by means of control buttons, as illustrated in the Figure 4.



Val = 85%

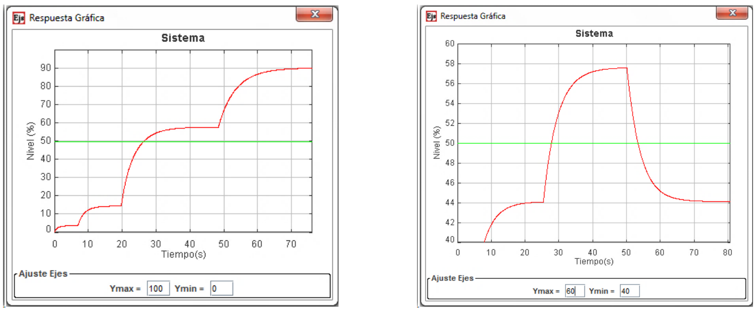
% = 85

Tiempo (s) = 48.8

☑ Gráfica

Figure 4: Interactive animation ‘Valve and Tank’.

In the second window (registration window), the behavior of the level in the time domain is recorded; the development of the proposed activities in the view by tabs (see Figure 2) allows students obtain the behaviors of Figure 5.



Ymax = 100 Ymin = 0

Ymax = 60 Ymin = 40

a) Non-linear behavior b) Linear behavior

Figure 5: Graphic behavior of the level in the time domain.

The analysis of the discussion questions, allows to identify the behavior of a non-linear system (the level behavior is different for each valve opening), Figure 5a, and linear (the level behavior opening and closing the valve around an operating point), Figure 5b. Through differential equations and physical laws is obtained the nonlinear and linear mathematical model which describes the system behavior for each case (equations This paper shows the design and implementation of Key Performance Indicators (KPI) to assess the effectiveness, efficiency and developed learning, in executing the improvement projects resolution process, applying Six Sigma methodology, in an auxiliary company of automotive sector. In the application, it was found as key factors: the commitment of the leadership, the culture or habits in the company, effort dedicated to team work and the involvement of the tutor or coach.

Keywords: Improvement Projects Resolution Process (IPRP), Six Sigma, Key Performance Indicators (KPI) of the Continuous Improvement Process.

and (2) respectively).

$$A\frac{dh(t)}{dt} = q_i(t) - k\sqrt{h(t)}\ , h(t_0) = h_0, \quad (1) \qquad A\frac{dh(t)}{dt} = q_i(t) - \frac{h(t)}{R}\ , h(t_0) = h_0, \quad (2)$$

where $h(t)$ is the level, $q_i(t)$ is the input flow, A is the area of the tank and k the gain of the output flow (proportional to square root of level). R is defined as the resistance to the flow passing in the discharge, at the operating point.

HASC

Once the system is modeled, is performed the analysis procedure to obtain and evaluate the response of the system. The HASC application is a tool that allows the students perform the analysis of a dynamic system remotely; it is based on a 'Client – Server' architecture that uses the TCP/IP communication protocol, as illustrated in the Figure 6.

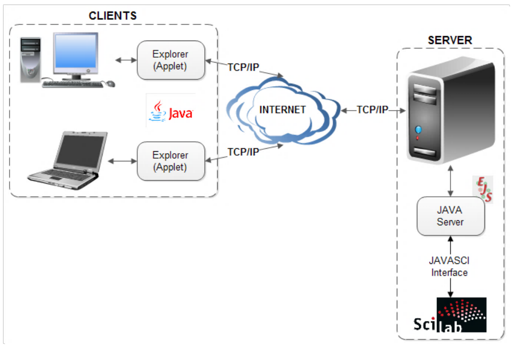


Figure 6: 'Client – Server' architecture of HASC.

Users utilize the client application as interface to send requests of different analyses towards server application, which is responsible for processing these requests through the Scilab software by means of interface *Javasci V2* (Cornet & Ledru 2011), and returns the result of the requested analysis. HASC allows several analysis of control systems (Ogata 2010), such as time, frequency or root locus of a continuous or discrete system represented by its Transfer Function TF or a model represented in the State Space SS; also performs the transformations between continuous and discrete domains and model representations (from TF to SS and vice versa); the coefficients of these transformations are displayed in an additional window. The analysis and transformations of HASC are shown in Figure 7.

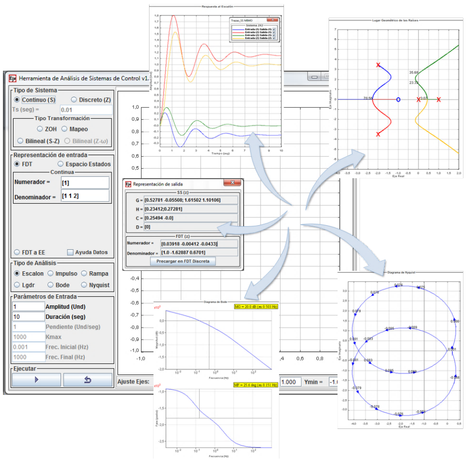


Figure 7: Analysis and transformations in HASC.

Didactic strategy

During the learning of analysis topics of time, frequency and root locus, the HASC application is used in the examples facilitating understanding of these analysis methods. At end of each topic, exercises are given to use HASC in the analysis of behaviors; similarly, in the project analysis phase, the students use HASC for each particular project.

To illustrate it, next is shown how to use HASC in the temporal analysis topic. The aim in temporal analysis is obtaining different parameters that characterize the temporal response of a dynamical system, as response velocity, damping oscillation, maximum and minimum values and permanent accuracy. These parameters are obtained by means of test input signals as step, impulse or ramp. At the end of this topic is given the next exercise:

Exercise 1: Consider the control system of Figure 1

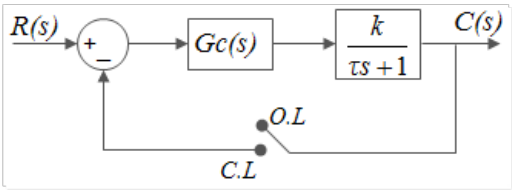


Figure 1: Control system of exercise 1.

The plant parameters are k = 0.9 and τ = 1. In open loop (O.L), a proportional controller is used Gc(s) = Kp = 1. In closed loop (C.L), an integral controller is used Gc(s) = 1/s. Analyze and compare the performance of the system in open loop and closed loop, using the respective controllers, with respect to: response velocity, oscillation (damping), maximum overshoot, steady-state value and steady-state error (e_{ss}) of the response due to a step in the reference.

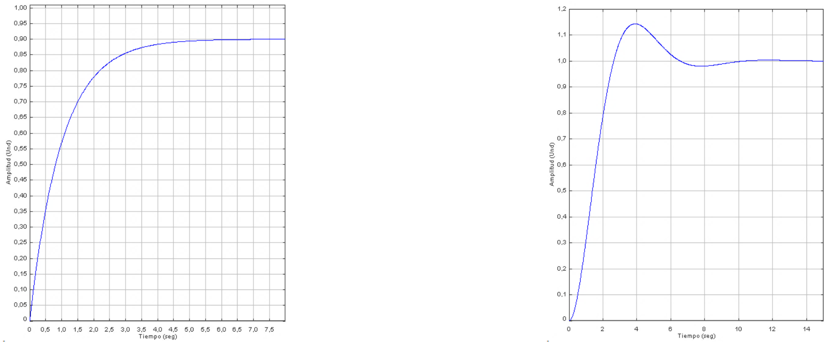
Suggestion: Use the HASC application as support tool.

Figure 8: Exercise proposed in 'Analysis of the temporal response' topic.

To solve this exercise, the student initially represents in Transfer Function TF the system in OL and CL, (equations (3) and (4) respectively).

$$Gp_{RA}(s) = \frac{0.9}{s+1} \quad (3) \qquad\qquad Gp_{RC}(s) = \frac{0.9}{s^2+s+0.9} \quad (4)$$

Using HASC introduces the coefficients of these TF, executes the step analysis and obtains the responses of Figure 9.



a) First order System b) Second order System

Figure 9: Temporal responses obtained for a step input.

Analysing the Figure 9a, the student observes that the temporal response corresponds to a first order system with settling time (response velocity indicator) of 4 second, over-damped response without overshoot, with steady state value of 0.9 and e_{ss} of 10%. While analysing the Figure 9b, observes that now the temporal response corresponds to a second order system with settling time of 8 second, damping coefficient of 0.5, maximum overshoot of 1.16 and a steady state value of 1, with zero e_{ss}. He can conclude that feedback with an integral action, does a twice slower system with zero steady state error.

HAPID

The main objective of control systems is achieving a desired performance that must be obtained with proper design of a control strategy. In control systems, the control strategy most used is to act in the input plant through the Proportion, Integration and/or Derivation, of the system error. The PID controller is used in near 95% of industrial control loops, due to its simplicity, easy fit, flexibility and robustness. (Ramirez Scarpetta 2014).

The HAPID application is an interactive animation that recreates an environment of a Supervisory Control and Data Acquisition SCADA, for a heat exchanger controlled with the PID, see 'Proceso' window in Figure 10; this application allows to realize the analysis and design of a practical PID controller, and support activities for the learning of the diverse operation functions and fault detection in control loops. HAPID has practical implementation aspects like: (Corripio 2001), (Åström & Hägglund 2006)

- Control action: ISA standard structure of PID (TIC/101) control action:

$$U(s) = \pm\left[K_p\left(bR(s) - B(s) + \frac{1}{T_i s}\big(R(s) - B(s)\big) + \frac{T_d s}{1 + \frac{T_d}{N}s}\big(cR(s) - B(s)\big)\right) + A_b(s)\right], \quad (5)$$

  where *U(s)* is control signal, *R(s)* is reference input, *B(s)* is controlled output, *Kp* is proportional gain, *Ti* is integral time, *Td* is derivative time, *b* and *c* are weight constant in the reference of action P and D, *Ab(s)* is manual compensation (bias) in the control signal for P or PD action. The sign ± defines the control action, direct (+) or inverse (−).
- Filtering the derivative: To avoid amplify the measurement noise is added a first order filter with time constant 'Td/N' to pure derivative action.
- Integrator 'Windup': To avoid large values of the integral action (due to saturation of the actuator), the integral part of controller is recalculated.
- Manual-Automatic bumpless transfer: To ensure a bumpless transfer between Manual and Automatic mode.
- Control valve (CV/101) (actuator) with hysteresis, dead-band and flow characteristics.

- Temperature transmitter (TIT/101) (sensor) with noise and anti-aliasing filter in the feedback signal.

The application presents a SCADA environment composed by:

- Human Machine Interface HMI with: Process panel, formed by instruments and a control loop in representation according to Standard ANSI/ISA 5.1 (ISA 5.1 2009), Access panel ('Acceso' window in Figure 10), PID controller panel ('Control' window in Figure 10), with graphic record of process variables, Control valve panel ('Configuración Válvula' window in Figure 10) and Transmitter panel, ('Configuración Transmisor' window in Figure 10), both with graphic record of behaviors, Events panel ('Eventos' window in Figure 10) and Fault panel ('Fallas' window in Figure 10).
- Functionalities: Access control (with hierarchy levels: Engineer, Supervisor and Operator), Permission management, Alarm generation and acknowledgment, PID parameter setting, Operating mode (Manual - Automatic), Configuration of: control valve, transmitter and alarms, Event log, Reports generation (like: configuration parameters values, process variables data and events type), and generation of ten typical faults that affecting the elements (controller, actuator and sensor) of control loop.

The interfaces and functionalities of HAPID are shown in Figure 10.

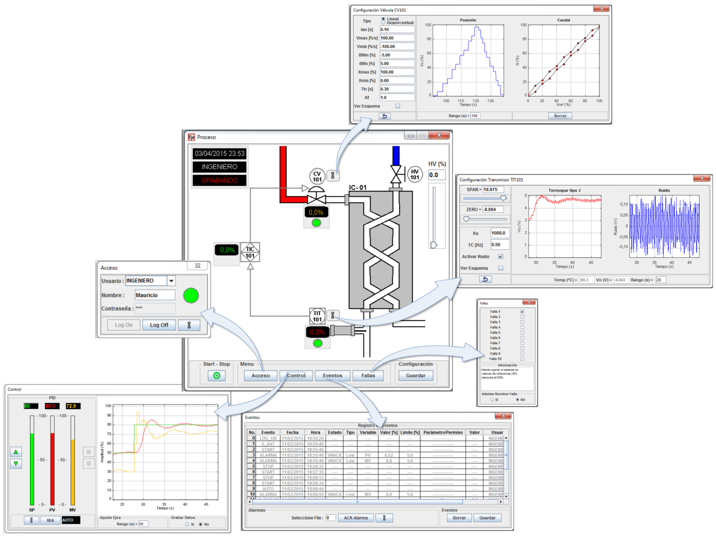


Figure 10: User interfaces and functionalities of HAPID.

Didactic strategy

At the end of the control actions topic, a typical control problem in industry is described; it requires to use the HAPID application for analysis, design and implementation of the solution. In the Figure 11, is shown a problem example:

> *<u>Problem:</u> The HAPID application presents a heat exchanger whose purpose is heat the input flow from a temperature $T_i(t)$, to an output desired temperature, $T_o(t)$. Design a control system that meets the following performance specifications:*
>
> 1. *Null steady state error e_{ss}.*
> 2. *Good damping of transient response, with a maximum of three oscillations before the stabilization.*

3. *Stabilization time t_s less than or equal of 10 seconds (2% criterion).*

Figure 11: Control problem description in 'Control actions' topic.

To meet the desired specifications, the student initially operates the system in 'Manual' mode, and in the 'Control panel' he observes the behavior of process temperature, as illustrated in Figure 12.

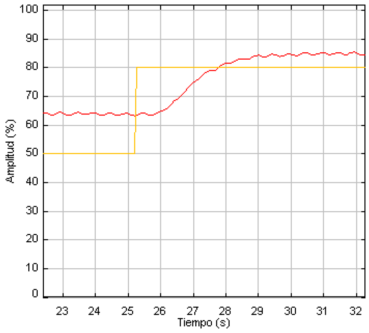
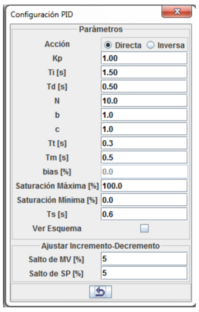


Figure 12: Process behavior in 'Manual' mode.

From this figure, he determines that the process presents a dead time of 0.5 seconds, a static gain of 0.7 and a time constant of 1 second (Ogata 2010). This behavior is represented by following TF:

$$G(s) = \frac{0.7e^{-0.5s}}{s+1} \qquad (6)$$

After the process identification, he designs the control strategy and adjusts the parameters in the 'Configuración PID' panel, as illustrated in Figure 13.



Acción: ● Directa ○ Inversa
Kp: 1.00
Ti [s]: 1.50
Td [s]: 0.50
N: 10.0
b: 1.0
c: 1.0
Tt [s]: 0.3
Tm [s]: 0.5
bias [%]: 0.0
Saturación Máxima [%]: 100.0
Saturación Mínima [%]: 0.0
Ts [s]: 0.6
Ver Esquema: ☐
Salto de MV [%]: 5
Salto de SP [%]: 5

Figure 13: 'Configuración PID' panel to adjust PID controller parameters.

Finally, he selects the 'Auto' mode and verifies that the system performance complies with desired requirements, as illustrated in Figure 14.

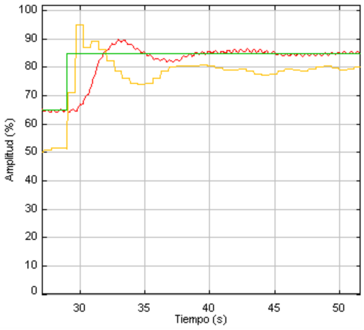


Figure 14: Process behavior in 'Auto' mode.

From this figure, the student determines that the controlled system has a t_s of 9 seconds, a damped transient response with two oscillations before stabilization and null steady state error. He concludes that behavior of the controlled system satisfies the desired performance specifications.

3 Assessment

The software tools were evaluated by means of surveys with a rating scale of 1-5, 1 Not satisfied, 2 Low, 3 Acceptable, 4 Good, and 5 Excellent. The results were analyzed taking into account three aspects: tool operation, learning contribution, and development of transversal skills. Interactive Animations were evaluated by students of System Modeling course at the Universidad Pedagógica y Tecnológica de Colombia UPTC, in first semester of 2014. The software tools HASC and HAPID, were assessed independently by teachers from universities Universidad del Valle and UPTC, in April of 2015. For analysis of the assessment results, the questions related to the Operation were differentiated with the letter 'F', the Learning with the letter 'A' and Transversal Skills with the letter 'H'.

Interactive Animations

In the System Modeling course, the students used and assessed the interactive animations 1, 2, 5, 6 and 7. In this case, for animation 1, 27 students answered the survey, 24 for animation 2, 22 for animation 5, 18 for animation 6 and 17 for animation 7. As the questions related to the aspect 'Learning' are different in each interactive animation, for comparison the overall average of the questions associated with this aspect was obtained, and was assigned the indicator ' QA(Av)'. Figure 15 contains the averages of each surveyed case and the overall average.

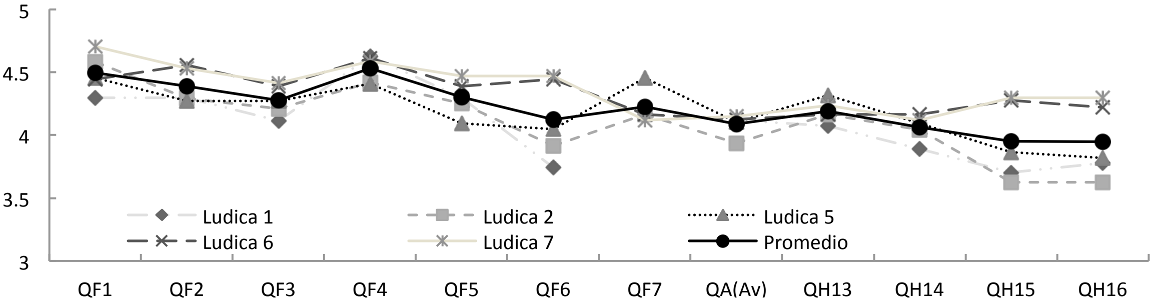


Figure 15: Evaluation results of the surveys for the interactive animations

Most of questions were rated with a higher score of 4.0, which shows an acceptance of students about of the interactive animations into their formation process. The question 'QF6' about *the execution speed of the animation* has a lower rating, due that the execution speed of the *Applet* may be affected by the *Java version* that the user have installed, and hardware and software limitations present on the machine from which the animation is run. The average value obtained for the 'Learning' aspect ‘QA(Av)’ was 4.1, which indicates that students consider that the interactive animations are useful and facilitate the concept learning. With regard to questions of the 'Transverse Skills' aspect, the consultations about the development of skills as, self-learning ‘QH13’ and decision making ‘QH14’ have similar ratings in the evaluated cases, there are differences in the average rating of the questions ‘QH15’ and ‘QH16’ about recursion and creativity, and the ability to problem solving, these differences may be related with the aim and topic of the interactive animations, major challenges such as those presented in the animations 6 and 7, may promote in greater degree these skills.

HASC

This software tool was evaluated by five users. In Figure 16 the averages of the survey questions are displayed.

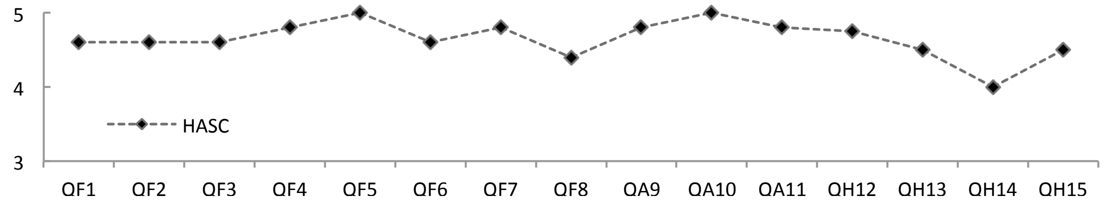


Figure 16: Evaluation results of the surveys for the HASC tool

The averages ratings for the aspects: Operation, Learning and Transversal Skills, were respectively 4.7, 4.9 and 4.4. All survey questions were rated with levels of compliance 'Good' or 'Excellent'. The user interface allows modify the parameters of the system dynamics, generating a student interaction with the tool in the simulation of different cases and operating conditions, whereby all users rated the question ‘QA10’ with 5.0, related to *the relevance of the tool to learning control systems*. In the transversal skills aspect, is shown a reduction in the questions related to recursion ‘QH14’, this rating is because this software tool is more focused on self-learning that other skills, aim that is validated through the qualification obtained by the question ‘QH12’, which was assessed with an average rating of 4.8.

HAPID

This software tool was evaluated by five users. In Figure 16 the averages of the survey questions are displayed.

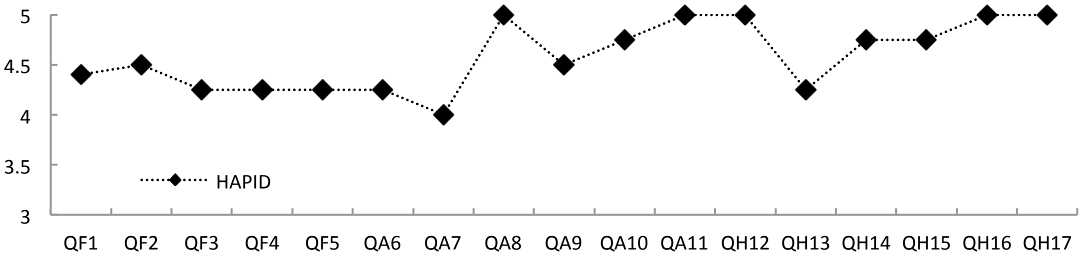


Figure 17: Evaluation results of the surveys for the HAPID tool

The Operation aspect obtained an average of 4.3, which indicates that users consider that this software tool it worked properly. With regard to questions of Learning aspect, this obtained an average of 4.6, where the qualification of the questions related to the operation ‘QA10’ and fault diagnostics ‘QA11’, obtained a "Excellent" level of compliance. Users mainly emphasize the similarity between the simulated environment with the HMI (*Human-Machine Interface*) of a SCADA. Users also find interesting the option of tool that allows set different levels of priority in the configuration and access, such as Engineers, Supervisors or operators, whereby, besides being a motivating introduction to the use of the tool, allows the possibility of designing different academic practices with students. The questions related to the development of transversal skills, were rated with a compliance average level of 'Excellent', obtaining an overall average rating of 4.8.

4 Conclusions

This paper presents three software tools: Interactive Animations, Analysis Tool of Control Systems HASC, and Analysis Tool of Proportional Integral and Derivative controller HAPID, oriented to support the project-based learning methodology in control systems. The developed software tools offer a learning environment, which allows students to develop different types of activities to learn abstract concepts, analyze behaviors and design control systems. Interactive Animations allows understand concepts without an explicit mathematical description and encourage students to learn in a fun way playing with the animations. HASC allows obtain easily and in a fast way, the time and frequency behavior, or the root locus of a dynamical system, which facilitates the analysis procedure. HAPID allows students to know an environment of industrial control and put into practice learning aspects as the implementation, test and adjustment of an industrial PID controller, and the maintenance based on generation of ten faults in the control loop. The designed applications are easy to operate and understand; they can be used by several students at any time and place, since they are free use and available in a website.

According to users, the software tools operate correctly, are interactive and friendly, support the project-based learning, encourage active learning and develop transversal skills like self-learning, decision making and problem solving.

Acknowledgment

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Learning engineering concepts in elementary school

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Abstract

This work proposes a methodology for helping kids to understand engineering concepts by using simple robotic prototypes. Likewise, the methodology seeks to propitiate the learning of basic engineering concepts by using technology. The proposed methodology is based on workspaces that facilitate the learning by playing. The methodology implies planning and designing a robot. Projects about zoomorphic robots thought to understand mechanical and electrical concepts have been developed for second and third grade. The methodology considers four stages: sensitizing, design, implementation and evaluation. The prototype is designed taking into account that must be safe, inexpensive and draw attention on the chosen engineering concepts. Children define aspects as the name of robot, basic features, its colour and decoration. In the implementation stage, engineering students explain the concepts to kids by using hands-on sessions. Special material and activities have been developed to teach the concepts. Kids with help of their parents and teachers implement the most of the parts of robotic prototypes. The evaluation stage centres in to test the robot and introduce the developed prototype to parents and friends in a public presentation at the end of academic year. The observations show that children identify clearly the addressed concepts, and the creativity of engineering students is challenged by new prototypes and concepts.

1 Introduction

Robotics has been widely used to encourage STEM (Science, Technology, Engineering and Mathematics) education. McLurkin et al. (McLurkin et al. 2013) described experiences using a low-cost robot for STEM education; Cielniak et al. (Cielniak, Bellotto, and Duckett 2013) showed the integration of robotics in a curriculum of computer science; Vona & Shekar (Vona and Shekar 2013) presented an interdisciplinary course of robotics that includes class sessions, lab exercises and a project to encourage competition-based learning; and Yilmaz et al. (Yilmaz et al. 2013) introduced a design-oriented robotics educational model that considers two courses supported with lab practices. These works appear in a special issue in Robotics Education (Padir and Chernova 2013), which addresses topics such as frameworks for distance education, platforms, teaching practices and novel approaches for engineering education.

Regarding robotics in school, several studies (Saygin et al. 2012, Lu and Mead 2012, Dorsey and Howard 2011, Brough, Baker, and Casadonte 2011) show different contributions about the use of robotics in K-12 education. Benitti (Benitti 2012) presents a literature review regarding the use of robotics in School, in which authors show comparing tables about aspects such as the subject, robot type and age range of kids. The reported results in Benitti's review (Benitti 2012) allow noting that robotics not only supports the teaching of subjects related to it but also promotes the development of transversal skills, such as problem solving, scientific inquiry, social communication and thinking skills.

Many institutions use commercial didactic platforms as LEGO in different educational levels, taking advantage of their features and modular components. For example, a previous study (Thai and Paulishen 2011) describes an experience carried out in a robotics course for senior level engineering. Another work (Oppliger 2002) presents the LEGO League as a scenario to enhance the education and motivation of engineering students. Others (Karp and Schneider 2011, Quevedo-Torrero 2011) showed experiences where LEGO robots are used in outreach programs to promote the enrolment of young people in engineering programs. Other researchers (Karp and Schneider 2011) described the evaluation results from an annual LEGO robotics competition for students in elementary and middle schools.

Moreover, LEGO robots are being used for learning STEM concepts in K-12 education. Pinto et al. (Pinto Salamanca, Barrera Lombana, and Pérez Holguín 2010) described an experience in preschool and elementary school developed by using LEGO robots to learn concepts related to numbers, colours and geometry. Likewise, most of the reported works in Benitti's review (Benitti 2012) are developed using LEGO robots.

To contribute to the challenge of teaching engineering concepts to children in preschool and elementary school, this work proposes a K-12 approach based on constructionism theory (Papert 1993) to facilitate the understanding of engineering concepts using simple and low cost robots. The designed K-12 approach seeks to propitiate the learning of basic concepts of STEM education. The proposed K-12 approach considers four stages to encourage the learning and offers an alternative to learn about robotics by means of practical exercises that involve schoolteachers, parents and kids.

This K-12 approach was developed by the Robotics and Automation Research Group (GIRA) at Universidad Pedagógica y Tecnológica de Colombia in Sogamoso, Colombia. The results presented herein correspond to the experiences observed at a local school during two years in preschool and second grade.

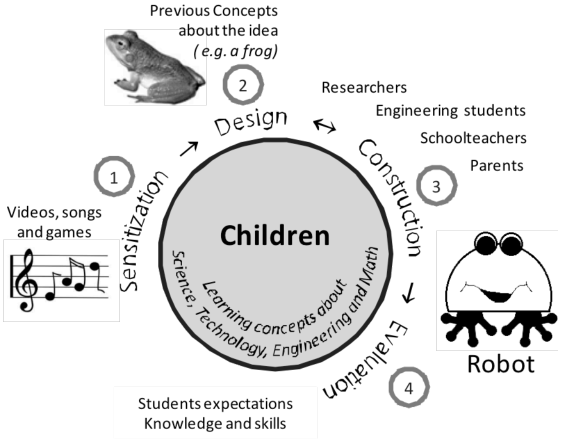


Figure 1: K-12 engineering education approach for preschool and elementary school.

2 Proposed K-12 Approach

The proposed K-12 approach implies the design and assembly of a robot, which are the core of the evaluation and academic activities. Figure 1 shows the stages of the K-12 approach, which are sensitization, robot design, robot construction and evaluation.

Sensitization

This stage engages students and their parents in the robotics world. The sensitization stage considers a phase called 'parents involving' aimed to show the importance, advantages and implications of robotics in the school's education. The second phase is 'ice breaking' focuses on getting the kid's attention. Other phases are oriented to construct the concept 'robot' by identifying its parts and main features, and kids choose the thematic and kind of robot they can construct, the chosen thematic must be widely known by all of the stakeholders. This approach uses 'animals' as a main topic for designing the robot because children feel strongly attracted to this. Finally, the phase 'Conceptualizing' focuses on understanding some basic engineering concepts. This phase employs workshops to understand specific concepts; for example, a talk about ‘bats’ for explaining the function of an ultrasonic sensor.

Other activities are developed to teach concepts that are not easily associated with animals, such as magnetic fields, electromechanical forces or mechanical advantage. Once an animal is chosen, researchers motivate children to observe aspects of the animal and analyze what components are necessary to build the robot. In short, the conceptualizing phase is aimed to learn concepts of subjects such as physics, electronics, mechanics, technology, mathematics, biology and foreign languages In this space, concepts are dealt together; robotics appears as a perfect means to encourage learning by playing (Huizinga 2004).

Robot design

This stage stresses on discussing characteristics of the chosen animal to define the features of the robot, considering the maximum cost defined for the robot (about US 20). Thus, researchers propose to children several draft prototypes of robots meeting parameters.

Robot Construction

The robot construction and design stages have a cyclical relationship and compose the basis of most of the academic activities.

Once the robot model is defined in the design phase, researchers use comparison workshops –similar to those used in the sensitization stage– to explain to the kids each part of the robot, its function and construction. They also plan hands-on sessions to guide kids, parents and school teachers during the robot construction and execute some tasks, specially, those that offer a risk for children and require precision or programming abilities. The approach also centers in enhancing the aesthetic dimension of kids, therefore, children also carry out activities such as cutting the robot’s pieces, painting and decoration, besides tasks related to the assembling of the robot.

Prototype evaluation

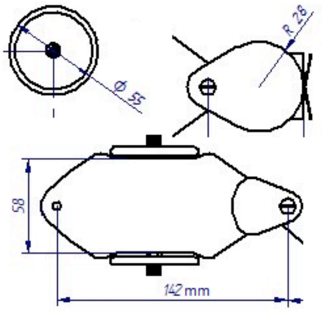
The workshops have become evaluation spaces that allow observing the learning outcomes and interaction of participants. In workshops, kids can learn from experiences of their classmates; stories, problems and solutions help children to judge their own work. At the end of the academic year, children present their robots in an academic event in which their parents and teachers participate.

3 An example Of Designed Robots

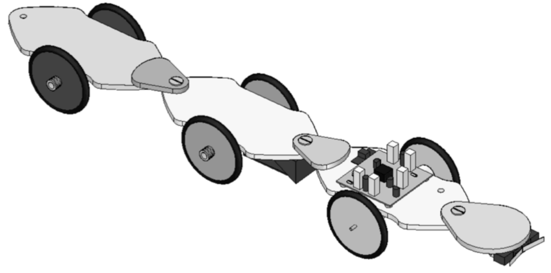
This section describes briefly a robot designed for the proposed K-12 approach: a worm (WormBot). The children’s contact with the environment and their work in the school farm inspires the design of these zoomorphic robots.

The WormBot is a robot designed to be used in second and third grade. This robot incorporates concepts, like mechanical advantage, serial and parallel circuits, transmission of motion, programming, and forward and reverse bias. New vocabulary like processor, microcontroller, transistor, resistor, LED and sensor, are included in this challenge.

The robot uses a small PCB for controlling two DC motors. This circuit is based on a microcontroller that receives signals from sensors (and controls the DC motors by means of two Pulse Width Modulation (PWM) signals. The PWM signals operate alternatively, so when a DC motor is turned on, the other is turned off, thus, causing the zigzag motion of the worm robot. If the robot hits an obstacle, one of the limit switches (worm antennas) changes the state of a microcontroller input, making the opposite DC motor to turn in reverse. Figure 2 presents the pieces that made up this robot.



a) wheel, head and body unit



b)

Figure 2: WormBot. a) Modules that made up the robot, measurements in mm, b) assembled robot

It is important to note that although kids do not know programming of microcontrollers, they understand perfectly its function in the robot operation, arousing their curiosity to learn about engineering.

The activities of WormBot are also oriented to explore the multiple intelligences of kids (Smith 2002,2008). For example, cutting pieces seeks to enhance the children's fine motor skills related to the kinesthetic intelligence, which is an important goal in elementary and preschool education.

4 Impact Assessment of the Proposed Approach

To assess the impact of the K-12 approach, different methods for data gathering were used. Considering the age range of the kids, researchers preferred to use questionnaires oriented to know the parents' and schoolteachers' impressions. In both questionnaires, the queries are presented as statements. Herein, researchers will present the results from Questionnaire 1 designed for parents, which asks about four aspects: 1) robotics as a didactic resource; 2) robotics as a way to keep in touch with technology; 3) the robot features; and 4) knowing how the robot construction activity favors the relationship between parents and kids. The responders used a scale that ranges from 1 to 5 to answer the questionnaires, in which 1 means 'no compliance' and 5 is 'an excellent level of compliance of the statement'.

The reliability of the Questionnaire 1 was evaluated using the Alpha Cronbach Coefficient, (Ledesma 2004), which values between 0.8 and 1.0 indicate a good reliability of the survey. The Alpha Cronbach Coefficient for this questionnaire was 0.942.

Table 1 has the queries for Questionnaire 1, twenty-six parents responded to the survey, all queries were graded over 3.4, and the score average of the queries was 3.8 (see Figure 3). These results indicate that parents feel that robotics positively influences their children's education.

An analysis about the aspect 'robotics as didactic resource' shows that most of parents graded the queries of this aspect with four and five, indicating that they agree that the robot is a support resource in the classroom .

Table 1: Questionnaire 1 for Children's Parents

Robotics as didactic resource
QP1: Your kid was stimulated with the robot construction activity
QP2: Your kid speaks with confidence about the robot, its purpose and functions
QP3: Your kid developed the robot construction activity under her/his responsibility with little or no help
Robotics keeps in touch with technology
QP4: The robot construction helps your kid to deal with topics about physics, electronics and mechanics. Please, list the new topics related with robotics mentioned by your kid.
Robot features
QP5: The robot was inexpensive
QP6: The robot was easy to build
QP7: The robot can be assembled without the advice of an expert.
QP8: The robot design takes into account the expectations and interests of children
Favoring of relationship between parents and kids
QP9: I participated in the construction of the robot
QP10: I spent more time with my kid during the construction of the robot
QP11: I learned about robotics thanks to my kid

*The original text is in Spanish.

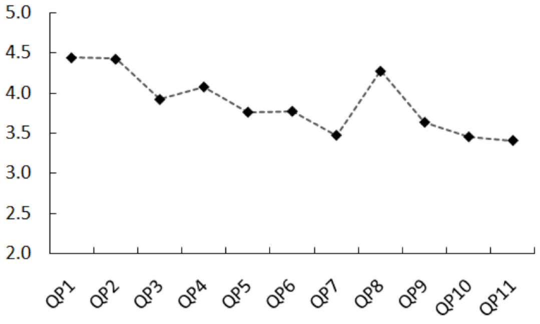


Figure 3: Results of Questionnaire 1. The horizontal axis corresponds to the number of the query. The scale used is from 1 to 5, 1 = no compliance and 5 = excellent level of compliance of the statement.

Parents' feedback

It is worth noting that in the aspect 'robotics keeps in touch with technology', parents scored the query QP4 with 4.0, which stresses on the kid's knowledge about physics, electronics and mechanics. Likewise, parents state that their children talk about new topics, such as microchips, motors, electronic components, mechanisms, springs, lights, pulleys, and antennas, when robotics is included in the syllabus.

Regarding the aspect of ‘robot features’, some parents consider that the robot is not inexpensive enough. Though the cost of the robot is about US 20, this price can appear a little high for some parents, taking into account the average income of the families (in Colombia, the minimum wage is about US 312). Likewise, some parents think that their kids should be more involved in the assembling activities, especially those related to programming. In this regard, it is important to note that some activities require expertise and equipment not usually available in school. Finally, query QP8 obtained the best score average of this group of statements; most parents graded this query with 4.0 or 5.0 (see Figure 3).

The last group of queries is devoted to measure how the parents are engaged in the robotics world through their kids (QP9 and QP10) and allows knowing whether the work on the robot makes parents spend more time with their kids (QP10). Although most of the parents score the questions with a level of compliance of four and five, others admit that they were not committed enough with the robot construction. When parents were consulted about ‘who helps their kids with the homework and assignments’, they referred to other relatives, such as sisters, grandparents, aunts or uncles.

Questionnaire 1 also has open questions aimed to identify positive and negative aspects of the approach. Regarding to positive aspects, the parents stated opinions such as *“it helps my kid to develop his/her intellect”, “it helps to open his/her mind”, “it helps to develop his/her creativity and understand why and how lifeless things can move”, “it promotes autonomy”, “it is as a toy that moves”, etc. About negative aspects, parents said things such as “it is very expensive”, “my kid almost cannot manipulate the elements for assembling the robot by himself without help… ”* etc. In short, most of parents think that the robot design and its construction contributes largely to the education of their kids, especially in the development of creativity and learning about electronics, mechanics and technology; however, some considers that kids need more autonomy for the robot assembly.

5 Concluding Remarks

The K-12 approach exploits the creativity of the kids; it uses their previous knowledge to define the features of the robots. Children participate enthusiastically in the activities related to the robot construction, especially those related to enhance their aesthetic dimension. Likewise, the designed K-12 approach helps kids to learn concepts of subjects such as physics, electronics, mechanics, technology, mathematics, biology and language and promotes the development of transversal skills like teamwork, decision-making, self-learning and problem solving, as well as others related to the children’s educational grade and context.

The children’s parents think that the robot is a good didactic resource that helps the kids improve their knowledge retention and stimulate their creativity, innovation and research abilities. Likewise, they consider that robotics brings the technology to the classroom and the robot facilitates knowing new concepts about engineering. However, they state that the robot is not inexpensive enough and some assembling activities are unknown to the kids.

Currently, the Robotics and Industrial Automation Research Group (GIRA) at Universidad Pedagógica y Tecnológica de Colombia is developing robots using recycling materials to decrease the cost of the robots. The score given by parents and teachers about the cost of the robot shows that it is necessary to work on cheaper solutions, mainly oriented to public schools, kids who cannot pay the cost of the current robot prototypes, and contexts in which commercial platforms are not affordable.

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Active Learning and ICT in TEM

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Abstract

The University of Twente is a young and dynamic research university in the Netherlands where the development of new and relevant technological knowledge is at the forefront in research and education. The UT radically redesigned all the bachelor's programmes in the academic year 2013-2014. All new bachelor's programmes are designed according to our own Twente Educational Model (TEM). The TEM principles are (1) modular education, (2) active learning - project based work, (3) personal responsibility, (4) learning together and (5) quick and correct fit to get students in the most suitable degree programme. In the last two years several pilots focusing on active learning and ICT have been carried out within the TEM curriculum. These pilots include a peer feedback project, a peer instruction project and a digital portfolio system. All pilots are done in collaboration with faculty staff. They supply useful information for other Faculties. In this paper we focus in particular on peer feedback.

1 University of Twente

The University of Twente is a young and dynamic research university in the Netherlands where the development of new and relevant technological knowledge is at the forefront. UT stands for "High Tech, Human Touch", which means that we approach technology in the context of the life sciences, management sciences and social sciences. In addition the UT boasts the spirit of entrepreneurship.

Our students are not only trained to become skilled researchers, they are also educated to become designers and organizers. (Naar een Twents Onderwijsmodel, 2013). These ambitious characteristics are the true profile of the University of Twente. To maintain this profile, we ensure that we constantly (re)develop our degree programmes and to keep pace with a rapidly changing society and an even more diverse student population with different educational needs than their predecessors. Students nowadays have different educational demands and lifestyles and they handle information in other ways than those of previous generations.

Universities are no longer the only source of knowledge. In a time when all kind of courses can be found and followed via the internet, it is all the more important for a university to be able to provide relevant and outstanding education.

The highly educated no longer assume they will practice the same profession throughout their lives. Many contemporary occupations did not exist 20 years ago. Therefore it is not possible to predict what our students will be doing 20 years from now. According to Oskam (2009) 'Engineers are concerned it is no longer sufficient to be simply a good project manager, researcher or engineer. In a field of work in which innovation is gaining increasing attention and where more and more work is being done in interdisciplinary teams in an open innovation environment, different requirements are now being set for the knowledge, skills and attitude of the young technical professional'. Highly educated professional engineers should therefore become more of a so-called T-shaped professional, a concept that was introduced by IDEA, an American design agency (Kelley & Littman, 2005). The University of Twente embraces the idea of the T-shaped professional and wants to educate students to develop in depth knowledge of their field (the vertical leg of the T), and, in collaboration with society and other disciplines, apply their knowledge more widely. They should be able to venture off the beaten path (the horizontal leg of the T).

With this in mind, the UT is since the academic year 2014-2015 in the process of radically redesigning all the bachelor programmes, to provide our students with an unique and relevant educational experience. All of the bachelor's programmes are designed according to our own Twente Educational Model (Naar een Twents Onderwijsmodel, 2013)

2 Twente Educational Model

The Twente Educational Model (TEM) has five principles. These principles are (1) modular education, (2) active learning - project based work, (3) personal responsibility, (4) students learn together and (5) quick and correct fit to get students fast in the most suitable study programme. (Tom Principles, 2015). We use 1 quartile modules, each module consists of a project and several relevant courses.

At the University of Twente we want our students to study actively. Participating in a programme is regarded as a full time occupation (40 hours a week). This way students can complete their bachelor studies within three years. Therefore, it is important that education is attractive and that students are motivated to become future academics who represent the UT profile. Besides the project work (the core of TEM) other teaching methods are deployed when certain subjects lend themselves more to a different approach. Examples of different teaching methods include formal lectures and seminars, practical's, tutorials, practical exercises and video lectures. Because of TEM education at the UT is focused on active and attractive instructional methods. A number of teachers and Educational Support employees have carried out projects on active learning: peer feedback, peer instruction, flipping the classroom and the classroom of the future. In this paper we focus on active learning – peer feedback projects-. They are described below.

3 Peer Feedback

Feedback

Regarding feedback as a gift is the historically dominant paradigm (Askew & Lodge, 2000). Feedback was given by the teacher to the student and students were relatively passive recipients receiving the feedback. In TEM students have to play a more active part in their learning process. For two reasons students are more involved in giving and receiving feedback. First, peer feedback enables students to take an active role in the management of their own learning (Liu & Carless, 2006). Providing feedback to peers can fill the gap between what students know and what students have to know and therefore it stimulates students to reflect on their own performance which enhances 'deep learning'. The second reason is that development of the skill 'giving and receiving feedback' is very important to constant learning in everyday life and work (Boud & Falchikov, 2006).

In recent years, the process of peer feedback is being facilitated by the use of educational software. Online peer feedback can considerably simplify the logistics of peer assessment. Online peer feedback can support didactical aspects as well as face to face feedback. As mentioned by Gehringer (2001) and Trahasch (2004), it allows higher degrees of interactivity between students and offers teachers better possibilities to monitor and guide this interactive process.

There are several ways in which elements of peer feedback can be categorized. At our university we make a distinction between (1) feedback on teamwork, (2) feedback on a written report and (3) feedback to process the learning materials. We will discuss pilots with computer based tooling on all three distinctive forms.

Optimizing teamwork with WebPA

A tool used for optimizing group work is WebPA[1]. This is an open source online automated tool that enables every project member to score individual contributions to group work directly into the WebPA system. So WebPA helps students to reflect on their own work and assess the contribution of other project members.

WebPA is mainly used to give and collect feedback on students teamwork skills and afterwards discuss the results in the project group. It results in formulating recommendations for the individual students and for the team. In the first year bachelor modules are multiple pilots running with WebPA. We did a pilot in the degree programme of Creative Technology, of Industrial Engineering and Management and of applied Mathematics. These three pilots will be outlined below.

In the three pilot modules students have the possibility to attend lectures and tutorials and to study books and online materials, these are the instructional methods used in the courses. In the project the students work together, make a project plan, divide tasks, brainstorm and discuss ideas, evaluate results, write a report and present the outcomes of the project.

3.2.1.Creative Technology

In the project of the module *Art Impact and Technology* students design and realize an interactive installation for GOGBOT 2014[2], using and integrating methods and techniques from previous Creative Technology projects. The primary design criterium is to have high impact on the spectator/participant of the installation, irrespective of its practical application, utility or deployment. The students have to explain (the creation of) their installation, both visually and textually and relate it to the context of application, for a variety of audiences. During the project "Have Fun and Play!" students will be asked to reflect on their functioning as a team and to assess their peers on their collaboration skills. All this is intended to become familiar with each other capacities and to apply their capacities in such a manner that the whole group benefits and that the performances of the whole group is improved.

3.2.2. Industrial Engineering and management

In the project of the module *Business Intelligence and IT* students design a database, design and implement a Balanced Scorecard Dashboard for a given business company and develop a web application. Students work

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[1] http://webpaproject.lboro.ac.uk/

[2] http://en.wikipedia.org/wiki/GOGBOT

in a mixed group of six students from two degree programs. The project work (group mark) contributes 40% of the final grade for the module. The group mark makes it worthwhile to spend attention on the individual contribution of each student to the group process. Halfway through the project students are asked to fill out the WebPA system about the contribution of their group members. Questions concern for example the quality of the work, the way of communication, the effort the team member is putting in the group process, etc. The outcomes will be (anonymous) discussed in the project group, this gives students the chance to improve their behaviour during the remainder of the module. At the end of the module students were asked to fill out the WebPA system again. This time it may influence the end mark of the individual student for the project.

3.2.3. Applied Mathematics

In the project in the module *Certain and Uncertain information* the students work together in a group of five students. They have to work on the following question: *Can you predict what period of the day tomorrow, after tomorrow and next week the water level is above 1.50 meters relative to NAP in the bend of the river Walsoorden in the Netherlands. And can you say something about the quality of your predictions?* Students also used WebPA to evaluate the contribution of the group members.

Stimulate better understanding with PeerWise

Peerwise[3] is a tool to stimulate better understanding of the learning materials. Peerwise is a web based online tool where students can create and present multiple choice questions with regard to the learning materials in a repository for their peers. Students can answer questions, give comments and communicate about the questions and answers with other students.

The pilot was executed in the module 'Living and Working Tomorrow' in the degree program Creative Technology. Students were asked to submit at least one question each week about the content of the indicated videos for that particular week. 5% of the final grade was determined by submitting the question on time. In addition to the question, students were encouraged to post as many questions as they liked, at any time, either about the videos, or about explanations given by the instructor during the class meetings. The students had to formulate their questions in line with the criteria for high quality multiple choice questions.

Feedback on a written report with Digital Portfolio

At the UT we developed our own Digital Portfolio System (DPS). Since the implementation of TEM the need for a system that incorporates the newly needed functionalities with regard to TEM increased. One of these functionalities of the digital portfolio is the function to ask for feedback. In the TEM modules students deal with many different roles, and all of them can give valuable feedback. The digital portfolio system has options to facilitate 360 degrees feedback. All kind of stakeholders can provide the student with relevant feedback. This means that a teacher, tutor, the project members or friends from a student committee can provide feedback. In the DPS students can send a feedback request. In the request the student uploads his product file and may add an existing feedback form (predefined by a so called coordinator), the student can also add an empty feedback form and add his own items. The evaluator (the person who gives the feedback) fills out the form in the digital form and sends it back. The DPS collects all the feedback and products in the digital portfolio of the student

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[3] https://peerwise.cs.auckland.ac.nz/

The degree programme Industrial Engineering and Management started with the DPS as a pilot in 2013. In this programme the portfolio is used to monitor the development of academic and professional skills during the bachelor. Because of the success the system became a University-wide-system since February 2015. It is likely that more functionalities will be added in the near future.

4 Results

All pilots with computer based tooling were executed as standalone pilots. In this chapter we show preliminary conclusions. As a follow up we would like to set up pilots which give insight in the effects of the tools on the learning of the students and the time investment of the lecturers.

WebPA

In all pilots the teachers were enthusiastic using the new tool for enhanced learning. Unfortunately teachers were not impressed with the results. The first teacher using WebPA was not satisfied with the contributions of the students because students found it difficult to discuss the feedback they had given and received. It seems the students do not feel safe enough to discuss the feedback. Because of this attention should be paid to the influence students have on the assessment criteria and conditions. In future pilots students will be made part of the process to set up the assessment criteria. Some interesting student quotes include: *'Students should have the opportunity to opt out of peer assessments if it's not anonymous'.* Almost all students wanted future peer feedback to be anonymous.

Other students remarks include: *What's wrong with paper peer assignments? Why does every single thing that we do, need to be electronic?* This remark might be due to the fact that the pilot was executed in a very small group. The practical advantages of computer based tooling will be more evident when used in large groups. One could argue that you should only use computer based tooling in small group sizes when there is a clear pedagogical advantage.

PeerWise

In the PeerWise pilot the teacher concluded that the tool worked all right. Unfortunately the teacher was disappointed with the results, the multiple choice questions the students formulated were of poor quality. The implementation of the skill 'giving and receiving feedback' is hard. Students have to learn how to give and receive feedback, how to deal with feedback and how to discuss feedback to ensure the feeling of security amongst them. One solution is to pay more attention to the introduction of peer feedback by discussing good and bad examples of the multiple choice questions in PeerWise during the course and by focusing more on the fact that giving and receiving feedback is an important skill for the future.

Digital Portfolio

In the pilot the Digital Portfolio was used for academic and professional skills. The teachers and students are satisfied with the fact that there is a place where students can submit their products, ask for feedback and where teachers can monitor the student during the bachelor programme. Other programmes from the faculty Behavioural Management and Social sciences, Engineering Technology and Electrical Engineering, Mathematics and Computer Science became enthusiastic to use the same portfolio system.

On the downside it is still difficult to motivate students for academic and professional skills. Students know the importance of developing their professional skills, but don't give it priority in their study. The digital portfolio and the use of rubrics is just a facility. The curriculum and motivation of the students influences the usage of the portfolio system.

5 Discussion of the results and recommendations for interested parties

The number of peer feedback pilots is limited. Therefore we can only draw tentative conclusions. More empirical research is necessary to make strong scientific conclusions. Nevertheless we have formulated a few recommendations based upon the results of the pilots. These recommendations are of interest to other parties who would like to implement similar tools to activate students and to enable learning.

WebPA (feedback on the group process)

- Students should have influence on the assessment criteria to make the results more relevant
- Some students like anonymous feedback over not-anonymous, however not-anonymous feedback gives the discussion about the results more focus.
- Especially during the first year the lecturer/tutor should have the role of coach, monitor and process keeper to ensure an appropriate debate about the peer feedback results of the project members.

PeerWise (feedback on the professional skills and content)

- The lecturer has to give a clear introduction of the learning objectives of the use of this tool
- It's very important to motivate students, for example by giving bonus points
- The lecturer should explain more than once bad and good examples of multiple choice questions in PeerWise.
- Appointing a moderator in PeerWise might work as well.

Digital Portfolio (feedback on written work)

- It's useful to work with rubrics. Rubrics will help students to better understand the feedback and to get insight in what went well and not so well.
- Students have to learn how to give and receive feedback and have to be aware of the importance of feedback.
- The lecture/tutor should have the role of coach, monitor and process keeper.
- Working on a portfolio has to be an integrated part of the curriculum

We are glad to be able to conclude that these pilots gave a good introduction of computer based peer feedback tooling at our University. There is a growing interest in the system WebPA and the number of users of the Digital Portfolio system is increasing rapidly. Within the next year of TEM modules we are going to set up following pilots which give insight in the learning effects on the students in relation to the use of computer based peer feedback systems.

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Approach of an Active Learning Activity in Engineering through PBL

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Abstract

This work is aimed at presenting the methodological features of an experimental active learning activity in which have been carried out the joint operation of both PBL (Project-Based Learning) and Cooperative Learning in the context of the EHEA (European Higher Education Area). This training experience comprises the preparation, execution, evaluation and analysis of the work done and the outcomes resulting from the jointly performed project with students and teachers from two university centers of the University of the Basque Country UPV / EHU. The project performed from the point of view of cooperative learning involves the design, implementation, controlling and testing of a synchronous buck converter-based battery charging system in the field of solar energy.

In the proposed methodology various aspects are described, such as the subjects in which it has been proven, the content of the developed project itself, competencies to accomplish that have been taken into account when planning it, the way in which the outline of the project has been structured, activities that have been carried out and how the evaluation has been performed.

This first paper is complemented by a second one entitled "Prototype Development for an Active Learning Activity in Engineering through PBL", which is dedicated to the presentation of the design and implementation of the developed prototype from both software and hardware perspectives as well as to the assessment of this training experience.

1 Introduction

Presently in the university ambit, education is organized so as to allow student body to acquire a range of broad and specific competencies, seeking at all times the best to prepare it for an ever varying society (UPV/EHU, 2005). Besides, this constantly changing society has led into a new dynamic structure of bachelor, master's and doctorate degrees, where students are the main focus and become protagonist of their own learning through a continuously evaluated active teaching method.

From the point of view of the field of the engineering education, this new teaching structure should allow students to develop their dexterities by using both the appropriate technology and suitable strategies according to the current curriculum. To do that, it is essential to set up an equilibrium between theoretical lectures and practical activities in order to implement the concepts learned, encourage active student participation and enhance their self-learning. There is a wide range of activities that enables this sort of learning as are the teamwork and project development collectively, thus encouraging cooperation, responsibility, solidarity and the encounter, among other features of importance. In this context, teaching engineering by doing research can also provide students the opportunity to develop and acquire competencies orientated towards the paradigm of "learning to do" (National Research Council, 1996). This assertion of the National Research Council of USA is in favour of constructing a theoretical framework in order to teach and learn science and technology by means of a research-based teaching. In relation to this, it has to be highlighted the importance given to the learning of the students while, simultaneously, their involvement in the university life is stimulated. In this sense, collaborative and PBL (Project-Based Learning) methodological methods bring the opportunity for developing educational programs that integrate quality learning models, which in turn lead to a better preparation of students to compete in the global economy by acquiring the necessary skills. After all, quality education is the basis for the opportunity and innovation. By implementing these methodologies, in addition to promoting the understanding of the knowledge and stimulating the participation, also an improvement on the development of skills and transferable competencies can be achieved.

The faculty involved in that active teaching-learning activity had already participated in other educational experiences and have worked with students from the same centres (Oleagordia *et al*, 2008). In this particular case, the application of the methodologies chosen within this experience supposes a remarkable milestone, as this time students from the two centres have worked concurrently and in a coordinated manner, which has enabled the implementation of an active methodology, whereby not only a network of students has been created, but also their participation in the university life and their active participation in the development of the curriculum framework has been promoted.

Based on the aforementioned considerations, this first paper is dedicated to the descriptive analysis of the applied methodology in an active learning activity which has been carried out using cooperative learning and PBL-based methods, as well as to the presentation of the electronic book that has been built in an educational web platform that includes the theoretical content of the project developed. In a second paper entitled "*Prototype Development for an Active Learning Activity in Engineering through PBL*" the constructive aspects of the developed prototype are discussed from the hardware as well as the software perspective.

2 Approach to the Educational Challenge

A while back, when the above stated considerations became part of the present-day curriculum of the University of the Basque Country UPV / EHU, teachers from Electronic Communications, Automatic Control and Systems Engineering, and Electrical Engineering departments of the Technical Industrial Engineering Schools of Eibar and Bilbao, took the decision of implementing an innovative active teaching-learning activity, whose purpose was to develop and apply a collaborative and project-based learning methodologies. Therefore, this educational experience has consisted of planning, execution, and assessment of the outcomes of a project that has enabled students to study in-depth within various engineering fields, such as electricity, electronics, and automatic control. The activity has been jointly carried out by third-year students from both above mentioned university centres, in the degree of Technical Industrial Engineering in Industrial Electronics. The project itself comprises the whole designing and construction of a solar battery charging system, including the hardware implementation and the software development.

During this pilot experience, students have had to solve problems which can have multiple solutions and that to solve them, it has been necessary to resort to creative thinking, thereby stimulating the Cognitive Development (Robinson Ken, 2001). This active learning activity has been put into practise in the subject of Final Degree Project that is studied in the 2nd semester of the 3rd year of the above-mentioned degree, and in which the learning occurs in an environment characterized by practical exercises and theoretical lectures in form of exposition, which in turn have been focused from the point of view of the cooperative and project-based teaching-learning methodologies according to the EHEA guidelines.

When planning this learning activity the following goals were desired to be achieved:

- Apply knowledge in a practical way by setting out practices from the point of view of technological researches within the engineering field.
- Promote work discipline and research capacity.
- Provide a tool and methodology for learning new things effectively.
- Evaluate the acquisition of skills by students.

3 Strategizing for the Active Learning Activity

Several meetings took place during the school year of 2010-2011 among the members from both centres who were interested in this activity in order to stablish the guidelines to be followed when planning the activities to be done. In these meetings was reached a consensus that the basis of this experience would have to be focused on the class management and the learning environment instead of teaching itself. In this sense, it is necessary to know how to merge the technical knowledge, theory and practise, with the distinctive features that involve teaching, as are the educational program, number and characteristics of students (including their previous knowledge and their capacity to achieve accuracy in learning), available time, didactic means, etc.

Before putting this learning activity in action the next consecutive academic year, 2011-2012, the following considerations were taken into account:

- As it can be expected, most of the work should be developed in the laboratory.
- Before working in the laboratory, it is necessary to develop the theoretical concepts needed to perform the laboratory work, in such a way that it is facilitated the comprehension and planning of the activities to be done.
- After working in the laboratory, a detailed analysis and discussion of the results obtained should be performed. In this sense, the use of informatics and ICT (Information and Communications Technology) is becoming more and more relevant and crucial.
- Students should be stimulated in order to learn in an autonomous way, being tutored at the same time by teachers.
- Bearing in mind that not all that it could be taught, neither can nor should be taught in this learning activity, it is more important to provide learning tools and to create a good environment of learning than the mere accumulation of content. After all, in the scope of the engineering “to know is to do”.

Following is shown the structure for the teaching guide:

- The description of the subject and its teaching.
- The meaning of the subject within the curriculum.
- Theoretical and practical contents as well as the bibliography.
- Content of the project.
- Methodologies based on collaborative learning and PBL and available resources.
- Assessment of the results.
- Additional interesting information.

With reason of being a pilot experience, it has been taken special care when identifying and coordinating all the activities who students of both centres have to perform along the semester, as they have been carried out among the groups as well as within each of the groups, considering that these groups can belong to only one centre or to both simultaneously. In this respect, it has been necessary to estimate the relationship between the classroom work and the collaborative work that require the associated activities, considering for this, the amount of work that involves the application of this learning activity in the aforementioned subject.

In the following sections it is shown a brief description of the cooperative and PBL methodologies applied in this experience of active learning.

Methodology of Project-Based Learning

This methodology corresponds to a teaching method in which the learning is performed through the development of a project, in such a way that students have to identify problems derived from the project and find solutions in order to solve them. It can be compared to the way in which the real projects and research are conducted in the engineering field. Among others, the implementation of this method is appropriate for the achievement of the following objectives:

- Motivating students by proposing problems which not only facilitate comprehension but also favour retention of the learned theory.
- Empower students to work independently to build their own knowledge which in turn culminates in realistic goals.
- Focus learning on the concepts and principles of a discipline within the engineering ambit.
- Improve decision-taking, skills of leadership and communication, conflict resolution, time planning and assessment of results.
- Improving the preparation of the students to face the problems that may encounter when starting to work in the labour market.

Methodology of Cooperative Learning

This methodology corresponds to a learning method based on teamwork of students. It includes various techniques in which students work together in order to achieve certain common objectives for which all the members that integrate the team are responsible (Johnson *et al*, 2000).

One of the foundations on which cooperative learning is based, suggests that the sum of the works done by each individual is less than the work that can be performed by a group of students. This fact, in general, was confirmed by the students involved in this experience. The following key points have been followed aiming at its implementation (Millis & Cottell, 1998):

- Specify in a clear way the purpose of the course in general and of the lessons individually.
- Decide how the learning groups will be created before teaching begins.
- Explain with clarity to the students how the activities will be organized and the objectives to be accomplished.
- Supervise the cooperative efficacy of the learning groups and take part to encourage the participation of students, provide help when doubt exists, teach skills and strengthen the interpersonal skills within each group.
- Evaluate the obtained results and the involvement of students in the performed activities within each group as well as between groups.

Within the educational sphere, as regards to operative aspects, it exists a difference between the collaborative and cooperative learning. On one hand, an important aspect of the cooperative learning is that groups can be formed by people of various natures, while in collaborative learning the members of the groups have to be quite similar. On the other hand, unlike the cooperative learning, in which the knowledge is shared among all team members, in the collaborative learning the knowledge is unidirectional as it flows in a hierarchical way.

4 Description of the used Methodology

Suitable Subjects

The strategies that have been put into practice in this pilot experience also have been experienced in many different scenarios including subjects that have only a few credit (UNESCO, 1998). Nevertheless, instead of being applied in subjects with few teaching hours, these are more suitable for broad subjects, in which there is more time available to allow students to get involved further in the activities to be performed.

Bearing this in mind, initially it was considered the possibility of developing this methodology along two subjects, Technical Office and Final Degree Project, whose teaching occurs in the first and second semester, respectively, and whose workload consists of one hour per week of theoretical lessons, two hours per week of laboratory training and one hour per week of classroom training. Notwithstanding, even though these subjects are suitable because of their workload, finally it was rejected that proposal, as some students that were enrolled in the subject of the second semester had not coursed the subject of the first one. Trying to deal with this situation, it was considered the possibility of providing both traditional teaching and the corresponding to this pilot experience, which eventually it does not turned out achievable because of the schedules and the availability of the teachers. Finally, due to this problem the subject of Final Degree Project has been the only one in which this experience has been conducted.

Group formation

Small groups provide opportunities to exchange ideas with several people at the same time, in an environment free of competition, while discussions in large groups tend to inhibit the participation of the shyest students (Cooper, 1996). In this respect, in the Technical Industrial School of Eibar 21 students took part, distributed in 7 groups of 3 students per group, while in the Technical Industrial Engineering School of Bilbao 61 students have been involved, who were integrated into 13 groups of 4 students and another 3 groups of 3 students.

Content of the Developed Project

One of the objectives to be accomplished in this activity of active learning is that each cooperative group has to design and construct a battery charger prototype that optimizes the efficiency of the photovoltaic panels. To do that, a previous study has been conducted, in which students have to compile information on the different types of conditioning that exist for solar energy systems, and it also have to analyse the performance and the features of each one. All this, provides students the required knowledge about developing engineering concepts, techniques of design, carrying out project designs in-depth and elaboration of project documentation, which is aimed at preparing them to be capable of developing the tasks that companies will expect from them. In this sense, the project to be developed requires a multidisciplinary understanding, as it involves knowledge of various fields of engineering, whose concepts are learned in the subjects of Digital Techniques (2nd course 1st semester), Power Electronics (2nd course 2nd semester), Design and Electronic Simulation (2nd course 2nd semester) and Electronic Instrumentation (3rd course).

Competencies to be acquired

Despite the fact that the acquisition of competencies were not explicitly contemplated in the curriculum in which this learning activity has been experienced but were present in an implicitly manner, they were considered when planning it. Thank to this, it would be possible to carry this methodology, making the necessary adjustments previously, into the present curriculum. Thus, this methodology can be adapted in order to apply it in the subjects of the current Bachelor's Degree in Industrial Electronics and Automation, which are Project Management (4th course, 1st semester) and Final Degree Work (4th course, 2nd semester).

The generic or transversal and specific competencies to be achieved that have been taken into account are the following:

Generic or transversal competencies:

- Ability to apply knowledge in real projects, solve problems, research, manage information, capacity for organization, planning, analysing and synthesising, communication, ability to make decisions and to adapt to new situations.

Specific competencies:

- Cognitive: design methods and ability to analyse and work with complex data.
- Procedural and instrumental: work estimation and scheduling, technical documentation interpretation and preparation, work valuation and project value estimation over time.
- Attitudinal: use of the ICTs and analyse the needs of the technology market.

Outline of the project

The outline of the project is one of the component of the teaching guide associated with this experience. It is available, in the virtual classroom dedicated to it, in the Moodle teaching platform prior to the commencement of the activities. The outline is structured as follows:

1) Specify the process to be developed in a qualitative and quantitative manner. To achieve that a top-down model is used, that is, from the general to the particular.
2) List the general objectives as the partial ones in each of the parts in which the project is divided.
3) Describe not only the practical tasks to be carried out from the perspective of both hardware and software, but also from the materials to be used.
4) Describe and synchronize the distribution of the different tasks to be performed among the groups in order to achieve the objectives.

Students preparation

In order to understand the tasks that will be performed in the laboratory, each student of each group should study the theory in which these tasks are based and apply it in exercises. In regards to this, students take advantage of classroom trainings and tutorials.

Laboratory Work

It is the cornerstone of this experience. The practical work is performed during the session of 2 hours of training per week that is established according to the schedule of the activities of each group. A brief description of the objectives to be achieved in the session 4 is shown in Table 1.

Table 10: Description of the objectives to be accomplished in the session 4.

Simulation and waveform analysis of a buck converter using PSIM software. Continuous and discontinuous modes.
Experimental analysis of the simple buck converter.
Experimental analysis of the synchronous buck converter.
Experimental analysis of the synchronous buck converter integrated with solar panel and control.
Discussion of the obtained results.

Along sessions, meetings among groups and between the members of each group are held, in order to distribute, organize and perform the work and discuss the outcomes. By way of illustration, in the first place planning is carried out among groups and after between the members of each team members. Nevertheless in the stages of calculation and discussion of the results is done backwards, firstly an intra-group meeting is done and in the second place, among groups.

From a technological point of view, it can be considered that students already have enough theoretical and practical knowledge about the concepts involved in this activity, as they have been acquired in the subjects of Digital Techniques, Power Electronics, Design and Electronic Simulation and Electronic Instrumentation.

Virtual Learning Platform

The virtual learning platform, which is developed in Moodle environment, is allocated for the development of this experience. Among other aspects, it is used by students for documentation, writing up and submitting the reports related to this experience for its later evaluation by teachers. It is also used to complement previous work done in the laboratory, for instance, to find information and perform simulations in order to validate the exercises done in the classroom training. The systematically developed work is performed through an electronic work notebook.

Assessment of the Learning

The learning evaluation of the students within this experience has been carried out using both formative and summative strategies.

Formative Assessment

Each group has been assessed through formative evaluation to know about the learning degree of all of its members. Figure 1 shows the feedback system in which consists this methodology.

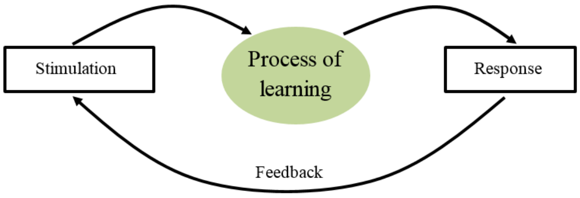


Figure 31: Feedback system applied to the used strategy.

The most important operational characteristics of the formative assessment are:

- It provides feedback on the degree of partial control that has been accomplished in a given task or unit of learning to both the work group and its members.
- It makes possible to find out the origin causes of the hindrances in the learning of students as well as of the groups.
- It provides faculty information on how accurate the teaching duties are.
- It provides teachers the opportunity to answer some questions such as: how are they learning? How are they doing? What type of obstacles have they to deal with? How can we help them?

It is particularly appropriate to:

- Know about how the learning process works.
- Verify the partial results of the learning level so that the course can be corrected.
- Serve as an interactive motivating function.

Summative Assessment

The summative assessment has been used at the end of one or more teaching units in order to determine quantitatively the attained knowledge level.

The most important operational characteristics of the summative assessment are:

- It makes possible to qualify and quantify the acquired level in each competency.
- It provides a global evaluation about the learning level acquired by the students in relation to the proposed objectives.
- It answers the question: have they achieved the skills to promote?

It is particularly appropriate to:

- Know the obtained product.
- Provide qualification marks.
- Use it as a feedback qualification function.

The assessment of each competency has been performed by using rubrics, in which are reflected the levels of the achieved goals.

Web Environment

The ICTs provide a suitable working space in the Cooperative and Project-Based Learning environments. However, the technological environment must be specifically designed in order to help students to progress in a successful manner.

In order to organize the resources and the project itself, all this from the students perspective, it is used the teaching platform Moodle as mentioned above.

Previously, in [4], an electronic book was elaborated on a CD, which contained a basic tutorial on autonomous photovoltaic systems, which was published in a web page by using of the Dreamweaver program. Similarly to the previous work, during the academic year in which has been experienced this learning activity, 2011-2012, another tutorial also in electronic book format about converters was edited and hosted in the intranet of the University of the Basque Country UPV/EHU, whose content and structure are exposed in the next section.

5 Structure of the Electronic Book

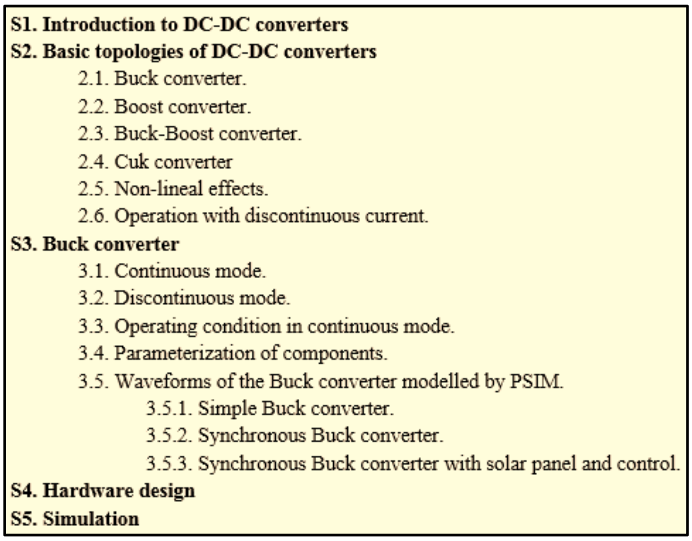
In this section the structure and content of an interactive tutorial on static converters, which is the content of the developed electronic book is exposed. A computer running an interactive tutorial program can facilitate the study in a given area of knowledge, in such a way as if it were a teacher that teach face to face a single student. Furthermore, when the theoretical concepts are combined with an interactive simulation and are integrated as hypertext, its functionality is improved.

The integrated simulations in the tutorial are based on a series of programs that can emulate real situations on a computer and provide accurate results. In this sense, the development of ad-hoc programs enables students to solve problems interactively in a clear and fast manner instead of having to solve them in a theoretical manner, which requires more time and is less illustrative.

Modelling and simulation are linked with a concept of design. When simulating a model the emphasis falls on the interaction of the user with the model through the software environment. Therefore the real power of simulations not only resides in progress and stimulation of the mind and in the intuition, but also in the invention and in hypothesis tests. Besides, it allow the understanding of the fundamental aspects of certain situations, instead to dealing only with the knowledge transmission.

Hypertext Architecture

The hypertext is hierarchically structured into three different levels as is shown in Figure 2.

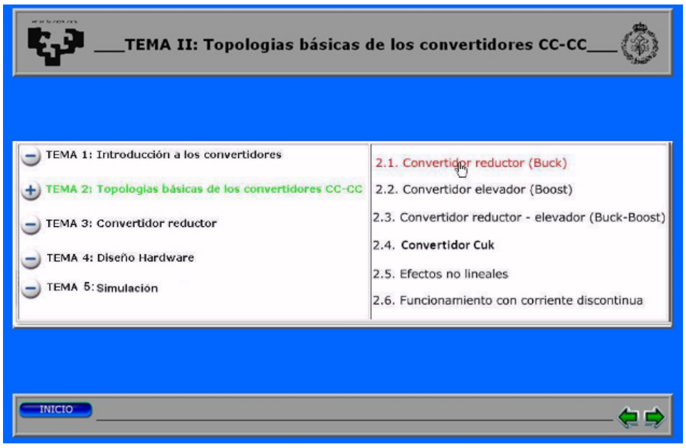


S1. Introduction to DC-DC converters
S2. Basic topologies of DC-DC converters
  2.1. Buck converter.
  2.2. Boost converter.
  2.3. Buck-Boost converter.
  2.4. Cuk converter
  2.5. Non-lineal effects.
  2.6. Operation with discontinuous current.
S3. Buck converter
  3.1. Continuous mode.
  3.2. Discontinuous mode.
  3.3. Operating condition in continuous mode.
  3.4. Parameterization of components.
  3.5. Waveforms of the Buck converter modelled by PSIM.
    3.5.1. Simple Buck converter.
    3.5.2. Synchronous Buck converter.
    3.5.3. Synchronous Buck converter with solar panel and control.
S4. Hardware design
S5. Simulation

Figure 2: Hierarchical structure of the Hypertext.

The main screen is in the first level, whereby it can be accessed to the principal lesson of DC.DC converters, which in turn is divided into five second level nodes from S1 to S5, named: S1, Introduction to the DC-DC converters; S2, Basic topologies of the converters; S3, Back converter; S4, Hardware design, and S5, Simulation.

As shown in Figure 3, the five nodes of the second level are divided in turn into multiple nodes of third level, each of them associated with different educational content corresponding to the matter of each second level node. Even though it is not graphically showed, by activating the corresponding links, it can be accessed from each node to many other nodes of different units of the knowledge. The theoretical development of the topic chosen starts is in the third level of the structure, as it is shown in the Figure 4. The bottom toolbar contains the links to navigate forward and backward pages and it also contains the home link in order to access the main page corresponding to the screen of the Figure 3.



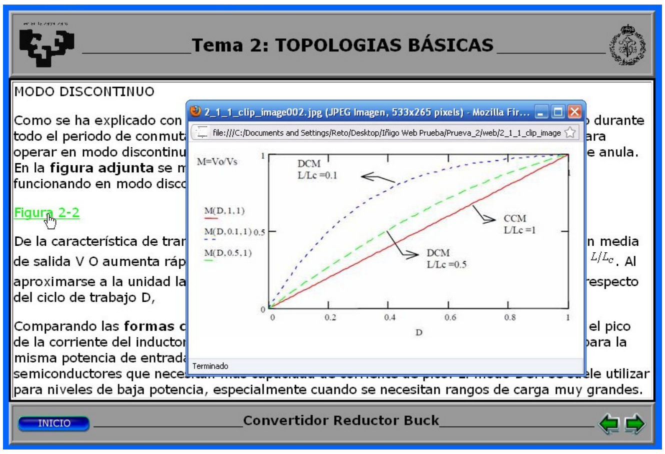
___TEMA II: Topologias básicas de los convertidores CC-CC___

- TEMA 1: Introducción a los convertidores
- TEMA 2: Topologias básicas de los convertidores CC-CC
- TEMA 3: Convertidor reductor
- TEMA 4: Diseño Hardware
- TEMA 5: Simulación

2.1. Convertidor reductor (Buck)
2.2. Convertidor elevador (Boost)
2.3. Convertidor reductor - elevador (Buck-Boost)
2.4. Convertidor Cuk
2.5. Efectos no lineales
2.6. Funcionamiento con corriente discontinua

Figure 3: Screen capture corresponding to the second and third level coming from the node S2.

The node of Hardware design (S4) is dedicated to the explanation of the electronic design process and the implementation of the controller card as well as the synchronous buck converter associated with the project of this learning activity.



Tema 2: TOPOLOGIAS BÁSICAS

MODO DISCONTINUO

Como se ha explicado con … durante
todo el periodo de conmut… ara
operar en modo discontinu… e anula.
En la **figura adjunta** se m…
funcionando en modo disc…

Figura 2-2

De la característica de tran… n media
de salida V O aumenta ráp… L/L_C. Al
aproximarse a la unidad la… respecto
del ciclo de trabajo D,

Comparando las **formas** … el pico
de la corriente del inductor… para la
misma potencia de entrada…
semiconductores que nece… le utilizar
para niveles de baja potencia, especialmente cuando se necesitan rangos de carga muy grandes.

2_1_1_clip_image002.jpg (JPEG Imagen, 533x265 pixels) - Mozilla Fir...

file:///C:/Documents and Settings/Reto/Desktop/Iñigo Web Prueba/Prueva_2/web/2_1_1_clip_image

Terminado

Convertidor Reductor Buck

Figure 4: Screen corresponding to the theoretical content of the selected node at level 3.

In the below section Simulation node (S5) is discussed, in which the models of the converter topologies are developed in a simulation environment through which users can interact to obtain the desired results.

Simulations

Simulations have been performed using the PSIM software, which is a simulation environment for power conversion and control [11]. Under several operating conditions, the functionality of the Buck, Cuk and Boost converters have been simulated, focusing these in the last topology as it is the one that has been developed in this project. In figure 5 it is shown the Synchronous Buck Converter integrated with solar panels and the battery storage system developed in PSIM environment.

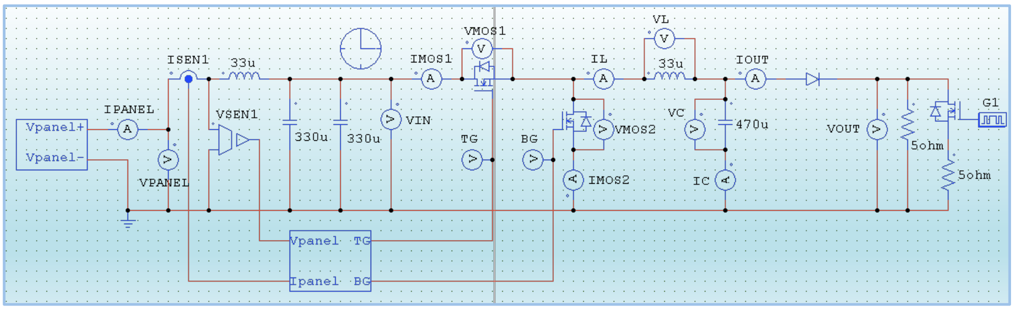


Figure 5: PSIM scheme of the Synchronous Buck Converter integrated with solar panels and the battery storage system.

In the simulation of each topology the waveforms of the most representative electrical magnitudes and the control signals for both continuous and discontinuous operation modes have been analysed. For instance, in Figure 6 it is shown the temporal interrelationship among the input current to the to the converter (IIN), current through the MOSFET 2 (IMOS2), the trigger signal of the MOSFET 1 (V1) and the trigger signal of the MOSFET 2 (V2) for a particular operation condition of the synchronous buck converter.

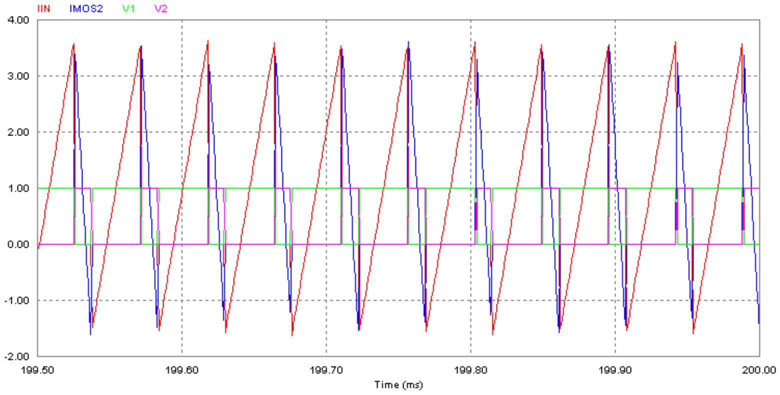


Figure 6: Waveforms in function of time of the input current to the converter (IIN red), current of MOSFET 2 (IMOS2 blue), with respect to the trigger signal of the MOSFET 1 (V1 green) and the trigger signal of the MOSFET 2 (V2 violet).

6 Outcomes

One of the positive aspects of the application of the methodology presented in this paper is that it has allowed students to participate actively in the development of the activities carried out during this learning experience. Besides, this methodology has made it possible to offer a high availability on the demands of students (in class and at tutoring sessions, by e-mail, through forums, etc.) and has favoured the communication between students and teachers. All this has led to an increase in the average qualifications of the students which, compared with the average qualifications obtained before applying the methodology, have been improved by 14,08 % in the USTIE of Eibar and by 10,45 % in the USTIE of Bilbao. Another positive aspect is that, the cooperative learning has made it possible to find solutions effectively when students have had problems in the learning process.

7 Discussion and conclusions

This paper has presented the methodological features of an experimental active learning activity carried out in an inter-institutional project managed by students and teachers of two universities.

The educational program has been focused from the point of view of the project-based learning and cooperative learning methodologies, aiming at developing the skills of the students to prepare them for the future exercise of the profession, such as increasing the knowledge about engineering concepts and project, developing design techniques in engineering, etc. To do that, various practical activities which facilitate the learning of the theoretical content concerning to the project developed have been proposed. The way in which this practical activities have been proposed has encouraged student participation and has promoted teamwork. Furthermore, activities that promote individual work within the cooperative learning, such as researching and searching for additional information have been proposed.

An integrative concept of the various areas of knowledge has been created by connecting the subject of Final Project Degree and other subjects related to the qualification in which is this experience is developed.

When the assessment procedures have been established, the opinion of the students has been considered, which in turn has motivated them since have participated actively in their learning process. The assessment methods applied in this experience have allowed to evaluate at all times the level of achievement of the competencies.

In regard to the methodology used, it has been found that the greatest difficulty has been to coordinate the students of each group, among the groups of each centre and between the groups of both centres. In this regard, the virtual learning platform of Moodle has facilitated this coordination by organizing all the activities involved in the learning activity

The learning environment as a result of the applied methodology has promoted reflective attitude and has helped to develop a good group atmosphere. In this sense, the cooperative learning has provided the faculty members the opportunity to be opened to dialogue in regards to the improvement of the teaching-learning process by attending to the queries of the student body.

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Prototype Development for an Active Learning Activity in Engineering through PBL

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Abstract

The goal of this paper, which is a continuation of the corresponding paper “Approach of an Active Learning Activity in Engineering through PBL", is to represent a summary of the development of a demonstration prototype for controlling and testing a battery charging system in the field of solar energy and to evaluate this active learning-teaching activity by project-based learning.

The building process describes the design, implementation and functional testing of the prototype. Firstly, using a data acquisition card, integrated circuits for signal conditioning and LabVIEW software, various tests on the solar panel used have been performed in order to obtain experimental data of the operating characteristics, which in turn has been used to model the solar panel. At this point, it is highlighted how important it is for the system to operate the solar panel at the maximum power point in order to achieve the maximum possible efficiency at all times. Secondly, the complete system is described from both the hardware (power conditioning, converter power board, converter control board, etc.) and the software (control algorithm) standpoints. Moreover, in order to create the needed virtual instrumentation and to develop the controller card, LabVIEW and Keil environment have been used, respectively. Finally, the functional testing of the whole system and an assessment of this pilot experience of active project-based learning is shown.

1 Introduction

As mentioned in the paper "Approach of an Active Learning Activity in Engineering through PBL", the technological part of this project-based and cooperative learning activity consists of the design, implementation, controlling and testing of an autonomous photovoltaic battery charging system based on a synchronous buck converter.

As it is shown in Figure 1, the photovoltaic system of battery charging is composed of the following main subsystems: photovoltaic panel, which converts the sun energy into electric power in order to charge the battery and supply the electronic devices of the system; buck converter, which adapts the electrical magnitudes in order to transfer energy from the photovoltaic panel to the battery; battery, which is responsible of storing electrochemically the energy coming from the photovoltaic panel; µC-Card, which controls the whole system in order to achieve at all times the maximum efficiency possible; PC, which it is used to monitor and store the signals locally or remotely via internet.

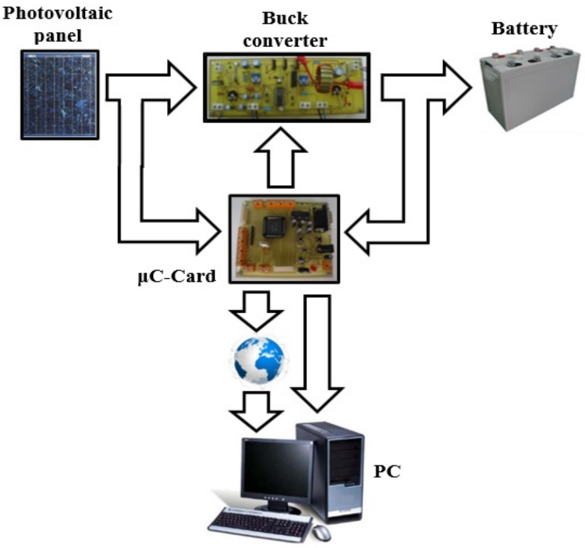

Figure 1: Block diagram of the battery charging system.

In the following sections all components in the system as well as the aspects involved in the control of the converter are discussed.

2 Photovoltaic Panel

The BP 340J has been the chosen solar panel, which has 40 W of electric power. Various tests have been performed, under different conditions of irradiance (between 400 and 1200 W/m^2) and temperature (between 15 and 28 ºC), in order to obtain its operational characteristics and model it, such as the open circuit voltage (V_{oc} = 21.8 V), short circuit voltage (I_{sc} = 2.54 A), maximum power voltage (V_{mp} = 17.3 V) and maximum power current (I_{mp} = 2.32 A).

To measure the current, an IC INA168 and a shunt resistance is used. The acquisition of the current and voltage samples is done with a DAQ NI USB 6211, and are stored in excel format files for their later statistical treatment. To avoid storage of illogical samples, it is compared the deviation between the average and the sample, and it is rejected if it is four times the average deviation.

In Figure 2 the I-V current-voltage characteristic curves of the BP 340J photovoltaic panel for different temperatures are shown. Figure 3 shows the same curve obtained from the experimental data with an irradiance and temperature of 1,000 W/m^2 and 25 ºC, respectively.

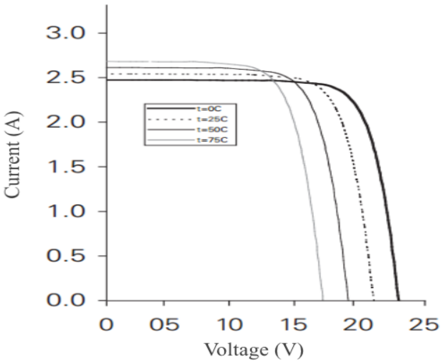

Figure 2: Electrical characteristics of the BP 340J solar panel.

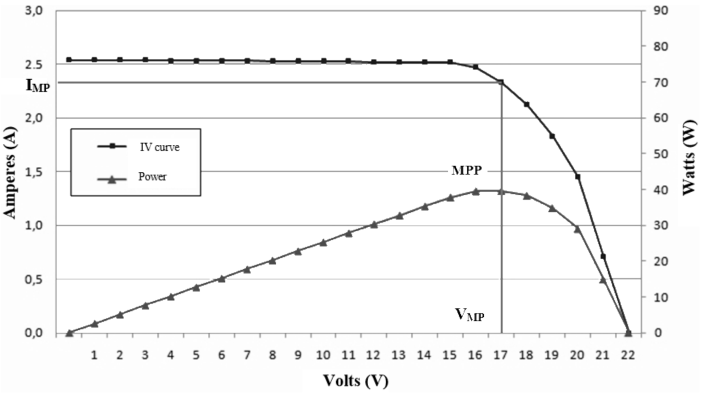

Figure 3: Electrical characteristics of the BP 340J solar panel obtained from experimental data.

As it can be observed, both I-V curves are equal, so once confirmed that the obtained data are valid, a model of the panel has been developed from the experimental data. This model has enabled the construction of an emulator of the performance of the photovoltaic panel in the LabVIEW environment (Lajara & Pelegrí, 2007), (Travis & Kring, 2006).

3 Power Electronic Conditioning

There exist several topologies for power conditioning systems in the field of solar battery charging. The choice of which of them to use depends on, among others features, the range of the electrical magnitudes of the devices in the system, the desired energy quality and the control that it is wanted to perform. For example, using a diode, battery charging with a panel voltage higher than the battery voltage is allowed, thus preventing battery from discharging when there is no solar irradiance. Nevertheless, this configuration does not allow to control the voltage level, so that when the solar panel voltage is lower than the voltage of the battery, it cannot be charged and besides, the solar panel cannot be operated in the MPP (Maximum Power Point) by applying a MPPT algorithm, which is necessary in order to extract the maximum possible power from the photovoltaic panel.

Figure 3 is taken as reference to explain how the system efficiency is improved by implementing a MPPT control algorithm. As it can be observed, until the voltage value corresponding to the voltage of MPP is reached, the current is practically constant and once exceeded this value it decreases quickly. Since electric power is proportional to the V I product, the power curve shows the same behaviour. Therefore, since the maximum power produced by the solar panel is given when the voltage is 17.3 V (MPP), a MPPT control algorithm aimed at controlling the voltage over the photovoltaic panel in order to extract at all times the maximum possible power from it is needed, maximizing thus the electrical efficiency of the system. In this sense, as the battery voltage is lower than the voltage supplied by the solar panel, a synchronous buck converter topology has been chosen for this system, which has allowed an efficient battery charging by applying a MPPT (Maximum Power Point Tracking) control algorithm

In Figure 4 it is shown a comparison between the power experimental results obtained from a variation in irradiance of the photovoltaic panel for both cases: MPPT on (1) and MPPT (2) off. As can be seen, the power extracted from the photovoltaic panel is around 22% higher when the MPPT control is activated.

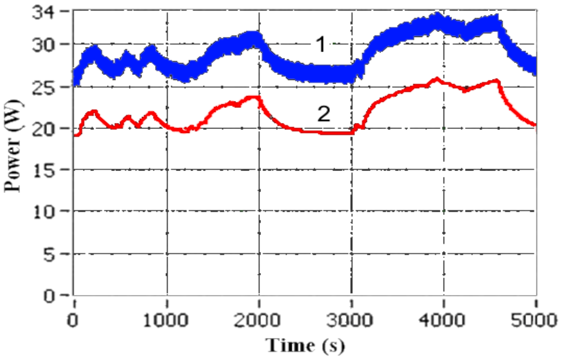

Figure 4: Power curves of the BP 340J panel for a variation in irradiance with the MPPT control on (1) and off (2).

4 Hardware Implementation

The hardware is divided into two boards: converter power board and converter control board. The power board contains the synchronous buck converter with the LT1158 driver. The converter control board contains the microcontroller and other necessary electronic devices to optimize the power generated by the photovoltaic panel. Regarding to the microcontroller, in each centre different types have been used, in the USTIE (University School of Technical Industrial Engineering) of Eibar an ATMEGA163 μC has been used while in the USTIE of Bilbao the ATMEGA163 μC a T89C51AC2 μC has been used.

In Figure 5 it is shown the scheme of the synchronous buck converter power board, which core consists of two NMOS MOSFETs M2 and M3, a coil L1 and a capacitor C3.

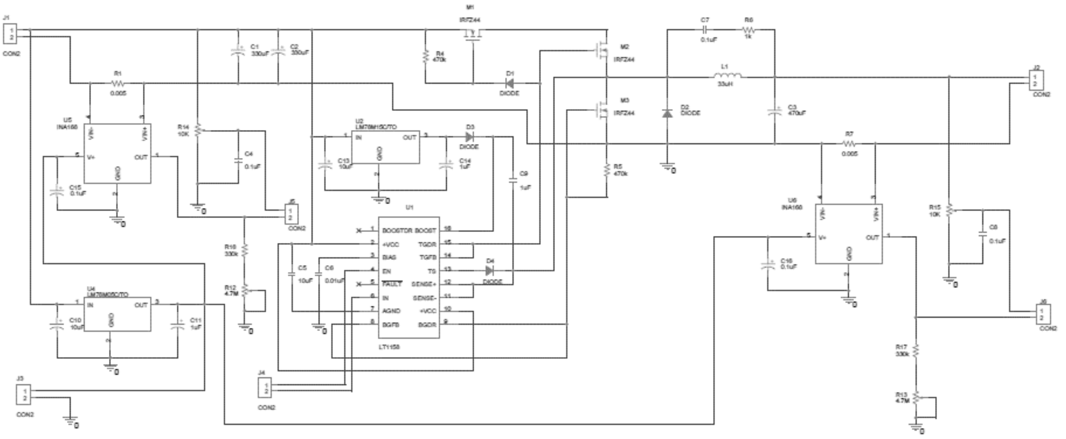

Figure 5: Scheme of the converter power board implemented in OrCAD.

The MOSFETs M2 and M3 are controlled by the LT1158 driver (U1) and two complementary PWM signals generated by the microcontroller. To avoid a simultaneous conduction of both MOSFETs, it is sampled the voltage of the connection point between the drain of the MOSFET M2 and the source of the MOSFET M3, so that it is ensured that the synchronous MOSFET M3 is not conducting before activating the gate of the control MOSFET M2. Should this occur, a path of very low impedance between the terminals of the photovoltaic panel would be formed (shoot through), which is detrimental to the panel.

As the A/D converters of each μC model use a voltage reference, all the signals to be measured have been conditioned in order to scale them to the input voltage range of each μC. To acquire the voltage of the photovoltaic panel and the battery voltage dividers are used, whose conditioning has been performed aside from each A/D converter of each μC.

The current sensing to measure the current output from the panel and the current input to the battery has been implemented with two INA168 IC (U5 and U6) and two shunt resistances (R1 and R7) (Patton, 1998).

Figure 6 shows the converter power board of the implemented synchronous buck converter.

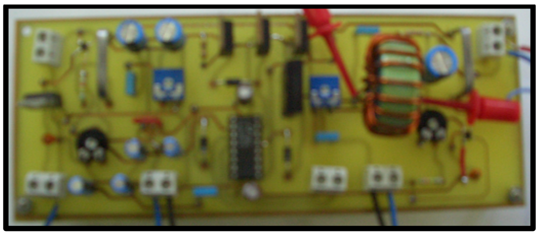

Figure 6: Synchronous Buck converter power board.

As can be seen in the scheme of the Figure 7, the converter control board consists of a μC (IC1) integrated together with a MAX232A IC (IC2) in order to adapt the TTL (Transistor-Transistor Logic) signals of the μC to the levels required for the RS232 communication with a PC. Therefore, the μC is used to acquire samples of the converter input and output voltage and current, execute the MPPT control algorithm, generate the control signals to control the MOSFETs as well as to transmit the measured values to a PC via RS232. In Figure 8 it is shown the converter control board based on the μC T89C51AC2 once implemented.

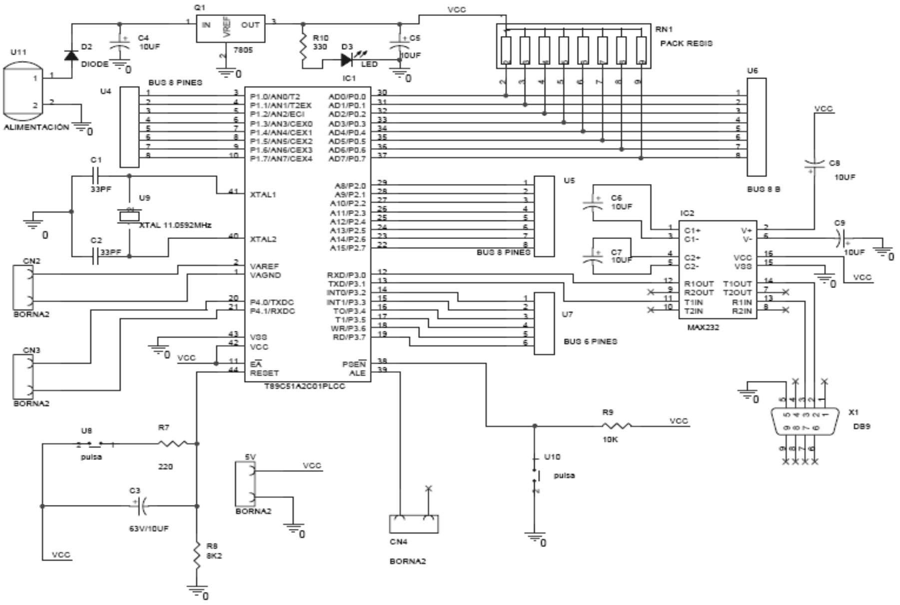

Figure 7: Scheme of the converter control board implemented in OrCAD.

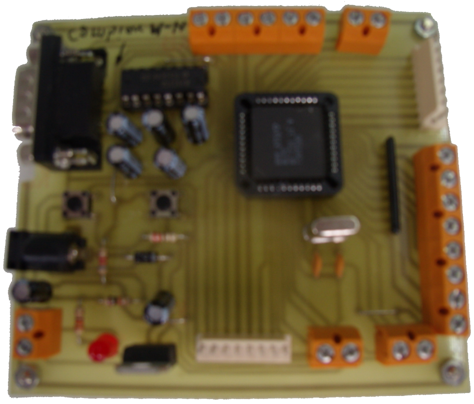

Figure 8: Converter control board based on the μC T89C51AC2.

After the stage of implementing the prototypes by the cooperative learning groups of both centres (USTIE of Eibar and Bilbao), aiming at verifying the functionality of these prototypes, various tests have been conducted, most of which have consisted of checking the proper range of values of voltage and current of the most representative nodes and lines, respectively. For instance, Figure 9 shows the waveform of the current flowing through the coil when applying an input voltage of 15 V with a 100 Ω resistance as load.

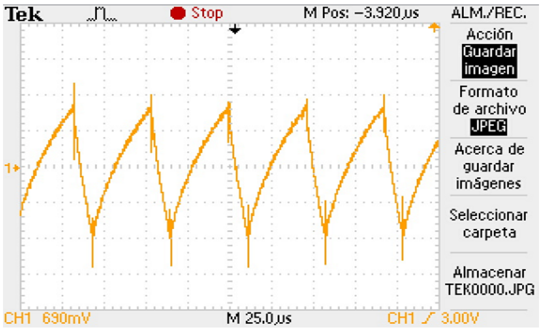

Figure 9: Current through the coil of the synchronous buck converter.

5 Software Implementation

To implement the software of each µC two different programs have been used: Code Vision AVR C Compiler for the µC ATMEGA163 and Keil µVision 2 for the µC T89C51AC2, using the ANSI-C language on both of them (Martínez & Barrón, 1995), (Barrón & Martínez, 2003). The necessary virtual instrumentation for monitoring and storing electrical signals has been developed in LabVIEW environment (Sokoloff, 2004), considering a top-down design methodology.

MPPT Algorithm

Among all the existing MPPT control algorithms, the based on the incremental conductance has been implemented, as it provides a good voltage control to changes in irradiance. The basis of this algorithm lies in the observation of the expression (3), obtained from the derivation of the power expression (1), along the power characteristic curve of the photovoltaic panel.

$$P = V \cdot I \tag{1}$$

$$\frac{dP}{dV} = V \cdot \frac{dI}{dV} + I = 0 \tag{2}$$

$$\frac{dI}{dV} = -\frac{I}{V} \tag{3}$$

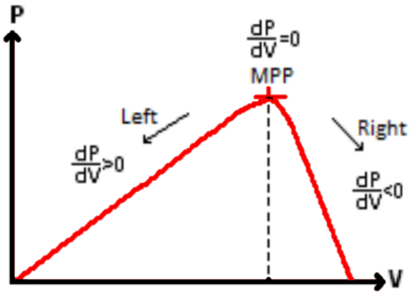

Figure 10: Locations of the photovoltaic panel operating point along the power curve.

As it can be seen in Figure 10, depending on the zone of the power curve in which the operating point is located, the following (4) to (6) inequalities are deduced:

$$\frac{dI}{dV} < -\frac{I}{V} \rightarrow \frac{dP}{dV} \in \left(-\infty, 0\right) \tag{4}$$

$$\frac{dI}{dV} > -\frac{I}{V} \rightarrow \frac{dP}{dV} \in \left(0, \infty\right) \tag{5}$$

$$\frac{dI}{dV} = -\frac{I}{V} \rightarrow \frac{dP}{dV} \in 0 \tag{6}$$

When (4) is satisfied, it mean that the operating point is located on the right of the MPP, being necessary to decrease the duty cycle in order to reach it, while if (5) is satisfied, it will be located on the left of the MPP and the duty cycle will have to be increased. Therefore, depending on the values of (4) and (5), the duty cycle will be varied until (6) is satisfied, which mean that the photovoltaic panel will be operating at the optimal operating point.

Additionally, when implementing the MPPT algorithm, an extra functionality that ensures a correct operation of the converter has been added. Since in a buck converter the input voltage must be greater than the output voltage, when this condition is not fulfilled, the control signals to the MOSFETs are cancelled, thus avoiding the converter operation under any type of anomaly that could occur. Furthermore, since the converter is designed for charging lead-acid batteries of 12 V, it has been also added a function to check the SOC (State Of Charge) of the battery connected to the system. It is considered that a battery is fully charged when its open circuit voltage has reached the voltage corresponding to a SOC of 100% specified by the manufacturer. Not interrupting the charging once the battery is fully charged would lead to an overload, which in turn would cause a reduction of its lifetime, possibly even its destruction.

In order to avoid this detrimental situation, the converter isolates the battery from the system once in a while to check the open circuit voltage of it. To do that, the µC controls a solid state relay that disconnects the battery when required. The time elapsed between two consecutive measurements should not be neither too long nor too short, so as to ensure that the battery is not damaged and to not decrease the efficiency of the converter. Given this, a checking time close to a minute has been chosen. When the SOC of the battery is at 100 %, the charging is interrupted until the battery voltage level drops to a pre-set threshold level.

System Monitoring and via RS232

As mentioned above, the virtual instrumentation for monitoring and storing electrical signals has been developed in LabVIEW environment. To do that, standard RS232 protocol for communication between the PC and the µC has been developed. The block diagram corresponding to the reception of data, via RS232 at 9600 baud, from the µC. In Figure 11 it is shown the graphical programming corresponding to the data reception via RS232, which has been carried out at 9600 baud.

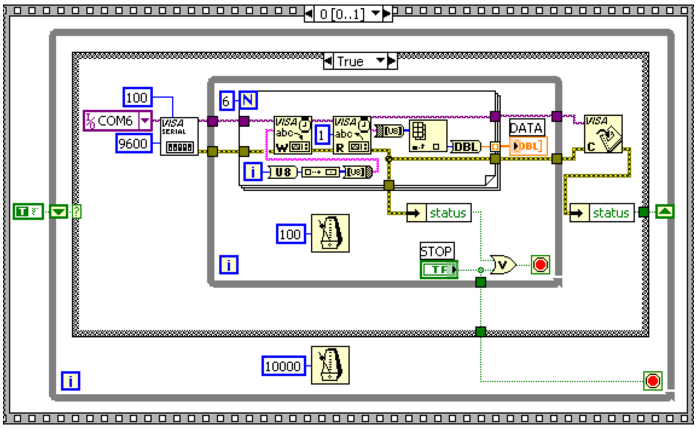

Figure 11: Graphical programming of the data receiving via RS232.

The received data from the μC correspond to the output voltage and current of the photovoltaic panel, voltage of the battery and current flowing it. The data received are processed in order to calculate and store the value of the power provided by the photovoltaic panel and the electrical energy stored in the battery.

Although it is not represented in this paper, the electrical magnitudes of the system not only can be monitored from a PC with a direct communication to the μC via RS232, but also it is possible to do it remotely via TCP / IP protocol. Storage time has been set in one minute, and the received data are stored in a text type file for importing them into excel for further treatment.

6 Evaluation of the Teaching Experience

In this section it is exposed how has been performed the evaluation of this active learning teaching activity. In order to encourage the active participation of all parties involved in this learning activity, it has been resorted to the EAS (Education Advisory Service) of University of the Basque Country. Among various evaluation methods, the method in which the assessment is focused exclusively on the opinion of the student body has been proposed, that is, to evaluate this experience only the opinion of students has been taken into account, which, has been gathered by questionnaires. For this purpose, it has been developed in conjunction with the EAS an assessment methodology based on questionnaires, which not only allow to assess the learning process, but also provide guidance for faculty so as to know how to be evaluated by students. The key aspects that have been taken into account when developing this methodology are the following:

- It should be developed in order to achieve an effective utility that will allow to perfect the teaching. With this regard, it is important to establish what criteria must be assessed by students in order to take advantage of their opinion to changing, for the better, that which can be improved or that which is being done wrong.
- It is a technique that should be focused on estimating the learning process quality level.
- The assessment process should allow researching about the teaching and learning process, so that it can be evaluated the changes and impact on students after applying the methodology as well as discuss further alternatives for improvement.
- The evaluation process should allow the faculty to be informed in order to help them to conduct the necessary changes.
- It should be kept in mind that depending on the teaching behaviour, the achievement of the desired aims could be facilitated. In this sense, the promotion of motivation done by teachers, plays an important role, so that, the more motivated students are, the greater their involvement will be, and therefore the easier will be to achieve the desired objectives.

The considered evaluation criteria are related to:

- Students orientation towards the desired objectives within the subject in which the learning takes place, as the degree of involvement that should have them during the project, how the assessment will be performed, etc.
- Organizing and planning the activities to be performed and objectives to be achieved in them, thus motivating the student body by enabling their participation in organizing and planning the activities, and by providing at all times the required assistance ().
- Development of teaching by implementing cooperative and project-based learning methodologies. In this regard, the cognitive abilities (rote learning, comprehension and perception, facing new situations by applying the acquired knowledge, critical analysing, creative analysis and integration in work teams) to be developed in students are considered, as well as the degree of importance that they have in the current social and labour environment (Mina & Moore, 2010).
- The assessment process of the acquired skills, in which the obtained learning results will enable knowing how to focus the evaluation and how to observe the accomplishments by students (Ramsden & Agnes, 1998). As has been exposed in the paper "Approach of an Active Learning Activity in Engineering through PBL", the evaluation has consisted of both formative and summative methods, which have been conducted through assessment rubrics.
- The mutual interaction of the participants, among students and between students and teachers in class as well as through the virtual teaching platform of Moodle. In this sense, indicators on the design of a particular relational architecture within the learning environment of this teaching experience have been set out.
- Motivation and Learning. Students will be motivated to learn if teachers are accessible to them and guide and provide them advice on how to proceed under any situation. Teachers should be adapted to their level of knowledge, trying to expose different point of views on a given subject in an impartial and tolerant manner and establishing relationships between contents developed in the subject and significant problems for students (Harding *et al*, 2007).
- The overall score of the learning activity from the viewpoint that a teacher is a permanent student of the world around him and that the students and the faculty form a learning community.

Six rubrics have been designed to assess the above seven evaluation criteria. For instance, in Table 1 it is shown the indicator "He knows how to be a mediator and tutoring-support", which corresponds to the assessment rubric of Motivation and Learning, which in turn consists of 18 indicators.

Table 1: Rubric of the indicator "*He knows how to be a mediator and tutoring-support*".

Indicator	*He knows how to be a mediator and tutoring-support*
Excellent 4	The teacher shows good communication skills, such as speaking, listening as well as writing and interacting. Supports and motivates the students, providing the necessary learning materials and electronic addresses, and can recognize their moods. He also guides students and facilitates their learning.
Very Good 3	The teacher resolves the doubts when it is required by the students, or when he realizes the students have made any mistake. The teacher suggests and provides support material to students.
Good 2	The teacher resolves the doubts of the students only when it is required by students. The teacher suggests and provides support material to students.
Poor 1	The teacher resolves the doubts of the students only when it is required by students. The teacher does not use motivation strategies.
Score	

7 Results

Regarding to obtained results in the students qualifications, it can be said that, although it has required a great deal of time and effort to plan and implement this new learning methodology, the average score of both centres have been increased by 12,27 % comparing it with the one obtained before applying this methodology. Thus, the average score of Eibar has incremented from 7.1 to 8.1, while in Bilbao it has incremented from 6.7 to 7.4. Besides, not only the results obtained in the students' qualifications have been satisfactory, but also the scores obtained on the assessment of this teaching experience have been satisfactory.

In Table 2 is shown the score of each above-mentioned evaluation criteria, for both centres Eibar and Bilbao.

Table 2: Obtained score in both centres.

Rubric	USTIE of Eibar	USTIE of Bilbao	Average score
Organizing and Planning	3.3	2.8	3.05
Development of Teaching	3.2	2.8	3
Assessment Process	3.4	3.2	3.3
Mutual Interaction	2.8	2.5	2.65
Learning and Motivation	3.5	3.1	3.3
Overall score of the experience	3.4	3	3.2

Even though the results have been satisfactory, there is a difference among students of USTIE of Eibar and Bilbao. In this sense, must be taken into account that students of Eibar were more familiarized with this type of learning, so they have assimilated better this learning activity. Besides, students of the USTIE of Bilbao had never been involved in an experience of this type.

During this learning activity, 6 students left the course in the USTIE of Bilbao, which has implied a reconfiguration of the groups, and finally have been formed 13 groups of 4 students each and another group of 3 students. In the USTIE of Eibar all the student completed the course. After the assessments have been performed, 55 students of the USTIE of Bilbao and 21 of the USTIE of Eibar passed the course.

8 Discussion and Conclusion

This teaching activity has enabled to orient the learning method used in the subject of Final Degree Work according to the EHEA guidelines, thus creating the elementary conditions of a teaching based on a cooperative and project-based learning in order to accomplish the necessary competencies by students.

Although it has been slightly noticed lack of participation of some members, all the conflicts that have emerged among members of the groups have been resolved by exposing in a properly manner the problems that have arisen, which in turn has allowed a rewarding restructuration of the work in group.

It has been noticed that when students know the necessities of their classmates "from inside", has facilitated the role performance of students as a mentor, which has given them the opportunity to respond to the specific needs of their classmates.

Six evaluation criteria have been considered when evaluating this experience, including the organizing and planning, mutual interaction, development of teaching, assessment process, motivation and learning and the overall evaluation. Based on the evaluation made by students, it is considered that the aims have been successfully fulfilled and that the acquired skills will be useful to organize future similar activities.

The implementation of this active learning activity based on a cooperative and project-based learning has not been easy, not only because the student body is not accustomed to work in group, but also because teachers tend to teach them in an individually manner. In this sense, this experience has served to reinforce learning for both students and teachers.

Although the implementation of this active learning activity has required effort, consistency and continuity, the results have been gratifying, so it is planned to extend progressively the applied methodology to another subjects.

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A STEM outreach program: case study of a scale up in two countries

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Abstract

The Pequeños Cientificos program began 15 years ago in Colombia as a literacy scientific program aimed towards K-5 schools founded by UniAndes (Universidad de Los Andes- Bogotá) in collaboration with other local players. A network of 6 Colombian Universities in association with the local government and some private foundations have conducted this program. Several international collaborations were being built with other countries like Panama and the Dominican Republic with an alliance with INTEC (Instituto Tecnológico de Santo Domingo). In particular, during the last 3 years a new version of the program has been developed in collaboration with the Dominican Republic that includes Mathematics and Technology following STEM programs around the world. At the same time the expertise built within this framework has allowed the collaboration with the Ministry of Education in Colombia in order to promote a National program designed to train more than 70.000 primary school teachers and also the conception of a new program that will reach high school in the country with a big reform starting in the second semester of 2015.

This paper presents the main lessons of this experience, specifically concerning the scale up of a STEM program that looks to transform education in a developing country. The findings highlight the importance of a well-structured situated professional development focused on pedagogical content Knowledge and conceived using the latest in this kind of interventions. These lessons will be used to develop a similar program by INTEC in the Dominican Republic; this country is currently involved in a small pilot project to be developed in 2015. Both the Colombian and DR projects seek the future, seek to have more and better candidates to follow STEM programs including different branches of sciences and even engineering carriers.

1 Introduction

Incrementally statements, studies and research insist on the growing demand for STEM professionals by society. STEM programs concern the education in Science, Technology, Engineering and Mathematics at all levels. In fact, STEM professionals are at the core of a nation's capacity building within the framework of an increasingly global market where the ability to innovate and to be competitive are essential attributes *(M. Duque and J. Celis, 2012 ; PCAST, 2012)*. Even countries like China, with 600,000 engineering graduates each year find that this number is insufficient and inappropriate for their growing needs *(D. Farrell and A. Grant, 2005)*.

However, building a society capable of innovation, entrepreneurship and competitiveness involves more than having good engineers or scientist, it requires a whole society that is in tune with these processes *(Council of competitiveness, 2004)*. Furthermore, the ability of a nation to innovate depends not only on the professional elites, but of the general education of all citizens in order to work and participate actively in these fields;

therefore just the training of good STEM professionals is an incomplete solution *(C. Baudelot and R. Establet, 2009)*, and in fact education for all (including all levels of education) is an important element among the factors associated with competitiveness *(K. Schwab, 2012)*.

In 2000, a Colombian pilot project named the Pequeños Cientificos Program was born at the Engineering school of Los Andes University. This program was created in partnership with French school Louis Pasteur and Maloka Science Museum, inspired by French initiative La main a la pate. Later, the National Science Academy joined the program and it became the national inquiry based education program. It was conceived as one of the strategic actions that the school of Engineering could develop to help the country's education system modernize their teaching approach, first in science and technology, and then in mathematics, in a response to the growing role of engineering education for all, as well as an intensive use of science and mathematics, as a generator of technology for education in the XXI century.

As the program grew, several universities, private foundations and companies partnered to support the program. The development of this pilot program, which has been considered in many countries as a model of success, included some of the best practices in teacher professional development and curriculum.

In recent years, the number of countries involved in these educational renewal movements has increased continuously. Currently, more than 30 countries include inquiry based learning as a strategy for teaching and learning of science and technology in schools. In Latin America, the network has grown, and today Chile, Argentina, Brazil, Venezuela, Bolivia, Peru, Panama, Costa Rica and the Dominican Republic have similar projects with different development levels. Some of them remain as small pilots, others have national impact, and others are now part of the national curriculum and teacher training policies. Particularly in Colombia, the project now has a national scope and this experience is being brought to the Dominican Republic, which thanks to the efforts of the private sector and academics, has taken important steps in this renewal of the teaching of science, mathematics and technology.

Although different players are involved in the success of these kinds of projects, Engineering schools have an important responsibility, and also the abilities to help society in order to reduce the gaps that separate most developed countries in relation with developing countries, like the Dominican Republic and Colombia. The involvement of engineering schools in improving the literacy for all in science, technology, engineering and mathematics is not only important but relevant, because it is part of their own mission: to help solve, with technology, humanity's largest problems *(M. Duque, 2011)*. Hence, universities must ensure that the training of all citizens is according to the challenges of today's society, and which involves constant innovation to stay competitive.

Although, there are national tests in basic and secondary levels that provide data on the performance of students in different subjects, there is currently no standardized tests to evaluate the skills of students in the early grades, which are the foundation for future learning.

2 Education in Science, Engineering and Mathematics in developing countries: Colombia and the Dominican Republic

Colombia

The national and international assessment results show that Colombia faces many challenges related to education in areas such as science, mathematics and language. The performance of 15 year olds in Colombia is low, compared with developed countries and even some developing countries as shown in PISA 2009 *(M. Duque and J. Celis, 2012)* (see Figure 1). In fact, less than 1% of students achieved outstanding performance in the three areas assessed by PISA 2009, which also shows a serious disadvantage in the country in terms of its ability to innovate and compete on equal terms with other regions *(ICFES, 2010)*. Similarly the TIMSS 2007 test does not show substantially different results *(M. Duque and J. Celis, 2012)* (see Figure 2).

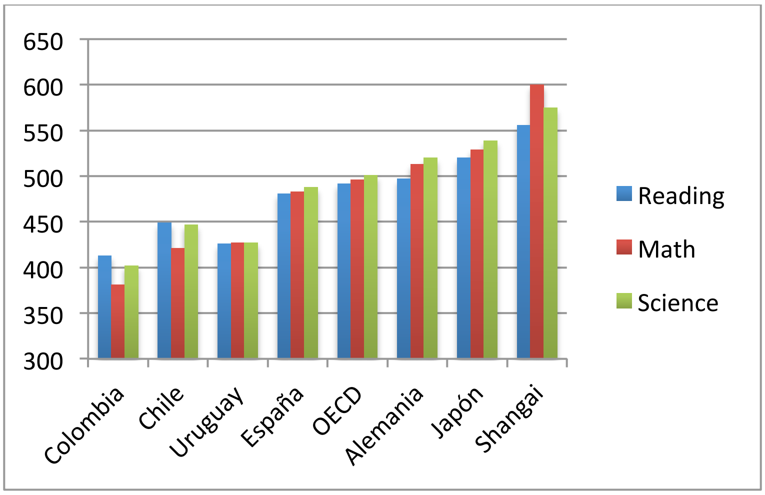


Figure 32: Comparative Results PISA 2009 *(Duque & Celis, 2012)*

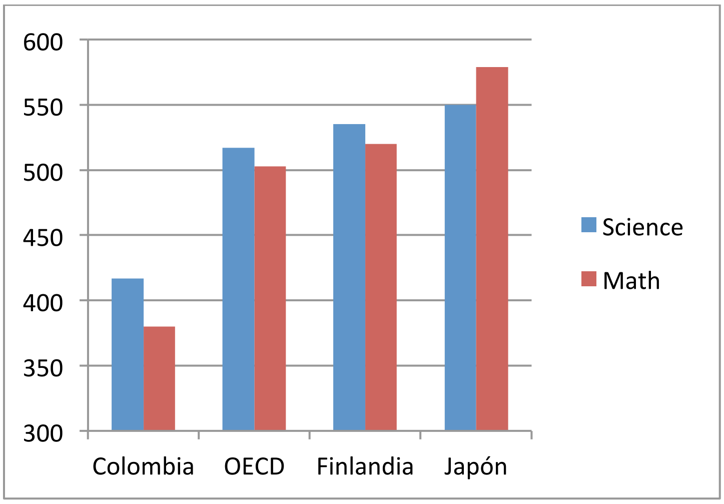


Figure 33: Comparative Results TIMMS 2007 *(Duque & Celis, 2012)*

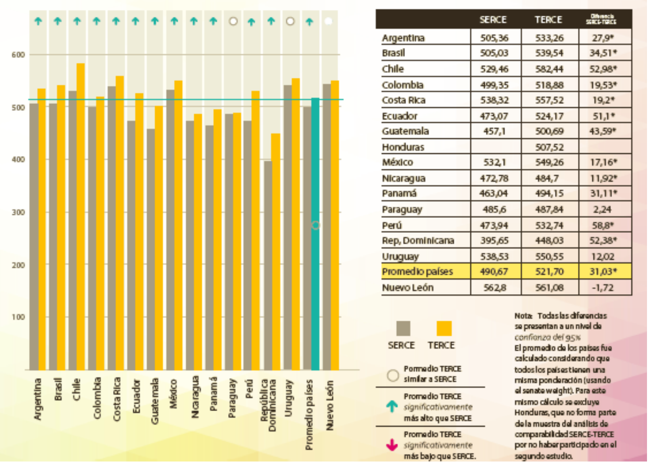
Another reference is the EGRA (Early Grade Reading Assessment) and EGMA (EGMA: Early Grade Math Assessment) application that showed very poor results, even though this test was applied in one of the cities with better educational performance in Colombia. In particular, a large share of students in 5th grade cannot even perform simple subtractions.

Dominican Republic

The situation in the Dominican Republic is not different from Colombia. It is the first time that this country will apply the PISA tests in 2015, and it has shown a worrisome behavior in the assessment of basic performance of language and mathematics in the early grades of the school's basic cycle *(C. Guadalupe et al., 2013)*. For example, for the EGMA test, in all cases it was observed that the students were able to answer less than half of the questions raised and during classroom observation it was determined that less than 10% reached a basic performance *(C. Guadalupe et al., 2013)*.

Figures 3 and 4 show the results of the TERCE and SERCE regional tests, which also assess language and mathematics in third grade, and language, math and science in sixth grade. The Dominican Republic showed the lowest results in the region *(M. Bilagher, 2013)*

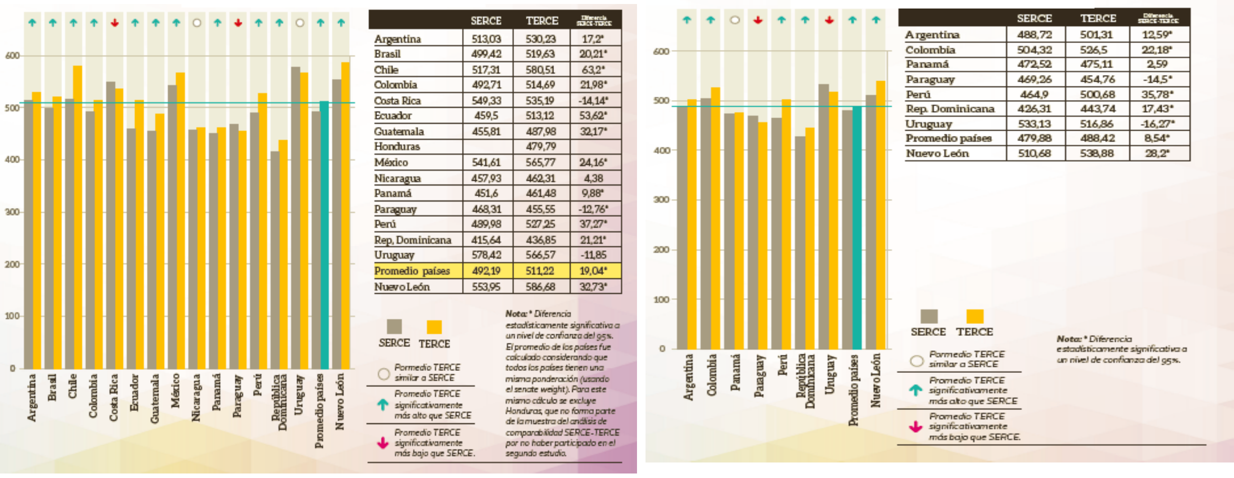
Mathematics



	SERCE	TERCE	Diferencia SERCE-TERCE
Argentina	505,36	533,26	27,9*
Brasil	505,03	539,54	34,51*
Chile	529,46	582,44	52,98*
Colombia	499,35	518,88	19,53*
Costa Rica	538,32	557,52	19,2*
Ecuador	473,07	524,17	51,1*
Guatemala	457,1	500,69	43,59*
Honduras		507,52	
México	532,1	549,26	17,16*
Nicaragua	472,78	484,7	11,92*
Panamá	463,04	494,15	31,11*
Paraguay	485,6	487,84	2,24
Perú	473,94	532,74	58,8*
Rep, Dominicana	395,65	448,03	52,38*
Uruguay	538,53	550,55	12,02
Promedio países	490,67	521,70	31,03*
Nuevo León	562,8	561,08	-1,72

Nota: Todas las diferencias se presentan a un nivel de confianza del 95% El promedio de los países fue calculado considerando que todos los países tienen una misma ponderación (usando el senate weight). Para este mismo cálculo se excluye Honduras, que no forma parte de la muestra del análisis de comparabilidad SERCE-TERCE por no haber participado en el segundo estudio.

Figure 34: Comparative Results SERCE-TERCE 3º Grade



Mathematics

	SERCE	TERCE	Diferencia SERCE-TERCE
Argentina	513,03	530,23	17,2*
Brasil	499,42	519,63	20,21*
Chile	517,31	580,51	63,2*
Colombia	492,71	514,69	21,98*
Costa Rica	549,33	535,19	-14,14*
Ecuador	459,5	513,12	53,62*
Guatemala	455,81	487,98	32,17*
Honduras		479,79	
México	541,61	565,77	24,16*
Nicaragua	457,93	462,31	4,38
Panamá	451,6	461,48	9,88*
Paraguay	468,31	455,55	-12,76*
Perú	489,98	527,25	37,27*
Rep, Dominicana	415,64	436,85	21,21*
Uruguay	578,42	566,57	-11,85
Promedio países	492,19	511,22	19,04*
Nuevo León	553,95	586,68	32,73*

Nota: * *Diferencia estadísticamente significativa a un nivel de confianza del 95%. El promedio de los países fue calculado considerando que todos los países tienen una misma ponderación (usando el senate weight). Para este mismo cálculo se excluye Honduras, que no forma parte de la muestra del análisis de comparabilidad SERCE-TERCE por no haber participado en el segundo estudio.*

Science

	SERCE	TERCE	Diferencia SERCE-TERCE
Argentina	488,72	501,31	12,59*
Colombia	504,32	526,5	22,18*
Panamá	472,52	475,11	2,59
Paraguay	469,26	454,76	-14,5*
Perú	464,9	500,68	35,78*
Rep. Dominicana	426,31	443,74	17,43*
Uruguay	533,13	516,86	-16,27*
Promedio países	479,88	488,42	8,54*
Nuevo León	510,68	538,88	28,2*

Nota: * *Diferencia estadísticamente significativa a un nivel de confianza del 95%.*

Figure 35: Comparative Results SERCE-TERCE 6º Grade

Based on these results, it is clear that efforts should be made to promote a profound transformation in the teaching and learning strategies, in order to train competent citizens with capabilities to make informed decisions in their daily lives. The lack of a good education in STEM is a major obstacle to be part of the XXI century society.

3 Pequeños Cientificos for the Transformation of Education, a pilot that can be scaled

The Pequeños Cientificos program was created as a response to the low performance of students in science *(M. Duque et al., 2002)*. This initiative by the engineering school at the Universidad de los Andes was based on other programs developed internationally in Europe (La main à la pâte) and the US (NSRC, CAPSI, FOSS, STC, INSIGHT). In Colombia, the collaboration with the Ministry of Education and the decisive support of the private sector through its foundations (Natural Gas Foundation and Siemens Foundation) allowed the construction of this program as a laboratory for research and development in teacher training, which has nourished the great projects of the Ministry of Education that currently reach more than 70,000 teachers in the country.

In the Dominican Republic, this initiative began from together with Universidad de los Andes in Colombia and the Propagas Foundation, who in alliance with INTEC conducted the Program to transform the teaching of science and mathematics.

In a class of Pequeños Cientificos, students observe a real problem and perform research that allows them to build explanations and knowledge associated with the problem. To do this, they develop hypotheses and consider arguments using their own words, discuss their own ideas and build scientific knowledge *(R. Belay, 2006)*. This approach to teaching science and technology, requires students to devote sufficient time to the problems and address them with logical sequences in which progress is made on the conceptual construction *(K. Worth et al., 2009)*. This means that the teacher must have the materials and teaching resources to engage students in small research that will act as "little scientists" carrying out observations and experiments to build knowledge that is new to them *(National Research Council, 2000)*.

But having these kinds of classes is not a simple task, it is important to balance the control of processes with the increasing need to have more autonomous teachers and schools. The scaling up considerations to bring projects as Pequeños Cientificos to a national level take in account a lot of different tensions, like the need for control and accountability, the sustainability of the actions taken, the cost, and the need for human resources to train and perform follow up.

In its 15 years of experience, Pequeños Cientificos has constructed and validated a framework that clarifies the objectives, the means and the resources to implement a strategy that is able to transform the quality of education in science, technology, engineering and mathematics (STEM) in primary school.

4 Conceptual frameworks for the implementation of an educational program in STEM

One of the lessons during the first 10 years of implementation of Pequeños Cientificos in Colombia, was the need to have well supported frameworks, to guide professional development activities, coaching of teachers and development or materials.

Figure 5 shows the dimensions of the frameworks developed for the implementation of a program that brings science, engineering and mathematics to elementary school.

Given that teachers' qualifications is one of the factors that influence the academic performance of students *(M. Cochran-Smith and K. Zeichner, 2005)* and that the basic primary school teachers rarely have specific training in one of the STEM areas, Pequeños Cientificos has developed a framework for professional development of teachers in service, the teachers' focused approach to scientific knowledge through research and investigation strategies that can be transferred to the process of teaching and learning in the classroom.

Pequeños Cientificos proposes a professional development strategy based on the orientation of inquiry learning in science and math problem solving *(National Research Council, 2000)* from the perspective of pedagogical content knowledge, PCK *(J. Loughran et al., 2012, S. Abell et al., 2009, L. Shulman, 1987, T. Kleickmann et al, 2013)*. This training is developed from the perspective of situated learning *(R. Putman and H. Borko, 2000, S. Loucks-Horsley et al., 2010*) in authentic contexts, and is focused on the development of didactic knowledge of the discipline that allows teachers not only to understand the ideas to teach, but to know the most appropriate strategies to ensure that their students learn *(L. Shulman, 1986)*.

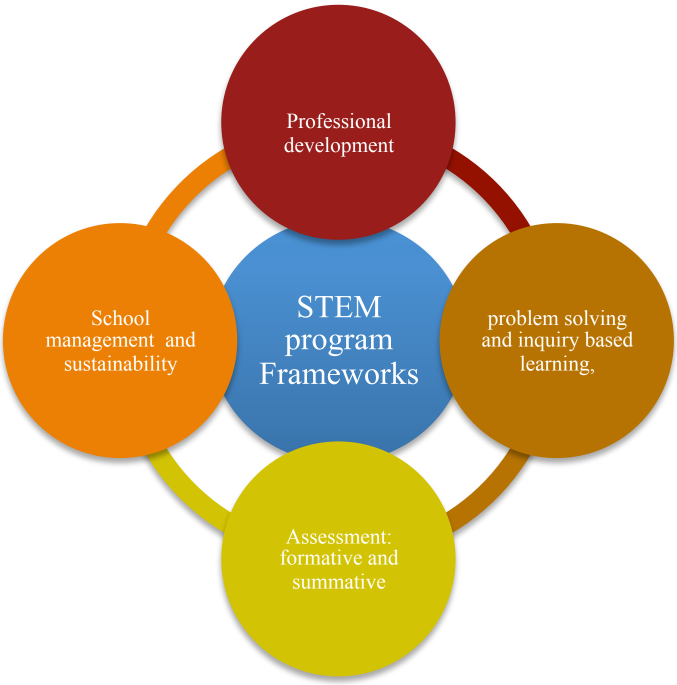


Figure 36: Frameworks for STEM education in Pequeños Cientificos

Formative assessment (or assessment for learning), which in turn has been identified as a key factor in both student learning and teachers is how to promote the improvement of teaching and learning in the areas of science, technology engineering and mathematics *(W. Dylan, 2011)*. The framework for the assessment is based on the description of knowledge expected in competent students in natural sciences, technology and math, and describes different types of cognitive achievements (declarative knowledge (factual, conceptual), procedural knowledge (stepper, condition-action), schematic knowledge (explanation), and finally strategic knowledge (problem solving and validity of the reasoning)). *(R. Shavelson et al., 2005, M. Li and R. Shavelson, 2002)*.

To promote this learning in school, it is achieved through the deliberate work of teachers, Pequeños Cientificos described a framework for teaching science, math, and technology based on inquiry. This framework defines the dimensions that should be taught in math, science, and technology and reflects the latest trends in disciplinary didactic approaches to STEM education *(R. Duschl, 2007)*. In particular, the Pequeños Cientificos Program recognizes four dimensions to the teaching of science:

Conceptual schemes that relate to the construction of science, technology and mathematics and its appropriation by student's ideas;

Process strategies, implying that students are taught how to develop science, technology and mathematics questions and predictions, build hypotheses and validate their findings;

Epistemological frameworks in which we expect the student to approach the nature of scientific and technological knowledge, recognizing for example the provisional nature of the ideas and conclusions and validity of knowledge supported by evidence.

Finally, a dimension of **social processes** related to communication, language and own argument of science, mathematics and technology are covered.

To transform the process of teaching and learning in STEM areas in primary school in Colombia and the Dominican Republic, we are forced to reflect on the science and math curriculum, transforming the vision of what is taught and learned in the classroom. In Colombia, for example, there is not a national curriculum and each institution is free to produce its own curriculum based on a very generic national standard. Most of those curriculums are very traditional despite the message on the national standard. It is important to transform the vision of a long list of content to a less extensive curriculum focused on the development of great ideas and core skills on science, mathematics and technology *(W. Harlen, 2010)* in various situations and learning production *(K. Worth et al., 2009)*. On the other hand, in the Dominican Republic, there is a unified curriculum, and teachers do not have good material except the text books themselves with the limitations they may have, enabling them to reach the desired goals and develop the required skills.

These frameworks, are mediated by the conviction that real transformation requires the involvement of different players from the community, including parents, teachers, managers, local decision makers and the productive sector.

So, the first consideration for an effective scale up of a STEM pilot project is to have a well-structured set of frameworks, represented in manuals, protocols, guidelines, and others that can be easily translated into concrete actions. This not only allows the follow up of the project but also maintains a pool of resources to be assessed and re-evaluated.

5 Organization and partnerships, to grow, it is important to share

Since the program's inception, Pequeños Cientificos has recognized that the success of this initiative depends on the coordinated networking with various stakeholders and has sought different parts of the region involved in the work of teacher training. The strategy to achieve this expansion of the program is the creation of a national and international network of centres, which are composed of a set of relevant actors for the transformation of education in STEM in regional players.

The quality of education in STEM areas depends not only on universities or local or central government. Pequeños Cientificos has mobilized since its inception, private companies interested in positively impacting basic education in order to improve living conditions and qualifications of their companies' work force.

The program works since 2002 with the support of the Gas Natural Foundation. In 2005 the Siemens Foundation in Colombia also began supporting the group. In 2011 Propagas Foundation in collaboration with the Universidad de Los Andes began the program in the Dominican Republic.

Other foundations such as MAMONAL, Dow Chemical, LUKER and Genesis Foundation have participated in teacher training programs developed by Pequeños Cientificos. In this way Pequeños Cientificos has become a strategy for corporate social responsibility for several enterprises in which public-private partnerships make use of the experience of universities to take science, engineering and mathematics to elementary school.

In the case of the Dominican Republic, Propagas Foundation in partnership with the INTEC has been developing a STEM program called Pequeños Cientificos RD. This has been a cooperative effort between the Colombian and the Dominican Republic team under which both initiatives, the Colombian and the Dominican Republic one, have improved strategies and learned from each other.

Both the Colombia and RD experience show that collaboration with different stakeholders as private companies, policymakers and non-governmental organizations is crucial for a sustainable scale up of a STEM project.

6 Achievements and Impact,

The Pequeños Cientificos program has impacted over 130,000 students in Colombia by working with close to 3000 teachers in basic education service. In the case of the Dominican Republic, the program has reached approximately 1,400 children and 50 teachers in their early years.

Additionally in Colombia, the program's experience has contributed to the creation of two programs belonging to the Ministry of Education of Colombia: Rural Education Program PER with about 9000 teachers in the areas of math and science *(MEN, 2013)* and everyone learn program (PTA) with about 70,000 teachers in language, arts and mathematics *(MEN, 2012)*.

As a recent result, an agreement between three universities (Universidad de Los Andes, Universidad Nacional and Universidad Externado) has been signed. In this framework, researchers of those universities will address 11 projects in order to improve different issues of the Colombian educational system including a new curriculum, improvement of teacher's initial education, and teachers' professional development in poor neighbourhoods to teach Language, Math and Science.

To evaluate the impact on learning, three types of instruments have been used:

- Standardized Testing multiple choice
- Open questions
- Performance Evaluations

These tests have been applied solely on two thematic: human body and circuits.

In particular, *(M. Figueroa, 2011)* tests were applied to 365 students including students of a control group in 5 different public schools in Bogota. Of this group, 140 students took the performance test. Globally the results showed better results for those students who worked under the Pequeños Cientificos Program, particularly in performance tests. On the other hand, the pen and pencil tests showed also better results for those students under the program but, the difference was not statistically significant. This aspect shows that students participating in the program learn the same as students in traditional classes in terms of content, and also use better skills for the development of experimental abilities.

It is really important to assess and evaluate these kinds of projects, since the results could be used to inform policymakers to design and implement wider projects at a national level. Although neither Colombia nor RD currently have an impact evaluation, it would be another important factor for the scale up of the project.

7 Citizenship Skills

Education in science, technology, engineering and mathematics can be reflected in the students' citizenship skills. Not only because a scientifically literate citizen is able to make informed decisions and participate effectively in society's current debates *(G. Charpak, 1998, E. Morin, 1999)*, but because the same exercise to learn science by science (or engineering by engineering) promotes skills for life within society. By analyzing the learning environment promoted by Young Scientists, it appears that some elements such as cooperative work, management and attitude towards the mistake, argument and conflict management, present and contribute to the development of cognitive, emotional communication and citizenship skills *(C. Carulla, 2006)*. Recently, a study conducted in 2012 showed that teachers perceive a positive effect from the elements of Young Scientists working to promote peaceful classroom environments. Teachers reported that indicators of non-violent classroom settings such as listening, curiosity, respect for the word, and autonomy were promoted when students were involved in the program *(M. Diaz, 2013)*. Figure 6 shows the relationship when teachers participate in the Pequeños Cientificos Program with the development of citizenship skills, promoted by the Ministry of Education (Ministry of National Education, 2004)

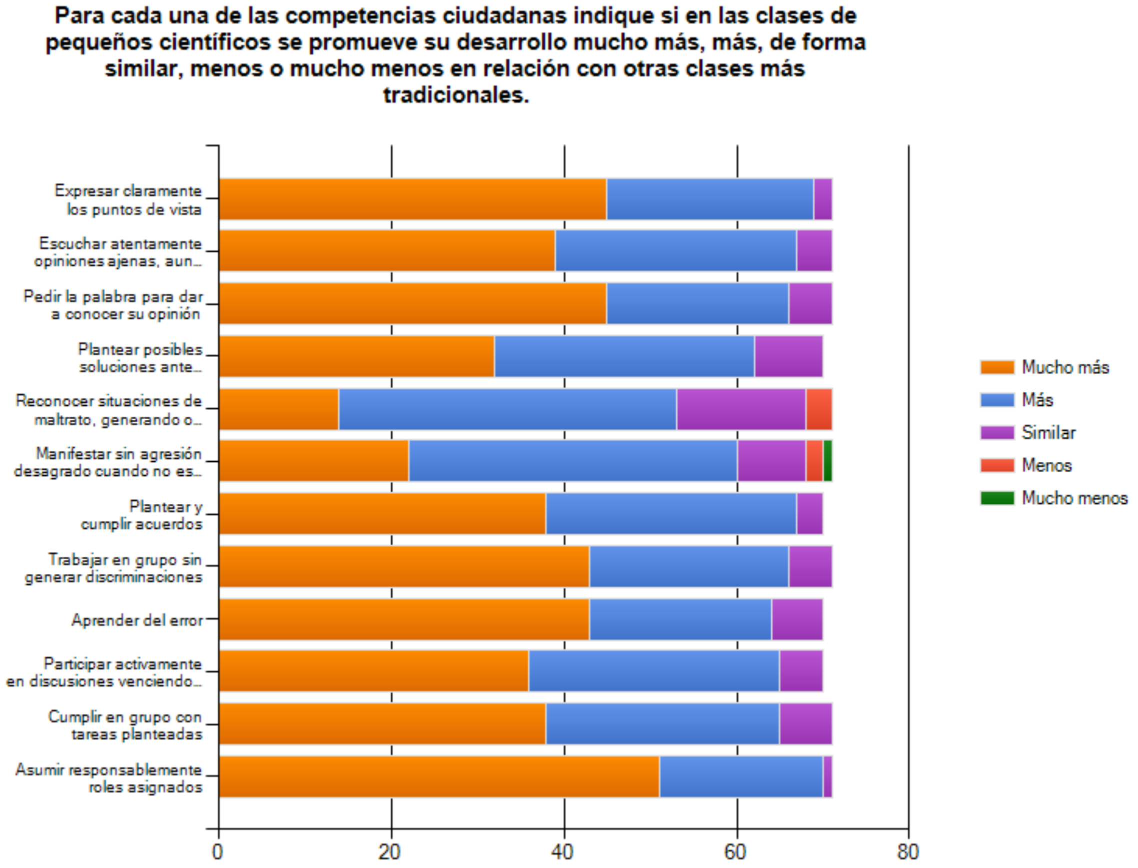


Figure 37: The program's contribution to the classroom atmosphere

Finally, these results show that other types of knowledge and skills are developed through these projects and this is also a consideration for the scale up. It is not only about results and standardized tests, the main focus of these projects is to build a better society through knowledge, and it is important not to lose focus.

8 Lessons learned from both programs

For the lessons learned for the experience in Colombia are now being applied and reviewed in the Dominican Republic, some of these lessons are important both for starting pilot projects and for the scale up of more structured programs.

The first lesson is that improving the quality of the education in STEM areas for all citizens needs a holistic program that addresses several parts of the system:

- Situated professional development of in service teachers focused on Pedagogical Content Knowledge, formative assessment, and classroom management
- Good educational materials and functional curriculum
- School infrastructure
- Better school organisation, in particular school director training
- An appropriated national STEM curriculum
- Improve initial education of teachers

In order to work in all these issues, the government's involvement is necessary. However, many of the weaknesses of the educational system are part of the different institutions of the government too. For this reason the involvement of the different stakeholders is important: families, universities, enterprises and private foundations.

In this context, programs like Pequeños Cientificos in Colombia or in the Dominican Republic don't have the possibility to directly transform the quality of the educational systems because they impact only a few schools, teachers and students. In fact, when the support program is completed, over the years teachers and directors are changed and the improvements disappear because new teachers that arrive don't have the proper training.

Those programs are in fact a laboratory that allows understanding what has to be done. This expertise has to be translated into public national programs including changes in national policy.

The new agreement between the universities and the Minister of Education to propose an updated national curriculum, good educational materials, professional development for in-service teachers, new policies for the accreditation of initial teacher education, and program evaluation is an example of the actions that could be carried out.

This kind of action has a major obstacle: government political changes that often interrupt big efforts to improve quality. We expect that the agreement between the country's best universities and the government could reduce the risk of lack of continuity.

9 Prospects

The issue of STEM education for all is slowly gaining momentum in Latin American countries *(M. Duque and J. Celis, 2012 ; PCAST, 2012)*. While the Pequeños Cientificos Program is one of the first of its kind in Latin America, possibly anticipating a Mexico program, currently an important part of the Latin American countries have projects of inquiry based learning for science and technology. Unfortunately, few countries have an initiative that seamlessly incorporates mathematics, as is now being addressed in the proposal under the Pequeños Cientificos program, which since 2013, is developing its first math pilot in elementary school.

The Pequeños Cientificos Program hopes to consolidate its proposal for STEM 2015 with the assistance of several research teams around the world, as it did to the initial proposal in science and technology, which had the support of at least 8 countries.

As part of the cooperation program between Colombia and the Dominican Republic it is fast becoming an inter-agency work, INTEC-UNIANDES in order to unite skills and experiences to support the process of improving education in both countries through the development of pilot projects, of strategies for the continuous training of teachers, and educational materials to support the transformation of the education systems of these countries under STEM.

This strategic partnership involves experts and research centers in other countries like PREST in Canada, and La Main à la Pâte in France in collaboration with experts from the US, Brazil, Panama and Argentina.

Acknowledgements

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All Together Now:
Project Learning, Tutor Training, Open Learning Objectives and their Evaluation in a Programming Course

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Abstract

Tis paper summarized the effects of introducing PBL ideas to our programming course in our Software Engineering program. We use a project, we use student groups, we use open learning goals and give the students as much responsibility for their learning as possible. Since the participants have widely varying prior knowledge, we support individual learning. The teacher and tutors are especially trained in Carl Rogers' principles of student-centered, respectful, encouraging interactions for discussions. Those discussions are also formative feedback on the team's work progress.

In midterm student write graded peer reviews based on an agreed set of quality requirements of the work in progress. This gives them the chance to stand back from their own current problems and look at the work of another team. Here also, respect encouragement and helpful advice is crucial. When returning to the own project, this reflection often helps to take a fresh look at the own projects.

The project requires many layers of professional learning goals. Besides the application of higher programming skills the teams are introduced to some helpful tools, general software engineering skills as well as personal and social skills helping them with problems and project decisions along the way.

An oral assessment for each team in the end evaluates their individual and team performance. Some learning goals can be used for normative grading. The oral assessment is also a place for individual feedback on the students' progress during the project. We are very happy that almost all of those who actively attend the course, pass with considerable skills and impressing individual gain.

Keywords: PBL, project, programming, software-engineering, drop-outs, oral assessment

1 Motivation

Our study of Software Engineering was founded in 1996. It is a computer science study with a strong focus on engineering issues. Software engineering techniques and principles are taught from the first semester on and cover a wide range of topics and courses. We teach programming skills in combination with relevant software engineering issues. Engineering calls for complex and practical projects, therefore we stress project work in many courses. We use project work since more than 15 years, and this special version with oral assessment since 2008. The special training of tutors is a project since 2012.

This paragraph describes the main issues of project-based learning and why we find it suitable for our situation in programming courses for undergraduates.

Project-Based Learning

Problem-Based Learning and Project-Based Learning have been around in various forms since the 1950s, and many educators agree to the basic concepts. Project-Based Learning, as performed in Alborg, Denmark, is our most influential example [Kolmos & Holgaard 2007].

The idea behind this is compelling: it gives the student the responsibility for the learning outcome. The student decides about the project's level, its complexity, about time and space when and where to do the work.

[Schmidt & Moust 2000] found evidence that PBL increases motivation. They observed small teams and had good results with PBL. We all observe, unmotivated students might successfully pass a final exam, but then tend to avoid the subject in their later studies and work life. Emotion plays a key role here, and positive feelings have an impact on learning [Delaney & Mitchell 2002].

Coupling learning with a project motivates most students much better than any lecture. The project as a "real" result, can be shown and tested, can be compared to other solutions. It resembles the work situation of all those students who will work in a real company. Even pure research can be organized as a project.

The facilitator's role is different from a traditional teacher. The noble task is to help students organize their time, ask the right questions, take time to reflect [Cowan 2006]. We have many reasons to love this approach:

- We observe that learning actually happens when we ask and explore, when we work on a problem. Many interesting learning situations do not come from an educational background, but from "the rest of our life". Those very rarely use lectures and passive reception of material. We have some small short lectures with the whole class, and many individual group discussions.
- Secondly, traditional teaching and learning has not been successful with many of our students. In school, they learn to reproduce ready knowledge in teachers' excerpts, but in university this is not enough: they should be able to think out of the box, to explore more than is written in a textbook.
- We also decided to train our tutors in a special way in order to create a friendly and open learning atmosphere. Finally, we evaluate what we expect the students to do throughout the project: the project results, the individual contributions and individual progress of students, as well as some of the team processes. Chapter 3 will describe this in detail.

1.1 Restrictions to PBL at a German University of Applied Science

After learning about curriculum design and organization of the ideal PBL courses in 2007 we came back to our real situation. Our university has no suitable group rooms. The semester's schedule fragments the weeks into small blocks covering all subjects of the semester. Those courses take place in various classrooms, so students and teachers settle for a 90 minute lecture in some classroom, then switch to a different classroom for another 90 minutes lecture on a different topic. Many teachers prefer this traditional way of giving lectures, so there was no chance to really change the time situation — not to speak of the space situation with huge classrooms.

In 2000 our department of software engineering agreed to install a special project week at the 10th week of each semester. The usual schedule is replaced by a single topic that spreads across the project week.

The European Bolongna declaration [Bolongna 1999] shifts the teaching focus to the learners and defines learning objectives and how those goals can be measured. The goal "Understand chapter 7 in a certain book" is hard to prove. A more descriptive goal says what a student can do after the course. A project is therefore a good starting point of evaluating these abilities.

1.2 Our Problem: Wide Variety of Students' Abilities

PBL works wonderful with learners that understand the importance of questions, reflection and doubt [Cowan 2006]. In reality our students often tend to jump to any solution in order to gain some ground. To many, asking a question seems to reveal their weakness and is a waste of time. They want to meet the teacher's expectations as quickly and perfectly as possible. So, if at all, they ask the wrong questions like "*How many pages shall we write?", "How many classes should this Java program have?"*

The course "Programming for Undergraduates" runs for a whole year and has — as in any other university — really dramatic drop-out rates of 40% to 60% [Benz & Jaeger 2008, 2009], [Delaney & Mitchell 2002]. Although all students want to be able to program, their performance varies widely. In Heilbronn we need a "non-school" situation to motivate those first year students with lesser competencies, since their prior learning experience was not suitable and should not be repeated. We found that they responded well when confronted with a real life project. They worked literally day and night [Benz & Jaeger 2009], [Jaeger & Rosenauer 2013].

On the other hand, approximately 10% to 20% of our freshmen are high performers and need a challenge to really learn something new. We have to cover this wide variety of abilities, which forbids a pure lecture situation, and again calls for project work.

2 Implement the Project Week

Our project week takes place at the 10th week in the second semester. Before that the class has been taught by short lectures and elaborate training hours, supported by tutors. Typically, our tutors come from the previous year, which is a sign that they liked the experience and want to share it with the next generation.

Performance before the Project Week

We have 60 to 80 students in this course. Usually only 50 to 60 Students really participate in the lectures and training hours. Those we call our active students, the others just enroll, never show up or drop out after one or two weeks.

Before the week starts, we have two tests about the actual knowledge. One is a small written exam, the other is a live programming task. Our active students perform as follows:

Table 1: Performance before project week 1:

Performance	Student rate
Very good (80-90%)	20%
Moderate (50-70 %)	20%
Weak (under 50%)	60%

Team Organization

In order to give them as much responsibility for their work, teams form themselves. They also chose a project within a given framework. We discuss the project idea and decide whether it is too thin or too challenging for that group. The group however, decides in the end about the complexity. We accept a modest project idea and will encourage some bonus extensions later on, if possible. We suggest teams of 3 to 4 members.

Project Framework: Basics and Optional Bonus Extensions

The teams invent a game and implement it within the Greenfoot framework for simple visualization of actors in a world [Kölling 2009]. This framework is well suited for (graphically) simple games, as well as simulations.

In order to have some means of comparison between projects, there is always a generic task for the whole class. For example, in 2015 we suggest a simulation of producer/consumer situations like elevators, assembly lines, self service cafeterias etc. Another example is the domino-like game we did in 2013 for instance. We suggested games that were variations of Domino, where players place tokens with values and properties (like Carcassonne™), the world is a grid of positions (and maybe values attached like in Scrabble™). Within these boundaries teams were free to invent new games. It was not allowed to re-implement existing games.

The basic project task is to implement the game mechanics for 2 to 4 players. The world itself, tokens, properties, values, and players are described in XML files, whereas the code itself should be as generic as possible. We want the code to be robust against changes to the size of the world, to the number of players, and some other properties of the game. Ideally, the XML data can be manipulated for special test situations, while the code never changes.

Also we encouraged the use of design patterns [Gamma et al 1999] like observer, singleton, state machine and others. Those we bonus extensions which result in a more complex solution than the simple basic game.

Week Organization

In the mornings, we offer short optional lectures on selected technical topics and bonus tasks.

The week has a structure of milestones. In the middle of the week, teams perform peer reviews for other teams. That helps to step back from the own code and take a look at the work of others. Typically, they see all the major problems there and suggest good solutions, but their own implementations suffer from the same flaws.

Teams are encouraged to work in the classrooms. For questions and help, a group of tutors with a special training (see 2.4) is available all the time.

At the end of the week, the teams present the current state of their project. We make clear that it is crucial to have a version that really works, that the version should be fully documented and understood by all members of the team.

Tutor Training

Most of our tutors have experienced the course in the year before, so they remember what it feels to be a learner in this environment. We train them for two afternoons about being authentic, constructive, respectful and friendly. The basic theory stems from [Rogers 1969]. Many questions and problems are a mixture of several layers. On top, students ask technical questions. But underneath they have a problem with some tool, some basic concept, with the team, with their own learning methods, with health, money, friends and family.

Our tutors are no social workers, but they should know that often there is no simple answer to questions and problems. They respectfully try to sort out the real knot behind a question. We train them to not give a quick answer but to ask back, so that a kind of discussion starts about code variations, small steps to find the error in thinking, and hints at helpful information or methods. Gradually, our students experience that this kind of working together helps them to help themselves, to be more responsible and independent. After a while they see that this is a friendly environment where questions are rewarded by useful help, and they trust our process. Class becomes more cheerful and open.

Learning Objectives

During preparation of the project week and the week itself we openly discuss and prepare the learning objectives and criteria of evaluation. Students are aware of what we expect from them. The most important learning objectives for our active students are:

1. Students can ask for help and discuss various ways of solving complex problems.
2. Since team members have inhomogeneous prior knowledge, a team can decide what helps all members to learn and perform.
3. In critical situations within a team, the tutors might see the problem, and the team is able to ask for help with the problem. For example, some teams suffer from master programmers who do not share their work with others. Or a team member is so badly prepared that she/he cannot contribute any substantial work.
4. Students can decide as a team, if and which bonus extensions (see 2.3) can be implemented in the given time. They also know how the chosen level will be graded.
5. Students can integrate the above mentioned new extensions into their game implementation.
6. Students write generic and robust code and test it with various situations described by the XML data.
7. Students analyze code of a different team and write friendly feedback with helpful suggestions.

Some of the learning objectives can be evaluated and graded, this applies to goals 4 to 7. The others will influence the technical performance but cannot easily be measured. Teamwork or, even simpler, the individual progress can be observed, should be discussed, but that will be formative feedback. During the project week, teacher and tutors observe and comment on all effects that are positive and carefully ask if any help is needed with more problematic things.

3 Assessment Sessions

During the semester, and especially the project week, all requirements and learning goals are discussed openly. The peer review uses a subset of our evaluation criteria, so the students know exactly what we will address at the assessment.

Assessment takes place in the week after the project week. Teams have a chance to finish their project at their chosen level. All team members attend the assessment, which takes about an hour. We start with discussing the current version of the project: look at the class structure, possible patterns, functionality and run some of the existing test scenarios. Then we slowly change the focus towards possible variations, extreme test situations and the most interesting or complex parts of the implementation. The teacher directs questions to individual members in order to get a more precise picture of their knowledge and contribution to the project.

Then the teams are sent out, after a short discussion among the assessing teachers (at least two) we tell them our impression about the project and the team members. At this point, the teams can contradict and explain their own conception of the work they have done. In our experience, this is always very fair. Teams and members openly admit their flaws and shortcomings or defend themselves in a plausible way. We then agree on a grading of both the team project and its bonus level, as well as individual grading of team members. At that point, some student might fail the project week, because the contribution (both quantity and quality) is not sufficient.

Normative feedback refers to the complexity of the project, its bonus tasks and functionality. All other aspects are only discussed. Students understand that we have to grade them in comparison with others. However, we often observe dramatic individual improvements of students with a very low starting point. They might have achieved only a moderate level of knowledge, but individually they made a huge step. We praise their progress and encourage them to move on from there.

Later in the coming semesters we find those students really loving the topics of programming and most of our tutors come from that group that gained the most ground.

4 Results

Student's Performance

Our course runs a whole year, therefore we have two teachers doing it in alternating semesters. They differ a lot in their teaching method, so we have an unintended "control group" that is taught in a traditional way: lectures, optional exercises and a series of written exams during the semester, but no project week. The two approaches differ slightly in the overall success rate. But when we look at the active students who partake in the PBL project week, our rate is encouraging. Unfortunately, there is no information about active/non active students in the traditional course.

We measure the success rate simply by the number of students who pass the course and its different tests or exams. Over the last 5 years the numbers stay within the range of table 2.

Table 2: Success rate of traditional vs. PBL course

	traditional	PBL
Success (all)	40 – 50%	50-60%
Success (active, ca. 70 – 80% of all)	unknown	80-90%

So, there is no significant difference between traditional and PBL teaching with all students, including no-shows and those who drop out early in the semester. However, the project week seems to be almost a guarantee of success.

If a student fails, it happens a long time before the project week. Most of those failures never attend the course, so we cannot say anything about their possible performance, motivation and situation. Almost all our active students pass the course. Very rarely a person fails the project in the end. In 2012 we had a whole team disqualified because of plagiarism, but something like that is the exception. Some single students drop out late, because their background is not solid enough and the team cannot help them with the oral assessment.

Reaction of Students

Feedback of Students is positive. Most students pass with the experience that they can do much more than they thought and showed in prior tests. They see themselves in a realistic light and understand the process they went through. This reflection is often new to them. They feel seen and respected and react well to it. Even in the oral assessment, they discuss their own and the performance of team members in a realistic and fair way. Students now have knowledge about the level of their own learning and understanding. This reflection helps them to concentrate on their weak spots and study more efficient on further courses.

5 Conclusion and Future Work

We will continue to work with PBL, because it attaches students to the topic, helps them to help themselves, and gives us a chance to adjust our teaching to their problems without lowering the expectations.

We will continue to train tutors on the basis of Carl Roger's learner-centered approach [Rogers 1969]. The tutors tell us, that this training helps them in everyday situations as well. It is a small compensation in exchange for their wonderful and underpaid work during class.

We should expand the project time. A week is very short. The weekly schedule reserves a whole day within a "normal" week to programming. We should start using this day more consequently for project work and lesser for lectures and exercises.

We found that students are very shy to explain themselves, use correct technical terms. We will start a new type of task for them, starting in the first semester: They have to explain concepts with text and suitable code examples. In 2014 we started to encourage the use of wikis in order to hyperlink concepts. It is too early to really evaluate this idea but a first report will be given in [Jaeger 2015].

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The Aalborg example – the visitors workshop at AAU

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Abstract

Problem-Based Learning (PBL) is an innovative method to organize the learning process in such a way that the students actively engage in finding answers by themselves. During the past 40 years PBL has evolved and diversified resulting in a multitude in variations in models and practices. However, the key principles remain the same everywhere. The University of Aalborg in Denmark started with PBL right from the start when the school was founded merging several educational institutes in Northern Denmark in 1974. The Aalborg PBL model is recognized around the world as an example or a source of inspiration, in particular in Engineering Education. In answer to the requests for visits the Aalborg Centre for Problem Based Learning in Engineering Science and Sustainability under the auspices of UNESCO (UCPBL) a two-day program for visitors is offered two times a year.

The workshop is an introduction workshop to the Aalborg PBL model and in general problem based and project based learning. We apply the principle of teach as you preach. This paper and the poster presented at the conference aim to outline the visitors workshop program showing the results of some recent evaluations.

1 Introduction

Around the world Problem-Based Learning (PBL) is known as a successful innovative educational method. The advantages of inspiring young people's learning by giving them practice-based assignments was recognized by several pedagogues in the early 20th century, like Jerome Bruner, John Dewey, Patrick and Maria Montessori. However, challenging the curiosity of the students was not common practice in higher education until the introduction of PBL at the medical curriculum of the university of McMaster in Canada at the end of the sixties (Woods, 1994; Schmidt & Moust, 2000; Graaff & Kolmos, 2007). During the past 40 years PBL has evolved and diversified resulting in a multitude in variations in models and practices (Kolmos, Graaff & Du, 2009; Savin-Baden, 2007). Graaff & Kolmos (2003) identify the main PBL principles as follows:

1. Problem orientation
2. Project organization through teams or group work
3. Participant-directed
4. Experiental learning
5. Activity-based learning
6. Interdisciplinary learning and
7. Exemplary practice.

Two main branches of PBL are the case based variety that started in medicine in McMaster and the project based type that originated in engineering (Kolmos and Graaff, 2014). The University of Aalborg in Denmark started with PBL right from the start when the school was founded merging several educational institutes in Northern Denmark in 1974. The Aalborg PBL model emulates engineering practice by letting students work together in small teams on authentic engineering problems. The project work comprises about half the curriculum time. The remainder is filled with courses helping students to build their knowledge base. The Aalborg mode is recognized around the world as an example or a source of inspiration, in particular in Engineering Education (Kolmos, Fink & Krogh, 2004).

In answer to frequent requests for visits the Aalborg Centre for Problem Based Learning in Engineering Science and Sustainability under the auspices of UNESCO (UCPBL) offers two times a year a two-day program for visitors. The section below outlines the setup of this workshop.

2 The Aalborg Visitors Workshop

People wanted to come to Aalborg to find inspiration in the PBL curriculum almost right from the start. In the beginning it depended mostly on the contact person that followed up on a request what kind of actions would follow. The ad hoc character of these visits turned out to be quite a strain for the Aalborg staff. Also the conditions of the visit would vary greatly, resulting in inequality for the respective visitors. Since the establishment of the UNESCO chair for PBL in 2008 the UCPBL has endeavoured to regulate the visitor-workshop.

Visitors come to Aalborg from diverse backgrounds and with different objectives. Some are educational leaders who want to introduce PBL in their own school; some are teachers who would like to experiment in their own classroom; some are researchers interested in finding out what makes PBL work. The visitors-workshop aims to cater for all these different wishes. Originally the programme consisted of a series of presentations by a number of local PBL experts and an excursion to the campus allowing visitors to meet students and teachers. In particular this last part was always highly appreciated by the visitors. Some commented on the presentations that they would have preferred a more PBL-like approach.

In 2013 the programme of the Aalborg visitors-workshop was renewed. This workshop is an introduction workshop to the Aalborg PBL model and in general problem based and project based learning. In table 1 below the outline of this new programme is presented. This programme retains the good elements of the old one adding a practice exercise in project work. Also the presentations are interactive with a lot of room for active participation, so you might say the new programme follows the principle of ‘teach as you preach’.

Table 1.: Programme for introduction and visitor workshop on Problem Based and Project Based Learning

Learning outcomes:

- participants to gain a knowledge of PBL as a system and the various elements in the system: problems, projects, courses, learning objectives, assessment, students process skills (PBL-skills), content,
- participants to address critical issues such as: students’ “gap” of knowledge and skills, cooperation among teachers, authority, learning
- participants to develop a dynamic to do list for utilising PBL principles

Day 1

09.00: Welcome by the head of UNESCO Chair
09.30: Introduction PBL
  - Definitions of PBL
  - PBL models and learning principles
  - The Aalborg Model

10.30: Project Work and teaching skills
12.00: Lunch
13.00: Case studies
14.00 PBL and first year programme
14:30: PBL courses for students and Question session with students
16.30: End of the day

Day 2

09.00: Visit to departments at the campus
12.00: Lunch
13.00: Assessment of study results in a PBL curriculum
14.00: Question session & issues not covered
15.00 Summing up and evaluation
15.30 End of day

3 Participant Experiences

The composition of the group has a big impact on the experience of the participants. In this case we will explore the evaluation results of the visitors workshop that took place in the spring of 2015 on March 12-13. Originally 14 participants signed up for this course – one less than the maximum of 15. Eighth participants came from a school in Kuwait that introduced PBL a few year back, the other six individuals came from various European countries. Just over a week before the start of workshop we got a request to add a group of eight participants from a school in Poland. This group was already in Aalborg for other purposes and they could join only on the first day. After some deliberations it was decided to accept this extra group of participants, resulting in a number of 22 participants for the first day and 14 of the second day. Since the evaluation usually takes place on day 2 we only have evaluation results for the original 14 participants that stayed on for two days. The results of the questionnaire that was filled in at the end are displayed in table 2 (see below). Besides the pre structured questionnaire items we also have open comments that were written down on the questionnaire forms and oral comments that were made during the evaluation session at the conclusion of the workshop.

Table 2.: Results Evaluation Visitors Workshop Spring 2015

Workshop logistics N = 14						
Please indicate your level of satisfaction (1=very dissatisfied / 5=very satisfied)	1	2	3	4	5	M
Information about the course was clear	1	2	4	5	2	3.36
Information about the course was in time		2	2	4	6	4.00
Relevance of PBL materials to teaching and learning in your University		2	3	5	4	3.64
Relevance of workshop material to your general academic profile	1	2	3	6	2	3.42
Workload of the workshop *(1=too much / 3= satisfied / 5= too little*		1	7	4	2	3.50
Presentations						
Relevance of the programme to your University's teaching and learning		4	4	5	1	3.21
Relevance of the programme to your general academic profile	1	3	5	3	2	3.14
The level of active involvement during the presentations		3	5	5	1	3.28

The averages in the table show a general level of positive appreciation for the workshop above the middle point of the scale. Actually, it is not allowed to calculate means on a Liker type scale. However, it can be used to compare answers to different questions. A closer look at the distribution of the answers reveals that the majority of the participants were positive, rating a 4 or a 5 on most items. However, on each item there are also three or four participants indicating they are not completely satisfied. During the session this was explained. A few participants told they had expected more expertise on PBL. It turned out these participants already worked with PBL themselves for several years.

The discussion and the written explanations on the questionnaire forms made clear there was still a high appreciation for the campus visit and contact with the students. Also, project work assignment on the first day had been valued. However, due to the large number of participants some felt there had not been enough time for this exercise. In particular it had not been possible to give everyone feedback on individual performance. With respect to the presentations there were marked differences depending on the presenters. Apparently we did not succeed sufficiently in creating an atmosphere of active involvement in all presentations. One comment actually talked about 'death by PowerPoint' with respect to one of the presentations. Yet the over-all evaluation remained positive on nearly all accounts, providing us with a number of valuable suggestions for improvement.

4 Conclusions and Discussion

The comments on the visitor workshop presented above most certainly give us cause for serious consideration. First of all is seems clear that adding the extra participants at the last moment was a mistake. Even if the programme could be run completely according to plan there was less individual attention for each participant. The effect was possibly intensified because big groups tend to stick together. On the first day there were Two groups of eight participants each one pair and four individual participants. Among them were the less satisfied persons.

Besides the complaints about the size of the group there were comments with respect to the presentations. In some cases there seems to have been some overlap and the timeliness could have been improved. In particular one of the presentations appears to have used too many slides. These comments will be dealt with at a practical level.

The comment that the workshop did not meet the expected level of sophistication with respect to PBL is more difficult to deal with. When it was put forward during the session it became clear that not all participants shared this view. Most participants had come to Aalborg to get inspiration and to talk to the local Aalborg experts. Their expectations did not exceed a basic introduction. In fact it was just a small number of participants who already had extensible PBL experience that had hoped to acquire more advanced insights in the PBL process. Although everyone recognized that this might be at odds with the other participants' need for basic information, it is important to recognize that there is need for more advanced training on PBL.

The general visitors-workshop is probably not the right place to expand to this level. Instead we could expand the programme offering a series of advanced PBL workshops (see table 3). These workshops could be offered once a year in Aalborg. The advanced workshop programme can also serve as a catalogue for selecting workshops to be offered in the client's home base as part of a consultancy contract.

Table 3.: Proposed Programme of Advanced PBL workshops

A1 - The role of the teacher in PBL as facilitator of the learning process
  - Facilitator skills and stimulation of self-directed learning

A2 - Case writing and project construction
  - Creating a challenging learning environment

A3 - Assessment in a PBL curriculum
  - Highlighting different assessment methods including the project exam

A4 – Curriculum development
  - Design of a PBL curriculum; Alignment of core elements

A5 - Management of Change
  - Engaging and motivating staff; organisation of the change process

A6 - Research on PBL

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Structuring team projects to improve confidence and commitment in engineering

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Extended Abstract

Team-based design projects are a popular form of active learning in engineering education, situating students in a holistic engineering experience and encouraging development of technical and professional skills. Collaborating on authentic engineering tasks challenges students, ideally increasing their interest in the field, motivation to learn and drive to complete an engineering degree. However, team projects are not always beneficial to students: a negative (or even neutral) project experience may result in students becoming less committed to an engineering degree or less confident in their ability to succeed in engineering. Low self-confidence is a major contributor to leaving engineering programs, especially for underrepresented groups (Seymour & Hewitt, 2000). We hypothesize that students may benefit less from project experiences when they spend less time on discipline-specific tasks (generally technical, rather than professional, activities), and thus do not have the opportunity to develop their skills and confidence in engineering. This may result in a reduced commitment to engineering or a diminished belief that they can complete their degree.

This poster presents a research study investigating students completing a hands-on, team-based engineering design course at a range of institutions and the relationship between the tasks that they complete and the subsequent change in their commitment to and confidence in completing an engineering degree. In particular, we are interested in both the types of tasks that students do and the proportion of time they devote to these tasks. We used a mixed-methods approach to data collection and analysis, using SigmaPlot (v13, Systat Software Inc.) for statistical analysis. We used a concurrent triangulation study design, meaning the results from analysing the quantitative and qualitative data simultaneously informed our research directions. We assessed student commitment to and confidence in completing an engineering degree with a pre- and post-course survey, which also asks questions related to demographics, personality (Gosling, Rentfrow, & Swann, 2003), academic self-confidence (Chachra & Kilgore, 2009), and tinkering and engineering self-efficacy (Baker, Krause, & Purzer, 2008). Students completed weekly activity logs, to track which project tasks they were engaged in and how much time they devoted to each activity. At the end of the course, students participated in individual semi-structured interviews, in which they were asked questions about their engagement in the project, the team experience, factors that may have affected their self-efficacy, and their decisions around and perceptions of engineering.

Our preliminary work has focused on two groups of students: one group in a small private engineering college and one group pooled from several large public universities. Contrary to our hypothesis, we found that a positive change in student confidence in completing their degree correlated to spending *less* time on hands-on tasks (at the small engineering college) or on engineering tasks (at the large public universities). However, in the large public universities, increased commitment to completing an engineering degree correlated to spending more time on research tasks. These preliminary findings suggest that the interaction between the tasks students engage in, the development of self-efficacy, and student confidence in and commitment to completing their engineering degree interact in complex ways. Analysis of qualitative data,

currently in progress, will be used to further investigate elements of student experiences that contributed to their interest, motivation and persistence in completing an engineering degree, with the goal of developing recommendations on how instructors can design and structure team-based engineering project courses to ensure that all students have the opportunity to complete tasks that align with their learning and professional goals. We anticipate that this will both improve the active learning experiences of students and increase their confidence in and commitment to engineering.

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An active methodology involving Engineering students in Mathematics lab practice skills apprenticeship

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Abstract

The materialization of the Bologna process has brought out the European Credit Transfer and Accumulation System (ECTS) as a standard for comparing the study attainment and performance of students of higher education across the European Union. Each ECTS is equivalent to 25–30 hours of study and this study may be carried out before, during and after each class. From this academic load just one third corresponds to contact hours in engineering studies at the Technical University of Valencia. The authors have developed an active methodology in Mathematics lab practice classes for Aerospace Engineering students that provide activities to be developed by them before each lab session as part of their apprenticeship.

In this way the lab classes for Mathematics I in Aerospace Engineering degree have undergone many methodological and assessment changes. The process of change that we have made is based on the following guidelines: a) the student must work outside of class more time, and less in the classroom; b) the teacher should synchronize with the theory, the activities that the students have to perform autonomously and independently; c) the teacher should organize the assessment of such activities.

The methodological framework is based on the use of a learning platform, in our case, PoliformaT developed at UPV based on the Sakai project. The course consists of 28 classroom sessions of laboratory practice which are related to the contents of the Theory/Problems (TP) sessions. The authors have adapted the content and sequencing of laboratory sessions in order to make the Bologna adaptation process as efficient as possible. Lab classes are structured so that they are closely related to the contents of the TP sessions and concepts and procedures learned in lab sessions cease from being simple calculus applications.

1 Introduction

Technical University of Valencia (Universitat Politècnica de València, UPV) is one of the four Spanish universities focused on science and technology. Though relatively young with less than 50 years of existence some of its schools, like the Design Engineering Higher Technical School, were born more than 100 years ago, where BEng Aerospace Engineering is one of the degrees delivered.

UPV has always encouraged the upcoming of the new technologies and this promotion found its match with the new ECTS structure that provided the setting to the fact that students should get more involved in their learning. This structure had into account the total amount of time dedicated by the students and at the same time a new more active role of the student was to be encouraged (Sánchez Ruiz *et al.*, 2012).

Mathematics is one of the most basic subjects in all engineering studies and it is very important that all students achieve basic competencies and skills in every aspect that later on they will need to use and develop. One of them is the proper use of mathematical software and due to the special skills to be achieved and their posterior needs, this a place where active performance is at the same time natural and a need.

In order to develop this natural and necessary work the authors are taking advantage of the possibilities of a very powerful mathematical software such as MATHEMATICA and an educational platform developed by

UPV, and known as PoliformaT, which is based upon the Sakai project (Sánchez Ruiz & Moraño, 2010) and includes several tools like document distribution, live chat, assignment uploads and online testing among others. This platform is available for all UPV instructors and students.

We will focus on Mathematics I (Design Engineering Higher Technical School of UPV, 2014) which is an annual compulsory subject delivered in the first year of BEng Aerospace Engineering. From a total of 120 contact hours (12 ECTS), 75% corresponds to Theory/Problems (TP) sessions and the rest, 25%, to Lab practice (LP) sessions where each student works the subject with a computer.

Technological change was taken as an opportunity to try to improve and modernize the learning possibilities of students. We decided to do this adaptation just on LP sessions by trying to evaluate in each session the skills taught in TP sessions. Indeed LP sessions should be considered not only an irreplaceable compound in order to achieve computational competences but also a support to theoretical contents learning process.

The LP methodology used involves blended learning with flipped learning as its main compound which involves an active attitude while preparing the class as well as during the contact hours. The details of this methodology will be presented in this paper along the assessment used and results obtained.

2 Implantation

Rationale

The authors have developed this new method to carry out the Math Lab sessions that students must take to keep them active and awake interest in the theoretical concepts facilitating its understanding. In some cases our methodology might minimize the loss of interest and the number of dropouts keeping the student as active as possible throughout the course, which is not the case in Aerospace Engineering as this kind of student in Spain is usually highly motivated.

Performing complex scientific and technological tasks involve that the concepts and processes that should be learnt require understanding, reflection and structuring of ideas whereas this is not required if the performance of the tasks is just seen how others perform it. In this sense, we considered that the students improve their learning if the tasks that they should do are performed by themselves instead of seeing how they are done.

In order to attain this goal every Lab session of last academic years has been adapted to a system based on a flipped classroom methodology (Bergmann *et al.*, 2013 and Hughes, 2012). Herein the students are requested to prepare adequately each Lab session before coming to class, thus avoiding the need to give classroom time to explain and perform easy examples that can be self-learnt.

This brings out a double effect, firstly preventing a possible lack of interest from students and on another hand enabling them to achieve a faster and more natural acquisition of specific math skills that the course offers. This methodology aims to increase the motivation and improve the perception of the Mathematics subject by engineering freshmen, helping them to understand the main topics.

Changes

The course consists of 28 weekly LP sessions and two exams, one in each semester. The first LP session is purely introductory and dedicated to reporting on the installation and basic use of both the educational platform PoliformaT and the scientific MATHEMATICA software. The remaining sessions follow a linked structure to TP sessions. In order to maintain this relationship, each of the sessions has been prepared with a division into three phases: the first one is dedicated to the preparation of the session based on the flipped learning methodology (Toto & Nguyen, 2009; Demetry, 2010), the second phase is reserved to clarify doubts and the third one to do some exercises to assess the skills related to that session.

The first part is performed by the student at home or in classrooms with free-access to computers where the teacher is not supporting him/her. For this preparation to be adequate and fully realized, the material provided by the instructor must contain everything that the student might need avoiding any problems in his/her autonomous work. The material in each practice is usually a pdf document and sometimes links to explanatory videos and virtual labs. This material is available to all students by means of PoliformaT. In this material, the first thing that students find is the link to the corresponding TP sessions and whose revision is recommended before continuing. After reviewing theoretical concepts, the commands that are useful in this unit, its structure, usefulness and possible options are presented and explained. This presentation is reinforced by performing some examples applying these commands enabling students to achieve the learning of the related skills. Finally, within this material, a series of exercises whose resolution requires the application of theoretical knowledge and the commands learnt are proposed. Commands, worked examples and proposed exercises are compiled into a textbook with the lab practices (Moraño & Sánchez Ruiz, 2012).

The second phase of each session can be considered as a form of collaborative learning (Beck & Chizhik, 2013). This part is done at class with the instructor, approximately during the first half of the class and it is dedicated to answering questions, examples and exercises that students propose where they have found some difficulty during the first phase. In addition, the instructor should explain some elements that he/she considers important for a more comprehensive learning.

Finally, the third phase is carried out at the end of the class. Using the educational platform, several exercises related to the skills and commands treated during the previous two phases are proposed. Students perform these exercises in class, individually but the teacher helps them with a suitable supervision/assistance. With these exercises, we search having an overview of the degree of acquisition of the mathematical competencies in the three phases.

Complications/Adversities

Apart from the good results obtained, some complications have appeared during the process and they should be reduced or avoided. For example, some freshmen feel mentally blocked when confronted with so many new developments, since they have to adapt to different working methods and technologies at the university at a dizzying pace. They have grown up surrounded with up-to-date technology and they are able to feel comfortable with it very quickly. However, it seems reasonable to devote the first 2 or 3 sessions to introduce the student to the new methodology and working environment. In these introductory sessions the students learn about the scientific software, educational platform and, specifically and thoroughly, the new working system, since this methodology consisting in the preparation of the classes in advance is uncommon in pre-university courses and they are not used to it.

Another complication that sometimes has been detected is when a student has not properly prepared the class in advance. If this is a punctual situation it may be sufficient to remind the student that his/her work during the session is going to be affected significantly. But if this situation becomes more general among the students, we might implement a new different strategy such as fulfilling a test before each session with some questions randomly drawn from a battery with the same level of difficulty as the examples found in the worked instructions.

Also, we have had to give solutions to certain problems that have arisen in the implementation process, such as 'What to do when a student does not attend a session?', 'Is it possible to prevent the results of the test to be shared by the students?' For the first question, in our case attendance to lab sessions is compulsory. Thus if there is no major reason for absence, the student misses the scores that were to be earned at the session. If absence is justified the student should work by himself, receive some aid if needed but he is not allowed to earn any score from the missed session but that session is not accounted in the number of sessions when grades are calculated. Related to the second question we have planned to use batteries of similar but not identical questions to evaluate the same target skills. This solution prevents not only the copy of the results between students but also avoids the advantage of knowing the responses from previous years.

3 Achievements

Results

The first consequence of the application of this system of weekly work has been achieving a massive participation in laboratory classes: 93% of students attend all LP sessions (97% if dropouts are not considered). Another useful effect of getting as much information on their performance is that they can detect very specifically the skills that have not been acquired and therefore act on them. Furthermore, students show great interest in maintaining the process of learning mathematics active throughout the course.

Although the performance of this methodology has just been developed in LP sessions, its effects have had great influence on the results of TP, in our opinion mainly due to the constant review of concepts that students must carry out during the preparation of LP sessions.

The total number of students of Mathematics I in the degree of BEng Aerospace Engineering was 126 during 2013/14, a value that serves as a reference for the relative values and percentages. However 5 out of 126 had got a maximum of two attendances, so they should be considered as if they had abandoned the course.

- 6 (4.7%) students did not take the LP exam almost matching the students with non-attendance at LP sessions. If we do not consider these 5 students, the percentage drops to 0.8%.
- 11 (8.7%) students did not take the TP tests which correspond to 4.7% of students not considering the 5 dropouts.
- The average grades obtained in the three TP tests were 6.1, 6.6 and 6.9, with standard deviations of 2.4, 2.6 and 2.1, respectively.
- The averages obtained in the two LP tests were 5.6 and 7.6 with deviations of 2.0 and 2.4.
- The average on the last 27 weekly sessions of PL was 8.7 with a deviation of 1.7.
- 112 (88.9%) students passed the subject, a 92.6% of students without accounting the 5 dropouts.

If we compare the difference of each student's average score in LP exams with the average in TP test scores we obtain the graph shown in Figure 1.

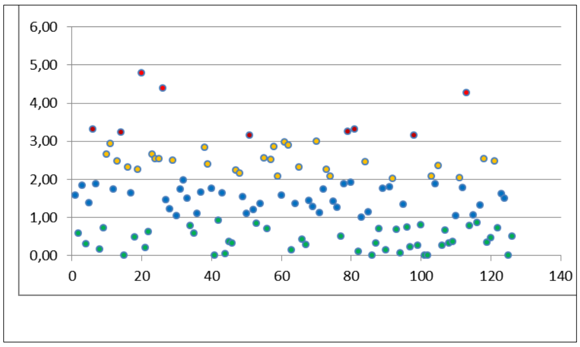

Figure 38: Dispersion of Theory/Problem and Lab practice grades

About 70% of the data differs by less than two points and in Figure 1 we can see the dispersion of the difference between TP scores and LP scores: almost all (92%) the differences are less than 3 points, 1.49 being the average of deviations. We think that the methodology used in LP has influenced the realization of a continuous work by students and almost constant feedback, keeping daily motivation and improving the skills of students.

We can see that there is a significant difference between the scores of weekly LP (WLP) sessions and the scores of both TP and LP exams (see Figure 2) but this result has a possible explanation in the fact that during lab sessions students work under the supervision, guidance and assistance of the instructor.

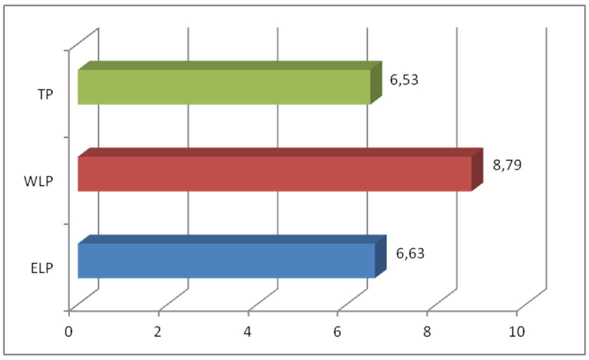

Figure 39: Averages of TP exams (green), WLP sessions (red) and LP exams

Students Perception

When the course was ending we gathered feedback from students about this methodology. We used for this task a tool from our platform, 'Polls'. This tool allows us make questions to students that they respond in an anonymous way. The issues raised try to collect the acceptance of students on the new methodology and its possible extension to TP sessions. In the following tables we can compare them.

The first two questions are concerned with the organization of the lab sessions itself. The questionnaire and opinions collected are shown in Table 1.

Table 1: Perception on laboratory practice in general

Do you think that the number of practices undertaken is adequate to learn the content of the subject?	
Yes	85%
There should be more	7%
There should be less	7%

Do you think the assessment of laboratory practice in each session fits to the content developed in class?	
Much	29%
Enough	58%
Little	13%

Clearly the vast majority of students thought that practices that had been done were very consistent within the course.

A second block of questions searched for the opinion of students about the benefits of using the platform in the laboratory practice sessions (Table 2).

Table 2: About the use of PoliformaT in lab practice

Using PoliformaT in the laboratory practices:	
Makes easier to learn contents of the subject	84%
Makes more difficult to learn the contents	2%

I think that being evaluated at the end of each lab session through Poliformat is good for my learning:	
Yes, it’s good	76%
No, it is not good	5%

Makes no difference in learning the contents	14%

I don’t know	18%

According to the results the students do not have a negative perspective towards the use of the platform (2-7% think it may be more difficult using it and just 5-11% do not like being evaluated at the end of each session).

The following question intends to seek the perception of the students on a possible transfer of this evaluation method to Theory-Problem classes (Table 3).

Table 3: Students opinion on transferring the method to TP

Do you think it would be a good option that sessions of TP carried out with a PoliformaT test during a day each week?	
Yes, it would be good	54%
No, it would not be a good idea	24%
I don’t know	22%

4 Conclusions

During the academic year 2013/2014 authors have changed the methodology of Lab classes in the subject Mathematics I in the first year of BEng Aerospace Engineering at Technical University of Valencia, UPV.

Our change is based on a flipped learning methodology also known as inverse classroom. This adaptation has forced us to design and generate lots of materials for the preparation of sessions (Phase 1) to be properly performed. We also have had to prepare and develop materials for the classes above with a number of evaluation questions.

The use of an educational platform, in our case PoliformaT, has been essential to follow this methodology since the distribution of materials, the evaluation of the sessions, many communications and the consultation of results are performed through it.

Another advantage observed is the high degree of follow-up that there is on the learning process for each student, allowing to propose adequate measures to correct deficiencies in the learning process faster and more efficiently.

As far as the results are concerned, it is very remarkable the low number of dropouts and the motivation of students to develop their learning in a continuous way. Good results also suggest that the methodology is adequate but some adjustments and improvements are always possible. Students have also shown a high level of acceptance of the system used.

Acknowledgments

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Encouraging active learning and creativity within STEM topics

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Abstract

Throughout the European Higher Education Area a number of common instruments have been developed within the Bologna Process to help in the process of transformation towards more student-centered systems. Between these instruments we find the common use of ECTS, the issuing of the Diploma Supplement and National Qualifications Frameworks. While the use of these instruments continues to grow and develop, usage is not always systematic, and a number of features are to be developed to move towards a learning outcomes orientation, focusing on what the student is expected to know, understand and be able to do. This contrasts with the traditional input-oriented approach to higher education focusing on the transmission of defined curriculum content. The shift towards a learning outcomes approach is really a major cultural transformation that is taking time to become fully implemented. As an attempt to tackle this issue the authors have developed an active methodology in Mathematics theoretical classes for Aerospace Engineering students that provide activities to be developed by them well in advance each theoretical and problem solving exam as part of their apprenticeship.

In this way the students have a chance to check and develop their competencies achievement by encouraging their deep understanding of the subject and having to face some exercises that encourage their engineering skill while learning basic and technical subjects such as Mathematics. Some of the questions have not got closed answer and are placed with this goal of making them struggle with challenging questions. These activities are not developed in a controlled environment and thus the students must perform some individual test at the time of delivery to check their full understanding of the processes developed at their activities. We will focus our approach to calculus comparing attitudes and skills in both groups of students.

1 Introduction

Technical University of Valencia (Universitat Politècnica de València, UPV) is a Spanish university focused on science and technology. It became a university in 1971, but some of its schools, like the Design Engineering Higher Technical School (Escuela Técnica Superior de Ingeniería del Diseño. ETSID), were born more than 100 years ago. BEng Aerospace Engineering is one of the degrees delivered at ETSID where the use of innovative teaching methods based on technology has been promoted from its outset. This promotion found its match with the new ECTS structure that provided the setting to the fact that students should get more involved in their learning since the academic load had into account the total amount of time dedicated by the students and at the same time a new more active role of the student was to be encouraged.

The main objective under Bologna Process is a shift of focus from teacher-driven provision to a student-centered learning (Croisier, 2007). Many efforts are being conducted at Higher Education in order to give to the students' point of view the role it demands in the digital and net society that we are living. They are not passive learners that watch the face-to-face master class anymore; they are active and fresh learners that arrive to our universities and classes asking for clues that allow them to create something new that can change their worlds.

This swift in perspective has introduced new teaching tools in our classrooms to trigger new learning goals: blended learning, active learning, collaborative learning, cooperative learning, problem-based learning, flipped learning, open learning, partnering learning, etc. among others. According to literature, all of them have very similar pedagogical focus: the university student learns on their own, alone or in groups, answers questions, solves problems (Prensky, 2004), and creates new questions helped by technological tools while following lecturer instructions. The difference among all of them is the roles played by the participants: teaching staff, student, stakeholder, digital media, curriculum and their peers.

Mathematics is one of the most basic subjects in all engineering studies and it is very important that all students achieve basic competencies and skills in every aspect that later on they will need to use and develop. One of them is the proper use of mathematical software and due to the special skills to be achieved and their posterior needs, this a place where active performance is at the same time natural and a need.

In order to develop this natural and necessary work the authors are taking advantage the possibilities of a very powerful mathematical software such as MATHEMATICA and an educational platform developed by UPV, and known as PoliformaT, which is based upon the Sakai project (Sakai, 2014) and includes several tools like document distribution, live chat, assignment uploads and online testing among others. This platform is available for all UPV instructors and students.

In Mathematics classes at Aerospace Engineering we encourage our students to an active learning approach that, as (Bonwell & Eison, 1991) states, leads to better student attitudes and improvements in student's thinking and writing, motivating students for further study and developing thinking skills.

We focus on Mathematics I which is an annual compulsory subject delivered in the first year at UPV (BEng Aerospace Engineering, 2014). From a total of 120 contact hours (12 ECTS), 75% corresponds to Theory/Problems (TP) sessions and the rest, 25%, to Lab practice (LP) sessions where every student works the subject with a computer.

The LP methodology used involves blended learning as flipped learning appears as its main component. In fact this involves an active attitude while preparing the class as well as during the contact hours. Perhaps the whole process might be done throughout all sessions but its full implementation means a large work for a single course. For this reason we decided to do this innovation just on LP sessions by trying to prepare and evaluate for each session at least one of the competences taught in TP sessions. Indeed LP sessions should be considered not only an irreplaceable compound in order to achieve computational competences but also a support to theoretical contents learning process.

In exchange we have tried to encourage active attitude by means of some assignments where problems were not closed either in the posing or possible answers. In this paper we expose some of the questions included in these assignments and the results obtained by the students.

In Section 2 of this paper we present the methodology followed. In Section 3, we display achievements and results of this academic year there being some pending issues that are also indicated. Finally, in Section 4 we present some conclusions which we have reached during the development of this work.

2 Blended learning methodology

As mentioned Mathematics I has got 120 contact hours assigned, from which 90 correspond to TP and 30 to LP. TP has got two sessions of 1 hour and 30 minutes per week during 30 weeks. LP sessions have got 1 hour session per week. Thus, in the methodology used and in their evaluation we distinguish these two components, TP and LP.

Students of Mathematics I are distributed in two different groups for TP sessions where the languages of instruction are respectively English and Spanish. For LP sessions English group students are distributed into 2 subgroups and Spanish group students are split into 3 subgroups. Each LP group has around 25 students.

Contents covered in Mathematics I are Calculus (of one and several real variables) and Linear Algebra. For all these topics the students have got the corresponding textbooks, (Sánchez Ruiz & Legua, 2008; Legua *et al*., 2010) for theory and problems and (Moraño & Sánchez Ruiz, 2012) for laboratory practice contents.

TP classes are standard and at the end of each topic, the instructors propose the students a collection of problems in which a set of basic exercises/problems must be solved fluently. If the student does not know how to solve them, he should go to a tutorship with the instructor.

Throughout the academic year, four theory/problems exams are performed. The instructors apply a continuous assessment. In each exam the new items covered and key questions related to previous topics are asked. This allows measuring the degree of student acquisition of competences.

Also, before each exam the student must perform at least an assignment. It is assigned by the instructors by using the PoliformaT tool Resources. Work done must be delivered hand written. Students have a week to do this work. These assignments allow the student to check before the exam their level of knowledge and degree of competence achieved.

Since learning is acquired, among many other ways, by: priming, imitation, action, associating within a context, acquiring competences, training, practicing, imagining, giving conditioned answers, and by creativity (Hoffmann 2011; Marina 2011), this year we have included some exercises that encourage this type of activity.

In fact creativity has been defined by Hoffmann as the process of transfer rules from one context to a completely different one. With previous knowledge, skills, and competences, creativity augments and enhances the richness of facts while training new sequences, breaking the rules, and making errors. This leads Hoffmann to describe the creativity cycle as shown in Figure 5.

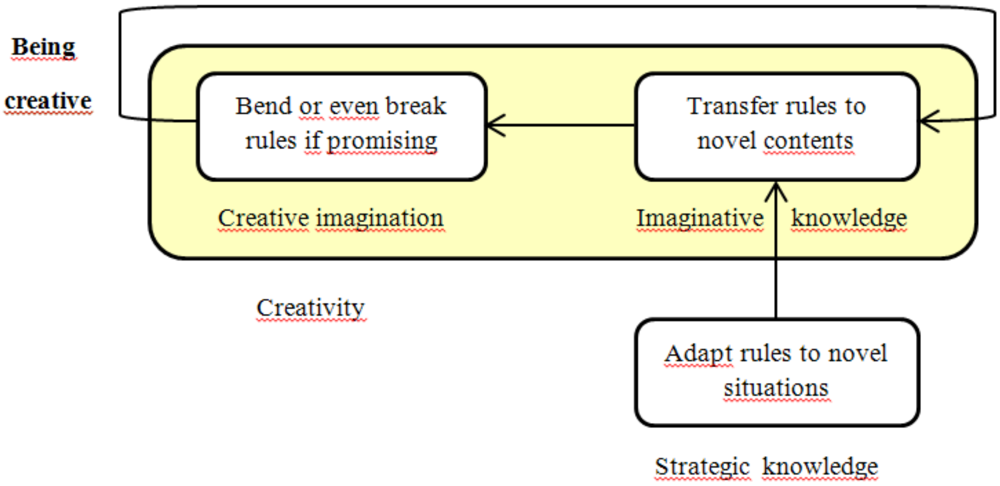


Figure 40: Hoffmann’s creativity cycle.

As students perform the assignment in an uncontrolled environment, then a quick multiple-choice test of 20 min was performed related to the assignment in classroom-hours. The global mark of the assignment includes both, work done at home and the multiple-choice test as explained in Section 3.

In what concerns Lab practice sessions we take advantage of the potential of MATHEMATICA CAS and students are instructed in their use and applications. The process can be divided into 3 stages: previous, at the moment and after each laboratory practice session and is explained in full detail in a paper within this IJCLE2015 (Moraño *et al.*, 2015) involving flipped learning (Bishop *et al.*, 2013; Mason *et al.*, 2013), weekly lab sessions with tests and individual lab semester exams.

3 Achievements and results

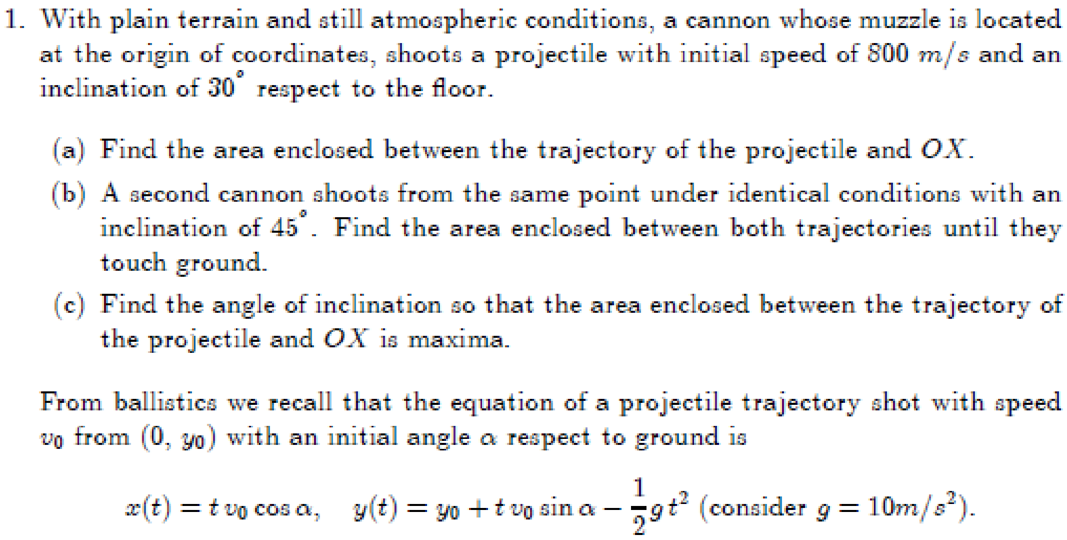
Under the perspective of facilitating the learning process we think that if an active attitude is promoted then the students have and feel the opportunity and desire to create something new and do it by their own. And when the student is motivated to learn something, they have the tools to go further in their learning process (Prensky, 2009).

In this section we are going to show some of the tasks that students are asked to solve during one week time Calculus assignment which included several types of questions related to:

- Standard math problems with some degree of difficulty (see Figure 2)
- Engineering related problems (see Figure 3 and Figure 4)
- Open questions with no closed answer (see Figure 5)

8. Find the area between the planar regions in which $x^2 + (y+2)^2 = 8$ splits the circumference $x^2 + y^2 = 4$.

Figure 41: Exercise 8 of Maths assignment.

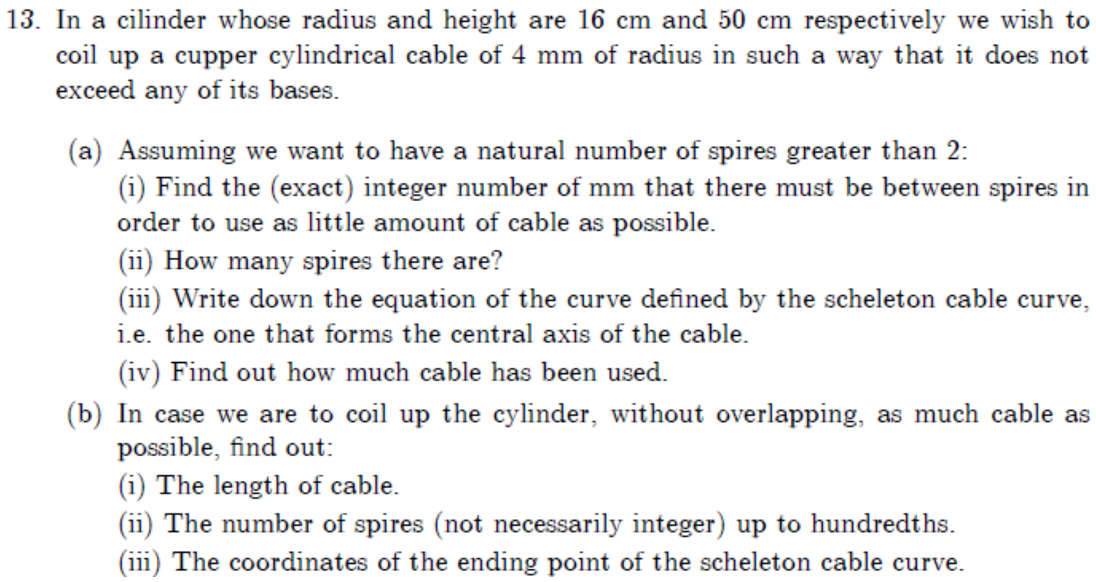


1. With plain terrain and still atmospheric conditions, a cannon whose muzzle is located at the origin of coordinates, shoots a projectile with initial speed of 800 m/s and an inclination of 30° respect to the floor.
   (a) Find the area enclosed between the trajectory of the projectile and OX.
   (b) A second cannon shoots from the same point under identical conditions with an inclination of 45°. Find the area enclosed between both trajectories until they touch ground.
   (c) Find the angle of inclination so that the area enclosed between the trajectory of the projectile and OX is maxima.

From ballistics we recall that the equation of a projectile trajectory shot with speed v_0 from $(0, y_0)$ with an initial angle α respect to ground is

$$x(t) = t\, v_0 \cos\alpha, \quad y(t) = y_0 + t\, v_0 \sin\alpha - \frac{1}{2} g\, t^2 \text{ (consider } g = 10 m/s^2\text{)}.$$

Figure 42: Exercise 1 of Maths assignment.



13. In a cilinder whose radius and height are 16 cm and 50 cm respectively we wish to coil up a cupper cylindrical cable of 4 mm of radius in such a way that it does not exceed any of its bases.

   (a) Assuming we want to have a natural number of spires greater than 2:
   (i) Find the (exact) integer number of mm that there must be between spires in order to use as little amount of cable as possible.
   (ii) How many spires there are?
   (iii) Write down the equation of the curve defined by the scheleton cable curve, i.e. the one that forms the central axis of the cable.
   (iv) Find out how much cable has been used.

   (b) In case we are to coil up the cylinder, without overlapping, as much cable as possible, find out:
   (i) The length of cable.
   (ii) The number of spires (not necessarily integer) up to hundredths.
   (iii) The coordinates of the ending point of the scheleton cable curve.

Figure 43: Exercise 13 of Maths assignment.

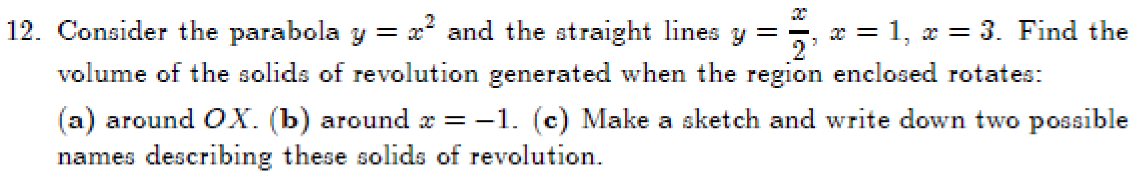
As seen there were all type of questions and the last one (Figure 5), specifically its c) section, was designed to encourage creative thinking.

Later we will mention the significant number of students that surprisingly did not answer or attempt to describe it, even more since they could make it for a long enough period to think about the questions and even about the nature of questions asked.

Prensky describes three types of students: the truly self-motivated, the one that think that his future may depend on the grades and credential that he gets, and finally those who think that school or university are totally irrelevant to their lives (Prensky, 2005) but they have to roll in.

Thus it maybe that despite Spanish Aerospace Engineering students being generally quite good, they still lack a full active attitude that might make them to answer to small challenges.

However the truth is that most of them did answer, and Mathematics I being a basic subject of first year, we think this a good oportunity to start acquaring this competency from the early stages of their university studies.



12. Consider the parabola $y = x^2$ and the straight lines $y = \frac{x}{2}$, $x = 1$, $x = 3$. Find the volume of the solids of revolution generated when the region enclosed rotates:
(a) around OX. **(b)** around $x = -1$. **(c)** Make a sketch and write down two possible names describing these solids of revolution.

Figure 44: Exercise 12 of Maths assignment.

The graph of the solids of revolution mentioned in Exercise 12 (Figure 5) are the ones shown in Figure 6.

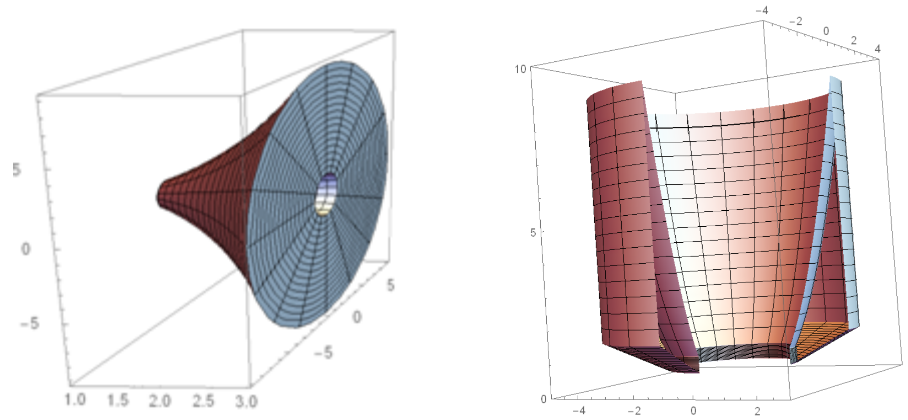


Figure 45: Solids of revolution: a) around OX (left); b) around x= -1 (right)

From the 120 students in the course, 22 did not do draw any sketch or give any name to the solid a) and 20 of them did not do anything at all with the solid b) of Figure 1. Some students just made a sketch and from those 37 students did not dare to give any description of solid a) while 38 students gave no name to solid b).

Some of the answers provided to the solid of revolution on the left at Figure 6 were truncated paraboloid lamp with cone inside, lamp, trumpet, megaphone, loudspeaker, bowl, volcano, “firstone”,..

Some of the answers provided to the solid of revolution on the right at Figure 6 were truncated cylinder with internal paraboloid ramp, stadium-bull arena, funnel, bucket, antenna, bowl, cup-like, “secondone”,…

As we see there were some geometrical descriptive attempts as well as shape related ones, and some very little informative in what concerns shape or form as the aforementioned last ones.

All non-environmentally controlled exercise is always difficult to assess. Having in mind this, students were requested to do a multiple-choice test at class related with the type of exercises they had been doing during a week. Figure 7 gathers the results of each student.

With very rare exceptions most of them performed better in the non-controlled environment (NCE), in blue in Figure 7, than at class under controlled environment (CE), in red in Figure 7. The assignment global mark, in green, was obtained by weighing these two results.

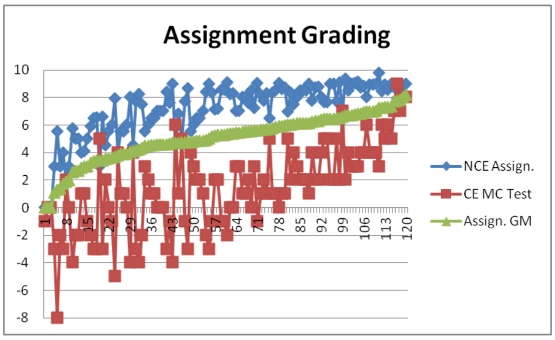


Figure 46: Assignment Grading: In blue Non Controlled Environment (NCE), in red multiple-choice related test under Controlled Environment (CE), in green the assignment global mark (GM).

In some very few cases we found a huge divergence in the performance at home, or wherever, and at class which leads to think that they received some kind of aid under NCE.

And it was strange but there happened the case in which they got a better result at class than under NCE, perhaps because they did not pay the assignment the due time or did not present it properly as this was an aspect which they had been told that would be taken into account as well.

In the multiple-choice test under CE students were allowed even to look at their home assignments, thus it was not a standard multiple-choice test. For that reason students knew that they would be awarded with the same positive (negative) absolute input in case of success (failure), with 0 input in case of no answer.

This is why there were some (very few) students who got a negative grading in the multiple-choice test which somehow compensated (35% of weigh) the perhaps excessive value given to the NCE (65%).

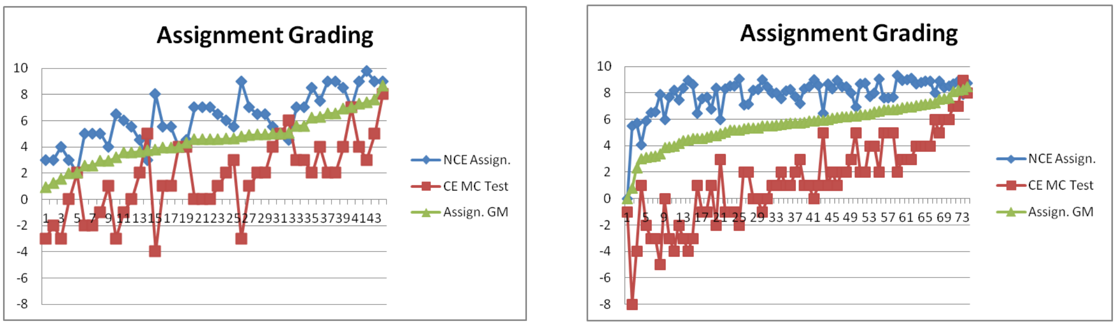


Figure 47: Assignment Grading: English group on the left, Spanish on the right.

Students are divided into two groups, one of them receiving instruction in English (45 students) and the others in Spanish (75 students), not there being a great difference in their performance, perhaps a small greater correlation in the Spanish group but not a significant one as shown in Figure 8.

Figure 9 gathers the results under NCE and CE of all students.

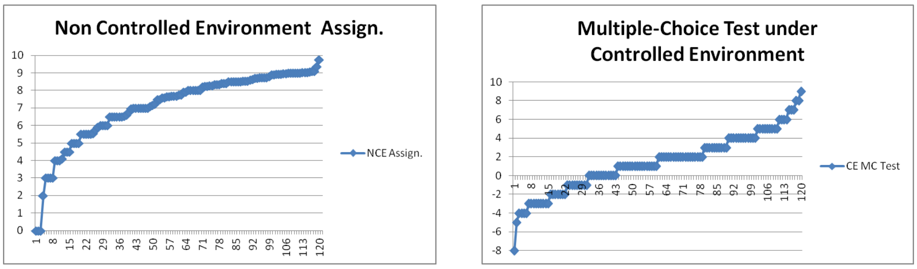


Figure 48: Results under NCE on the left, multiple-choice related test under CE on the right.

4 Conclusions

In active learning the students get activities, tools and approaches that together with their motivation, attention, emotions and intuition makes from the learning a creative attitude. The working memory, that is, the memory needed in the realization of a process (Reid, 2009) together with the capacity to apply many operative memories to the same object (Marina, 2011), makes that the new ideas are linked together in a complex matrix so that the learner can make sense of how everything fits, applying then that knowledge to the new situation (Reid, 2009). In this paper we describe the initiative taken in a basic subject of first year as Mathematics in Aerospace Engineering with the aim of favouring an active attitude between students from the early stages of their university studies. The results are promising and needs more effort to get a full implication of students.

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Water Quality Monitoring as a Tool for Professor Training

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Abstract

The use of water for many activities requires monitoring studies that, often, aim to identify impacts for the better management, restoration and maintenance of this resource, thus ensuring environmental quality. Based on this scenario, the University of Caxias do Sul – through Environmental Sanitation Institute – develops research locally, seeking to identify potential pollution sources and their impacts on water quality. Thus, the proposal involves the application of monitoring data via workshop development and virtual learning as tools for the continuous professor training. The objective is to reach students and the community closer to understanding the water bodies that drain the locality, as well as to promote awareness concerning its importance to the quality of life and balance of aquatic systems.

Keywords: environmental monitoring, continuing education, water resources

1 Introduction

Since the discovery of fire, man has been seeking for comfort and simplification of tasks. Therefore, it invested on increasingly advanced technologies and exploration of the world's natural resources. Man has removed, used and, at last, deposited residues in the environment without further concern about the impacts its actions could result. Consequently, the environmental degradation is reflected on the loss of life's quality, destruction of habitats and biodiversity reduction (Dias, 2004). Water resources can be mentioned as example, since they have been impacted by the expansion of urban centers – once used for recreation and source of supply – and currently have been used as waste deposits.

Water quality is essential for the maintenance of health and quality of human life and aquatic communities. The degradation of water quality occurs in both rural areas and urban centers located on the banks of rivers and small streams, which often receive domestic and industrial effluents.

The identification of areas hydrologically vulnerable to pollution is important for risk mitigation, development of public policies, management plans and educational programs that seek to protect the water resources of a river basin (Wang, 2001; Abdalla, 2008; Walls & McConnell, 2004). Monitoring of water resources is need, once the diagnosis of water quality in watersheds provides grants for planning necessary interventions to reverse or mitigate the degradation of water bodies. Such information must be provided in the appropriate format to society in general, respecting the principle of transparency. This principle, applied to the environmental area, has a wide legal support in Brazil, especially the Federal Law Number 10,650/2003, which regulates public access to environmental information. However, one realizes that the information is restricted to technical and institutions involved in the projects, whether idealizing or fulfilling. Its dissemination through formal and informal education can bring greater involvement of the community towards water resources.

Water was the topic of the project for being a current and comprehensive issue. It is possible to work with all areas of knowledge using this topic. More specifically in Chemistry, addressing issues such as: chemical properties, reactions, solubility, and polarity; in mathematics: systematizing and graphing data; interpreting them in biology through environmental health and aquatic ecosystems; and in physics through physical parameters, measures, thermometric scales, among others. The fact that 2013 has been considered by the UN as the "International Year of Water Cooperation", reinforces the idea that this feature requires attention and care. Whereas the disregard for water resources brings serious consequences and could even lead to the extinction of several organisms and endanger human health irreversibly.

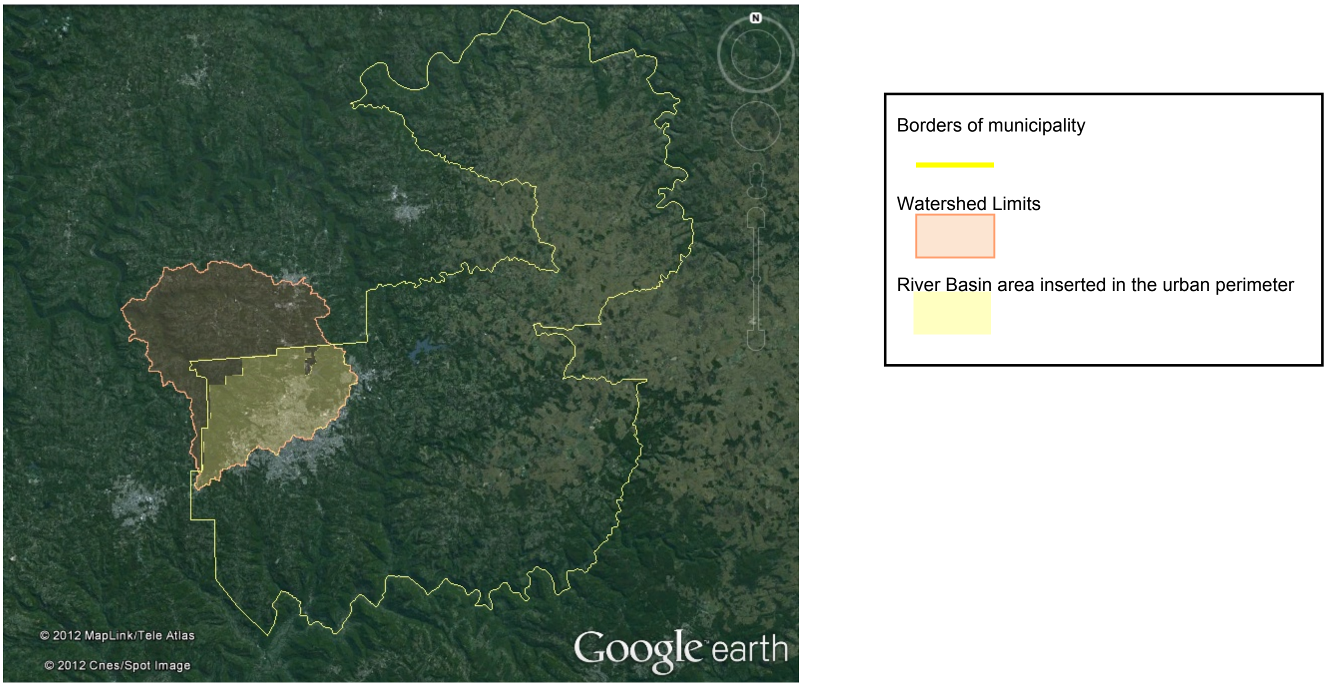
Against this background, the proposal of monitoring data utilization for the development of presential workshops is being developed. Such, work as an extra tool for the continuing education of professors, reaching students and community together when promoting a greater comprehension of the local watersheds and its importance to the balance of aquatic ecosystems.

2 Metodology

The methodology consists of choosing the experimental watershed; conducting monitoring and systematizing the data; and preparing courseware, a virtual learning environment and classroom workshops for training professors. The water quality data is obtained from the monitoring of urban watersheds from Caxias do Sul municipality, held in 30 points monitored by the Environmental Sanitation Institute (ISAM, in Portuguese) at the University of Caxias do Sul (UCS). The points are distributed in five watersheds of the city: Faxinal, Maestra (Sub Basin of Tega River), Belo, Pinhal, Piaí and Tega. The Tega River Basin contains 12 monitoring points, and was defined as the subject of this paper work, due to the great drainage area in the urban environment. It is known and recognized by population that the city development occurred around Tega River, including the industrial activities. Tega watershed is considered a supply source for some of its tributaries (Maestra, Dal Bó, Samuara) and also, as part of the sewer system, once a mixed system using natural/constructed channels connected and targeted to the main riverbed was adopted.

Tega River begins in the urban area of Caxias do Sul and, after 34 km through the city, has its confluence with the Rio das Antas, on the edge of the Flores da Cunha and Nova Pádua municipalities. The watershed presents a perimeter of 116.81 km and drains an area of 294.76 km^2, which extends from the municipalities of Caxias do Sul, Flores da Cunha and Nova Pádua. As shown in Figure 1, the watershed occupies the central-western portion of Caxias do Sul.

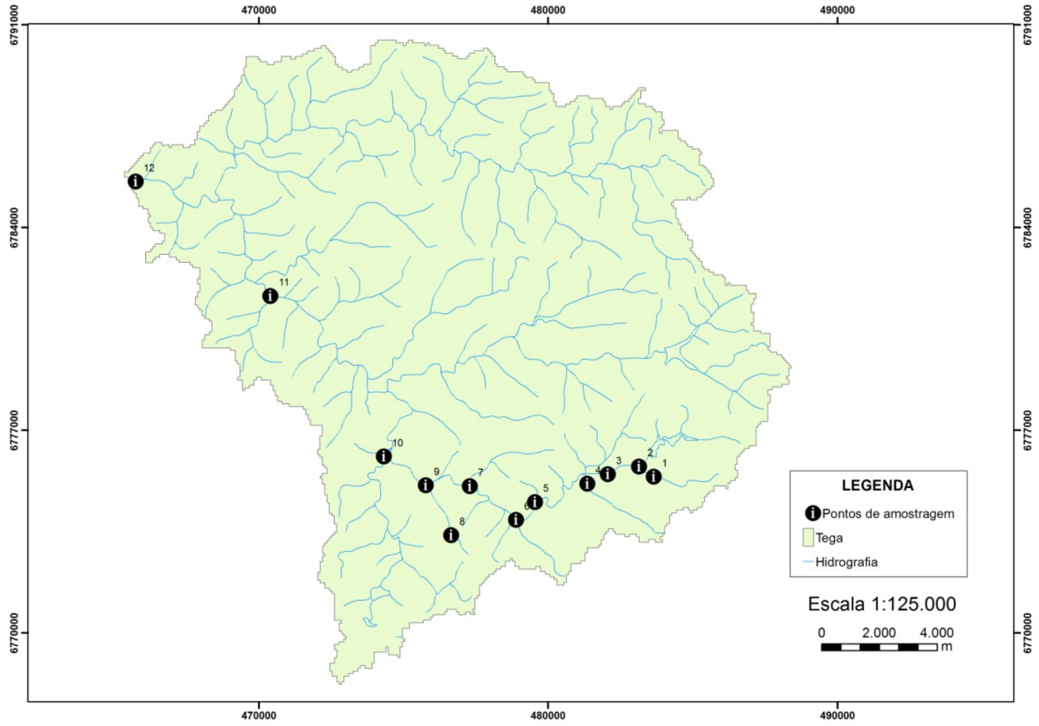
Figure 1. Location of Tega River Basin relative to Caxias do Sul and urban area



Tega River, which in past has been part of the population’s day life, is nowadays canalized on its majority. It has not only become invisible, but also a neglect or disgust target by population, since from the sanitary perspective, the river is considered a collector of domestic and industrial effluents. As a result, the forms of life in the waters are restricted to strongly pollution resistant organisms.

Quality monitoring is done through bimonthly sampling conducted by technicians and researchers of ISAM with the use of conventional analytical methods. The 12 points located in Tega River were defined considering the proximity to major sources of contamination. Points 1 to 6 are located in the urban area, and points 7 to 12, in the rural area. Point 12 is located at the mouth of the River, when it meets Rio das Antas. For each point, 25 physicochemical and biological parameters are analyzed, which are fundamental for assessing water quality and characterizing the source of effluents in the river course. The points' location is shown in Figure 2.

Figure 2: Location of sampling points in the Tega River Basin



The training seeks to prepare professors to identify impacts on environment and water quality, and occurs by conducting workshops with direct observation of the parameters established by CONAMA Resolution 357/2005 (solids, color, odor, turbidity, iridescence) and water quality that fits the Resolution CRH 121/2012, comparing results obtained with the established by CONAMA 357/2005. As a theoretical background, educational material on physical and chemical parameters and visual/olfactory perception is produced.

Initially, the training of 30 professors if planned, with workshops during 4 hours/class, occurring fortnightly. These professors act as multipliers in their schools. Taking into account that each professor will reach to a group of 10 new professors, at least 300 professors can be reached at end of the first semester. Not to mention the student interdisciplinary activities acting as multipliers as well.

3 Results and Discussion

The data obtained through monitoring allows students and professors to access information on the current situation of the local watersheds. Such information, inserted in the school context, creates opportunities to broaden the horizons regarding individual actions for the environment, mainly because it relates students and professors to their reality.

However, providing environmental information is not enough. It is necessary to train people who have access to its information, in order to possibly interpretations, in addition to enable their contact with different learning environments. This allows the contextualization of the subjects and application of knowledge in innovative strategies and diverse education.

Water quality data obtained so far proves the impairment of local watersheds and the lack of commitment of the population towards the rivers. It is evidenced by deposits of waste in the riverbed and banks, effluent discharges, bad odor and foams, resulting from domestic and industrial effluents, as shown in Figure 3.

Figure 3: Tega River Situation in terms of waste and foams

In this context, an educational intervention is necessary, so that the population can be warned on the current situation and be encouraged to act on behalf of the environment. It is expected that the access to regional information, combined with training and constant guidance, can reach students and community and bring individuals and society to establish environmental values, construct knowledge, acquire skills and adopt attitudes focused on the balance of the environment.

The proposal in under preparation of the Teaching Guide for professors. Training on an experimental basis is expected to take place on the first half of 2014.

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Marked Drops Experiment

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Abstract

Public high schools in Brazil lack sufficient resources to build and maintain laboratories, and classes on Physics in most schools arouse little interest among young people. A simple web search using conventional search tools can help the teacher to build a rich and motivational learning environment just by adapting experiments made with accessible materials to the classroom. This way, it will contextualize learning and the class will be followed. This article describes how to use one of these experiments not only as a demonstrative activity, but in order to illustrate a possible intervention to be performed in the classroom. The experiment procedure is formatted for a hands on session at Active Learning in Engineering Education Network -ALE. For so, it will be aided by two tutors (undergraduate students) and applied to a group of 16 participants divided into four groups. Each group will receive a black box containing the materials to conduct the experiment and some questions to think-tank. The activity is designed in such a way as to make learners work in a collaborative way, plan and execute the task and finally, analyze the result, based on particular concepts related to the Uniformly Accelerated Rectilinear Motion.

Keywords: active learning, high school education, physics classes, hands on activities.

1 Introduction

A look at higher education in Engineering points at the basic problems, which are critical: poor education at public schools, difficulties of access for socially disadvantaged classes and low female representation. In this sense, an outreach project named "Fast Girls" was created at the Faculty of Technology from the University of Brasilia, organizing and supporting action research in a public high school, in order to prepare a proposal to awaken vocations and motivate improvements in education, social inclusion and gender equity in careers in the technological field, particularly in the engineering courses.

The project aims at motivating students using active learning and exploring concepts related to automobile racing and contextualizing the contents of high school subjects, in particular Physics, and Math.

Public high schools in Brazil lack sufficient resources to build and maintain laboratories, and Physics classes in most schools arouse little interest among young people. Also "the lack or dispreparation of teachers, their bad working conditions, the reduced number of class hours, and the progressive lack of identity (of this subject) in the curriculum", contribute to the lack of interest. Besides, "the teaching of Physics in contemporary education promotes the rote learning of old contents" (Moreira, 2013).

A simple web search using conventional search tools can help the teacher to build a rich and motivational learning environment just adapting experiments made with accessible materials to classroom so it will contextualize the lecture will be followed.

This article describes how to use one of these experiments not only as a demonstrative activity, but in order to illustrate an active learning intervention to be performed in the classroom. The experiment procedure is formatted for a hands on session at Active Learning in Engineering Education Network -ALE.

The "Marked Drops Experiment" is based on the material available in *CiênciaMão* (Science in hand) (USP, 2015), and presented by Quirino and Lavarda (2015). In this work, specific original methodology is proposed to be applied in the conference.

The Hands on Session coordinator will be aided by two tutors (undergraduate students) and activity is prepared to be applied to a group of 16 participants divided into groups. Each group will receive a black box containing the materials to conduct the experiment and some guided questions. It is designed, so that learners need work in a collaborative way, plan and execute de task and analyze the result, in this case concepts related to Uniformly Accelerated Rectilinear Motion.

2 Apprenticeship goals

An active learning activity is a pedagogical practice that addresses the learning issue by students from a different perspective of classical learning techniques. Thus, the experiment aims at making students develop their own conceptualisations of a simple Physics lesson, more precisely Uniformly Accelerated Rectilinear Motion, so during the process they physically make neural connections in their brains. Therefore, the students are not just "receivers" of information, but rather part of the knowledge acquisition process through proactive engagement. For example, the study of the speed and acceleration of a specific car when a constant force is applied is conducted by observation of the market drops on a piece of paper.

3 Methodology

The experiment development is based on collaborative teamwork and it is student-centred. The participants are divided into small groups using colour cards and facilitators will monitor the activity in place of teaching it. The teams are motivated to work autonomously with creative thinking. Problem-solving is held by planning and performing the experiment, noticing some driving questions introduced to the same colour cards used to divide teams, observing, analysing and explaining the phenomenon. The total time for the activity, 90 minutes, includes the discussion and concepts consolidation with all participants involved, and is established in terms of session time. The activity does not require calculations and the analysis is qualitative and performed based on exploratory observations.

3.1 Participants

The activity is proposed to 16 participants divided into teams of 4, 1 coordinator and 2 tutors. The division of groups is made by distributing colour cards; so the same colour characterizes the same team.

The role of the coordinator is to introduce the activity, to act as a facilitator and control time and activity steps according to Hands on Session Procedure. The role of tutors is to welcome and accommodate the participants, to assist the coordinator in organizing the activity and to monitor teams acting as facilitators.

3.2 Materials

The following materials are placed in black boxes delivered to each team for assembling the apparatus as shown in Figure 1: Pickup car toy; plastic bottle for water (250 ml volume); colour food; paper to mark; string; double-sided tape; thin wire; metal paper clips; rubber band; sinkers with known weight; a set of drip tubes, thumbwheel, drip chamber and spike; scissors; a stopwatch and measuring tape. Then a subsequent analysis is executed.

Figure 49: Black box; contents and the assembled apparatus.

3.3 The Colour Cards

The cards distributed in the beginning of the session are numbered in order to establish the sequence of basic instructions and motivate think-tank to develop the activity. The information contents in the colour cards are presented in Table 1.

Table 11: Information contents in colour cards.

Colour Cards	Information
Card one: Problem-solving:	The Pickup car must be moved by a constant force along a linear path and the route will be marked with drops. Requirements: - Use the material provided in the black box to assemble the apparatus; - The drops should be released on the paper at constant time intervals, marking the path; - The route is marked with at least 5 drops and reaches at least 550 mm.
Card two: Guiding questions for planning	- How to develop the experiment as a whole? - What physics quantities can be observed during the experiment? - How to divide and perform the tasks among team members?
Card three: Guiding questions for performance	- How do the drops fall? - How to set the proper time interval between drops? (More drops or fewer) - How to apply a constant force?
Card four: Phenomenon observation and discussion	What analysis can be carried out - concerning the force acting on the car? - including the time? - on the displacement and path? Is the car speed constant? Where does the acceleration come from?

The first card states the problem-solving situation. The second card is related to the experiment, planning through some guiding questions. The third card is focused in the performance and the fourth one is related to the exploratory observation and discussion within the team.

3.4 Hands On Session Procedure

i) Distribute materials and address the problem to be solved (observe card one) - 10 minutes;

ii) General instructions on team organization to perform the experiment (observe card two) - 10 minutes;

iii) Assembly and first experimental test (observe card three) - 30 minutes;

After the first experimental test, the groups are encouraged to use different weights and repeat the experiment as many times as needed within the time.

iv) The implementation and observation of the experiment (observe card four) - 20 minutes;

v) Discussion and results analysis - 20 minutes.

4 Results and final remarks

The experimental results have the marks on the paper to facilitate the observation as the successive intervals distance increases, and the constant force is provided by a weight that falls under the action of gravity and pulls the car. This can be concluded through the drops at intervals of fairly constant times which the apparatus releases during the motion caused by a constant force.

Furthermore, participants find that the mass of sinker falling can be varied to show that under greater force, a greater acceleration will emerge and therefore, there will be a higher speed to go the same distance.

At the end of the experiment it is expected that the students have an understanding of how a scientific experiment occurs, and have learned about this type of motion in a playful and efficient way. Moreover, the car movement problem in the form that is constructed constitutes the basis for understanding concepts and relate physics quantities such as displacement, time, velocity, acceleration, force and vehicle for the development of solving skills. Besides, an improvement in team organization, time management, problem analysis and its results is intended, as well as a review of difficulties in the execution and how to achieve better results.

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Playing with a QoV model - A Competency-based Learning Approach

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Abstract

Foundational skills such as critical thinking, teamwork, and problem solving are climbing to the top of employer' wish lists, yet few institutional measures directly capture these attributes. *Competency-based Learning* (*CBL*) systems offer the potential to go beyond a limited view of higher education, giving students the opportunity to develop and practice the skills needed for a meaningful career, and life. Courses that are competency-based assess what students have learned and are able to do, rather than what they may know and the amount of time spent in a course. An application that allows and encourages the *Research-Based Learning* was developed. This facilitates the interaction of students with a real prototype under the *Plug & Play* approach. The experimental platform includes a prototype scale *Quarter of Vehicle* (*QoV*) model with an *Electro-Rheological* (*ER*) damper that represents a vehicle semi-active suspension system for the Vehicle Dynamics course. Students with minimal knowledge of hardware, low-level programming, signal processing or control design, intuitively could work with the *QoV* model and discover/build their knowledge. Early results show a more efficient teaching-learning system that promotes some skills based on high motivation because the easy use of the educational platform.

1 Introduction

México ended 2014 as the largest vehicle producer in Latin America and 7th worldwide. That year, Mexican automotive industry saw its consolidation as one of the top countries in vehicle production and export, as a result of Nissan, Honda and Mazda's new facilities opening in central México. During last year the Mexican automotive industry closed to 3.5 million produced vehicles, (Elie, 2013) and it will produce 5 million vehicles by 2020.

This will demand more professionals in automotive industry. The distribution requirements in terms of total employment are: (1) 52 % Manufacturing components, (2) 21 % Assembly, (3) 8 % Logistics and storage, (4) 8 % Administration, (5) 6 % Design and development product, (6) 3% Sales and Service customer and (7) 2 % Industrial safety. The employment in the sector is concentrated in manufacturing and assembly (73 %); but, the activity with greater value-added is Design. México can increase its focus on Design and Development Product to enhance the value-added sector. The technological development in México is mostly with undergraduate 87 %, graduates (masters and doctors) represent 13 %. *Tecnológico de Monterrey*, which is accredited by *ABET*, is working on these needs through different initiatives; one is using *Competency-based Leaning* (*CBL*) in several academic programs.

Additional to these needs, there are excellent universities in Latin America, but there are too many low quality "promising students a future that may not give them". According to the International Labour Organization, about 8 million young Latin Americans are unemployed and 27 million are working in the informal sector. In fact, 6 out of 10 youth employment in the region are in the informal market. Almost 42 % of young people in Latin America reach higher education, but what skills they teach universities need to find a real job in Latin America? (Cunningham, 2015).

This paper is organized as follows. Section 2 reviews the *CBL* approach. Section 3 justifies the development of educational technology. In section 4 some preliminary results are shared. Finally, section 5 concludes this preliminary research.

2 Competency Based Learning

Competency-based Learning (*CBL*) has gained interest from hundreds of higher education institutions, coupled with online learning, it will constitute a disruptive force in higher education. *US* corporations will increasingly recognize the value of competency based programs, (Kelchen R, 2015). *CBL* is a sometimes-controversial model that has gained ground in recent months. *CBL* puts the focus on students' capabilities rather than how many hours per week they spend in the classroom. The benefit for employers, they say, is that prospective employees can be judged more easily, based on their demonstrated competencies rather than guessing how their grades will translate to real-world work. At least 200 institutions have *CBL* programs (Button K, 2014)

In today's rapidly changing labour market, employers are emphasizing the importance of a more sophisticated mix of technical and 21st century skills, even for entry-level positions. *CBL* programs offer the potential to go beyond a limited view of higher education, giving students the opportunity to develop and practice the skills needed for a meaningful career, life, and citizenship.

CBL programs are built on specific competencies and enabling technologies that create a personalized, flexible program of study, which emphasizes relevant skills for future employment and career success. Programs that are competency-based assess what students have learned and are able to do, rather than what they may know and the amount of time spent in a course.

CBL programs enable students to earn credentials by demonstrating their competencies without the traditional confines of credit hours. The most important characteristic of *CBL* is that it measures learning rather than time spent in courses.

Students' progress by demonstrating their competence, which means they demonstrate that they have mastered the knowledge and competencies required for a particular course. *CBL* allows us to hold learning constant and let time vary.

These include instructions, competencies, training and learning, assignments/labs, discussion, and assessments. Each course has a pace chart, which provides a recommendation for the amount of time it should take to complete the course, with options for a slower or a quicker pace to completion.

Our proposal considered some principles of *CBL* tailored to a Vehicle Dynamics academic program. Several customized steps were considered to fit them into a traditional course where an educational technology application was developed to facilitate the teaching-learning approach, (Morales-Menendez, 2008).

3 Educational Technology

This study is for the Vehicle Dynamics course, which is a branch of vehicle mechanics that deals with the motional actions necessary for moving road vehicles and their resulting forces under consideration of the natural laws. One of the objectives of this course is: to introduce the basic mechanics governing vehicle dynamic performance in the longitudinal (acceleration and braking modes), ride (vertical and pitch motions) and handling (lateral, yaw and roll modes).

Engineering analysis techniques will be applied to basic systems and subsystems to derive the controlling equations. The equations reveal which vehicle properties are influential to a given mode of performance and provide a tool for its prediction. By understanding the derivation of the equations and practicing with a real vehicle, the students are made aware of the range of validity and limitations of the results. Experimental work is mandatory; but, working with real instrumented vehicles is expensive and it is not an easy task.

A *Quarter or Vehicle* (*QoV*) model is the most basic automotive suspension, Figure #1. Its use assumes an equivalent load distribution among the four corners and a linear dependency with respect to the translational and rotational chassis motions. The lateral and longitudinal wheel dynamics is not considered, while the wheel road contact is ensured. A *QoV* model is a well-known simplification for vertical dynamics analysis of vehicle.

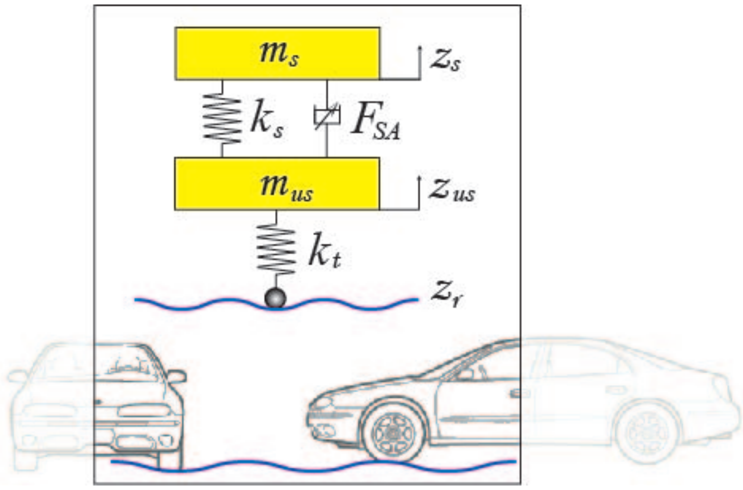


Figure 1 Conceptual QoV model

The system considers a sprung mass and an unsprung mass. A spring with stiffness coefficient and a semi-active damper represent the suspension between both masses. The semi-active damping force depends on a control input variable and it is highly nonlinear with respect to the suspension motion. The stiffness coefficient models the wheel tire. The vertical position of the masses are measured while road profile corresponds to the unknown road disturbance. Figure # 2 shows a prototype of the experimental *QoV* model, left picture represents the conceptual design, while right picture is a photo of the real system.

The primary functions of an automotive suspension system are to (Gillespie, 1992): (1) isolate the chassis motion from road irregularities, (2) keep the tire-road contact with minimal load variations, and (3) resist roll of the chassis. These objectives directly depend on the vertical force that it must transmit from the tires to the chassis.

According to the capability to adjust the damping force, the automobile suspensions can be classified as: passive, active or semi-active. Passive suspensions are only able to dissipate the energy and their damping characteristics are time invariant, while active ones are able to store, dissipate and generate energy through a variable damping coefficient but they are very expensive to apply because require an external power supply. Semi-active actuators has recently been an area of much interest because of its potential to provide similar performances of active actuators; but, without requiring a significant external power supply (Fijalkowski, 2011). The interest in semi-active suspensions derives from the potential for improvements to vehicle ride comfort performance with no compromise in handling (road holding).

To study the vertical dynamics of a vehicle is needed to instrument the *QoV* model and record synchronously several variables of interest. This requires a deep understanding of data acquisition systems (hardware and software). Implementation time and development are excessive and they are not studied in this course. A *Human Machine Interface* (*HMI*) was developed to easily interact with the experimental *QoV* model. This represents a *Hardware-in-the-the-Loop* (*HiL*) approach. *HiL* is a technique that is used in the development and test of complex real-time embedded systems.

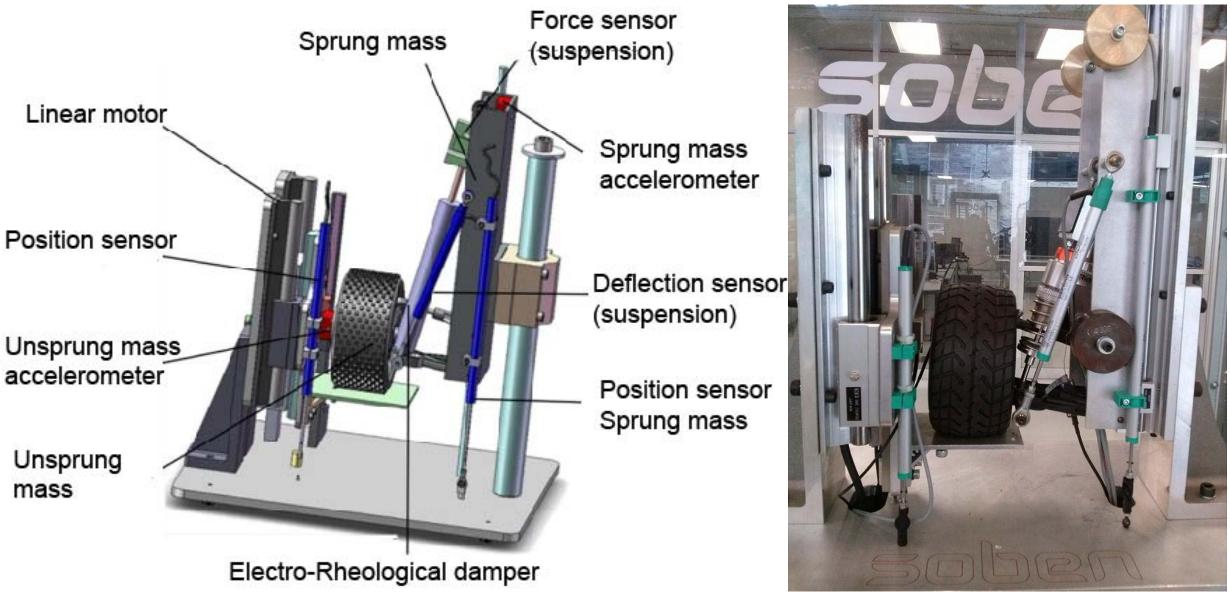


Figure 2 Experimental *QoV* model

Figure # 3 illustrates how a *Dspace* card talks with the experimental platform and *Matlab/Simulink* on real time. The *HMI* running on *Matlab* platform saves hundreds of hours of development and allows:

1) Design a control system as if you were drawing a block diagram, Figure # 4.
2) Reuse software such as: road profile, control algorithms, etc, using the *Plug and Play* approach, see Figure # 5.
3) Online plotting and registering.
4) Online access to the *Matlab* and toolboxes platform.

The main contribution of the educational technology was make available to students a data communication system between a computer and a *QoV* model to design and implement easily identification / modelling tests, data-based controllers, unconventional controllers, as well as the experimental validation of these, (Vivas-Lopez, 2015).

4 Early Results

Based on the educational technology three challenges were defined for the students to learn about (1) *QoV* modelling, (2) data-based controllers for comfort and ride holding goals and (3) model-based controllers. These challenges have to be solved during the term (5 months). Through these challenges students have to develop three main skills: critical thinking, teamwork and problem solving. The cornerstone of *CBL* student supports and a key difference versus the traditional program is access to an academic coach, who monitors academic progress, and assists students base in five working definitions of high-quality *CBL*, (Weise and Christensen 2014):

1. Students advance upon demonstrated mastery.
2. Competencies include explicit, measurable, transferable learning objectives that empower students.
3. Assessment is meaningful and a positive learning experience for students.
4. Students receive rapid, differentiated support based on their individual learning needs.
5. Learning outcomes emphasize competencies that include application and creation of knowledge along with the development of important skills and dispositions.

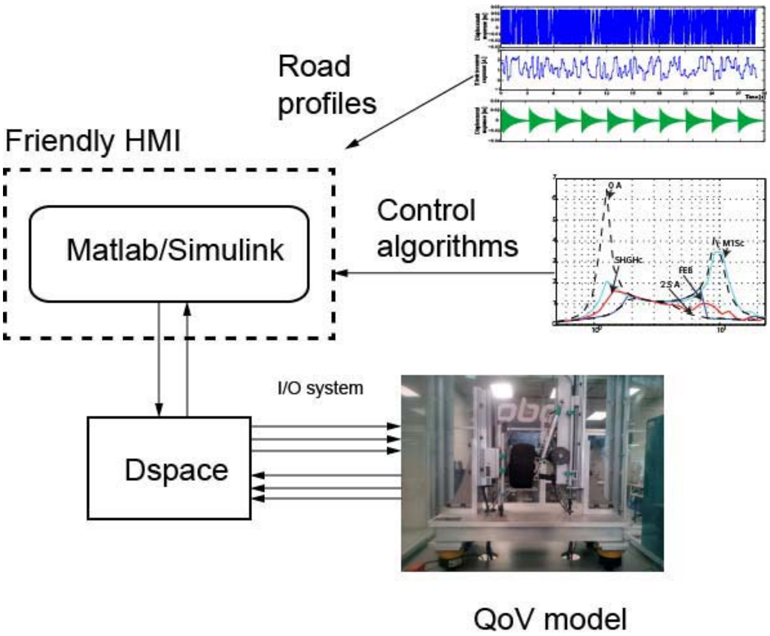


Figure 3: Communication system

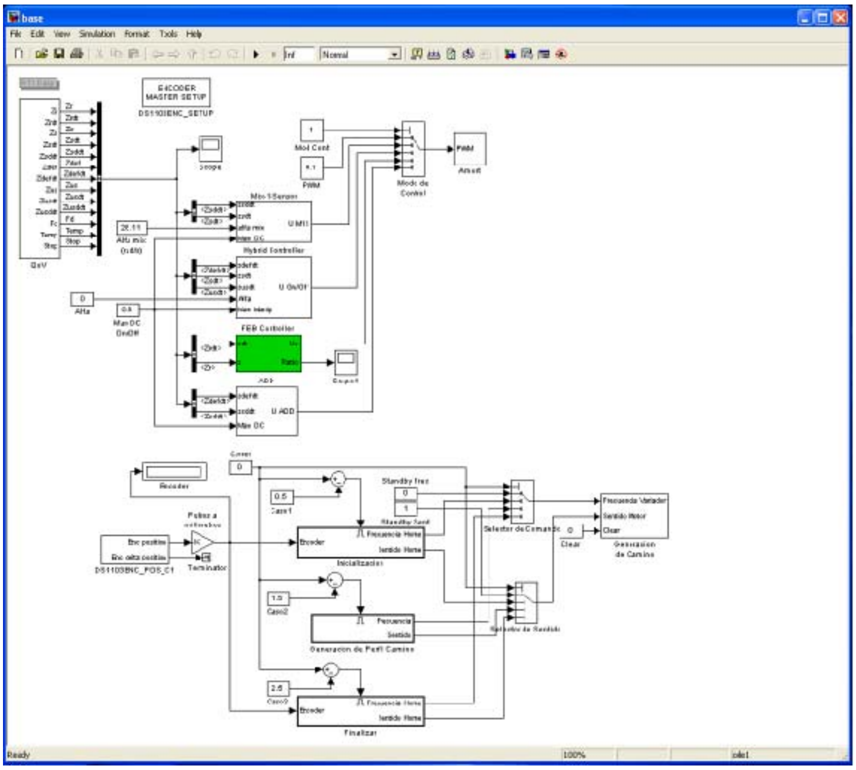


Figure 4: Simulink interface

CBL programs have no time-based unit. Learning is fixed, and time is variable; pacing is flexible. Students cannot move on until they have demonstrated proficiency and mastery of each competency, but are encouraged to try as many times as necessary to demonstrate their proficiency.

Additionally, there are manual, papers, videos to support students with the *HMI* system and experimental *QoV* model. Early results can be classified in 3 aspects: (a) *HMI*, (b) *CBL* and (c) Academic results

HMI

The main goal of the *HMI* is to allow students an easy and friendly operation of the experimental *QoV* model. Mechanical Engineering students have a low background in control systems, instrumentation, low-level programming, etc. students have a repository of several elements to design (to draw) a control system: different profile of the roads, type of standard tests, data-based control algorithms, model-based control algorithms, etc.

Students will be focus in the academic goal in the study without consuming time on implementation details. Eventually, students will be able to design and contribute to the repository with new ideas and code.

CBL

Several competencies were promoted during this course, but special emphasize was given to critical thinking, then teamwork and problem solving. A short term evaluation system based on rubrics was considered for the three skills. But, a long term monitoring system based on the *California Critical Thinking Skills Test* (*CCTST*) The *CCTST* is designed to permit test-takers to demonstrate the critical thinking skills required to succeed in educational or workplace settings where solving problems and making decisions by forming reasoned judgments are important. The *CCTST* has been proven to predict strength in critical thinking in authentic problem situations and success on professional licensure examinations. It provides an array of scale scores (*Analysis, Evaluation, Inference, Deduction, Induction and Overall Reasoning Skills*) describing strengths and weaknesses in various skill areas.

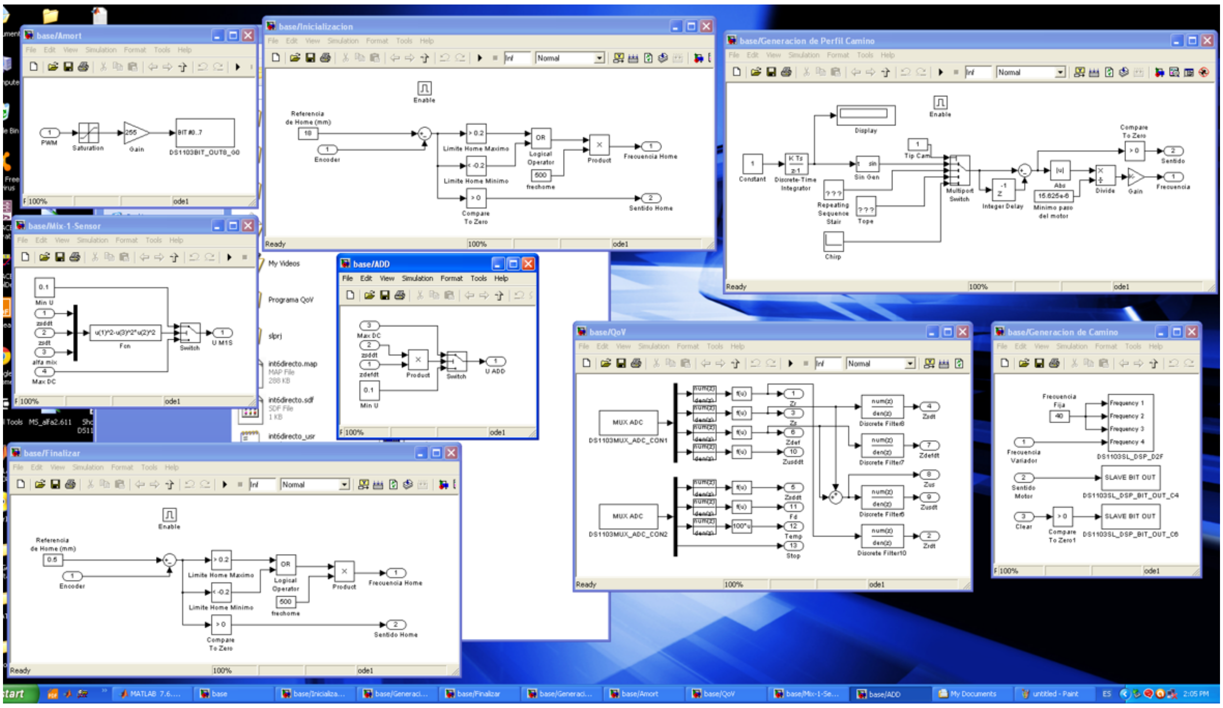


Figure 5: Simulink repository (control algorithms, road profiles)

Figure # 6 shows the Vehicle Dynamics course into the Mechanical Engineering curriculum (9 terms). The Critical Thinking Skill is promoted during the first three terms, then is developed during the second three terms and finally is evaluated during the last three terms. Rubrics are used in each course. The *CCTST* is applied to all students at the beginning and at the end of their studies. This feedback is exploited through the years. The Vehicle Dynamics course can be considered as two programs running in parallel: (1) the traditional program exploiting Active Learning but time based scheduled (i.e. students must work according to academic credit hours) and (2) the competency based learning where three challenges are the driving force but skills based scheduled (i.e. students must develop the skill). Students can move from challenge #1 to challenge #2 after they improve/develop the skill based on a rubric, Figure # 7.

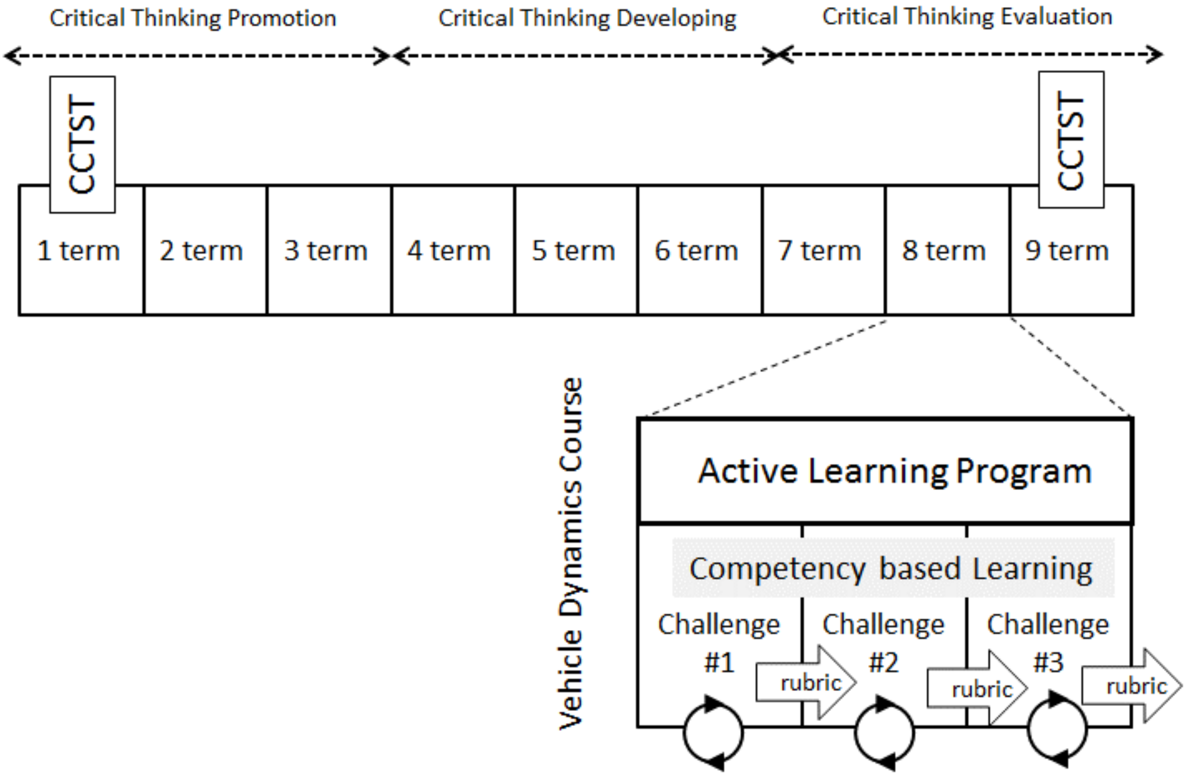


Figure 6: Academic roadmap

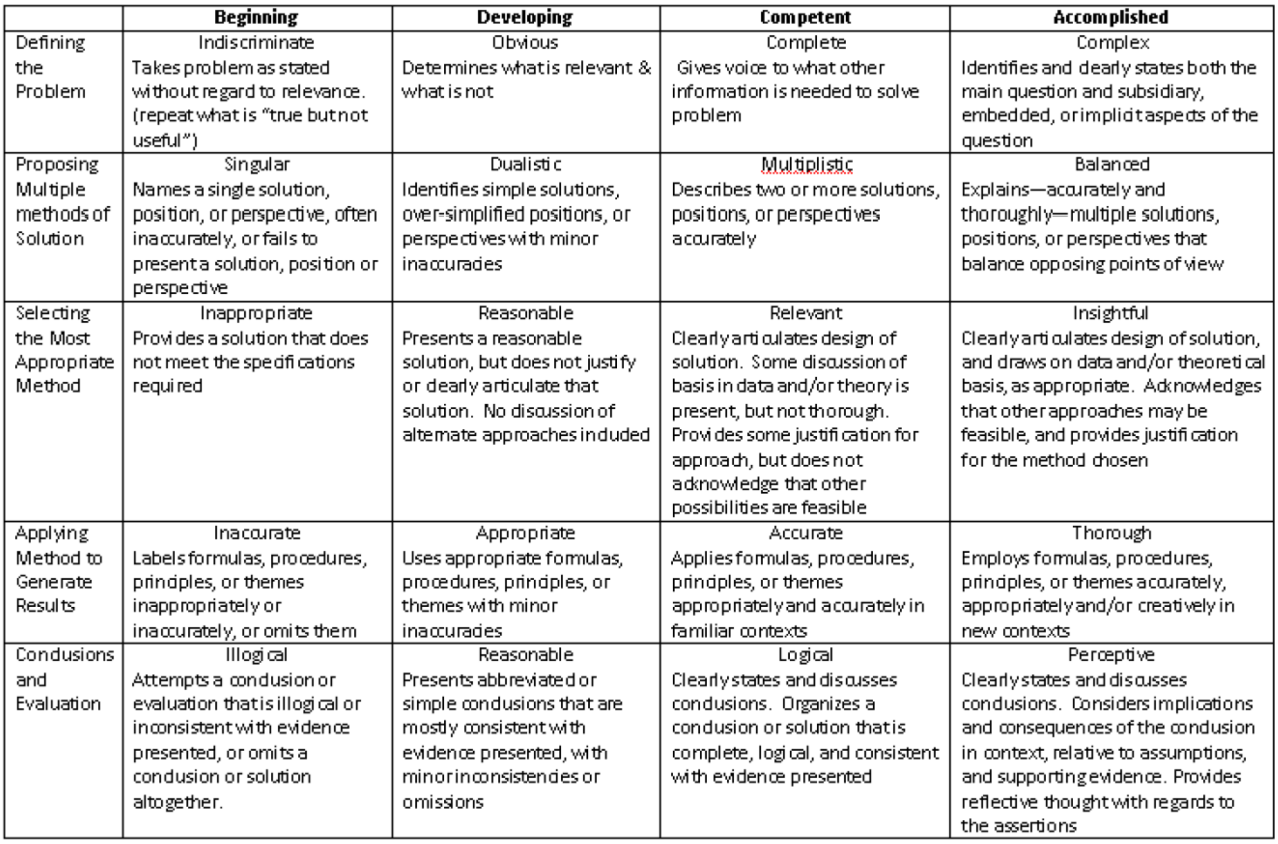
Different strategies for linking teaching and research were considered for the three challenges:

1. We incorporated current research directly. We presented industrial projects to motivate students. Graduate students participate and discuss their current research projects.
2. The latest research in the field was placed within its historical context.
3. Several damping theories were considered and different control algorithms. These elements have been changing with the technological advances in the automotive industry.
4. Learning activities around contemporary research issues were designed. Students were asked to explore cutting-edge research problems, i.e. analyze the tradeoff problem of comfort versus road-holding for different suspension systems. Investigate the status of this open question. Which are the issues related with the technological solution versus the business solution?
5. Teaching research methods, techniques and skills explicitly. Representative data comes from a special Design of Experiments of displacement and electric current pattern in the automotive frequency domain. Students learn about these research methods and how they can extended to others disciplines.
6. Students are encouraged to understand and aspire to researchers' values such as, (Baldwin, 2005): Openness to the new, Scepticism to received theories, Honesty with oneself as well as others, Respect for evidence, Respect to others, Tolerance of ambiguity, Respect for the subjects of study, Persistence, Analytical rigor, Accuracy, Humility, Willingness to admit error and Creativity.

Students’ point of view

Students tested the experimental *QoV* system and recognized some features related with the academic objectives:

1. Students could solve the challenges. They could off line validate their proposals using *Matlab/Simulink* before the experimental approach, then students implemented efficiently their solutions.
2. Students with basic background in *Matlab/Simulink* recognized the *HMI* was very ease of use, Figure # 8. However, students without this background said it is a good enough application.
3. All students showed high motivation; however, some of them were skeptics to the real vehicle behavior. The *QoV* model is an accepted model for this analysis even for practical applications; but certainly there are some limitations/constraints because only the vertical dynamics of the vehicle is considered.
4. All students showed high motivation for being part of a real problem with open question. Even practical solutions can be found in the automotive industry, multi-objective problems do not have global solution just local solutions.
5. All students appreciated the available code; some students modified it. Students recognized some values: advantage of collaboration, recognition of authorship, recognition of standards procedure as documentation of software.



	Beginning	**Developing**	**Competent**	**Accomplished**
Defining the Problem	Indiscriminate Takes problem as stated without regard to relevance. (repeat what is “true but not useful”)	Obvious Determines what is relevant & what is not	Complete Gives voice to what other information is needed to solve problem	Complex Identifies and clearly states both the main question and subsidiary, embedded, or implicit aspects of the question
Proposing Multiple methods of Solution	Singular Names a single solution, position, or perspective, often inaccurately, or fails to present a solution, position or perspective	Dualistic Identifies simple solutions, over-simplified positions, or perspectives with minor inaccuracies	Multiplistic Describes two or more solutions, positions, or perspectives accurately	Balanced Explains—accurately and thoroughly—multiple solutions, positions, or perspectives that balance opposing points of view
Selecting the Most Appropriate Method	Inappropriate Provides a solution that does not meet the specifications required	Reasonable Presents a reasonable solution, but does not justify or clearly articulate that solution. No discussion of alternate approaches included	Relevant Clearly articulates design of solution. Some discussion of basis in data and/or theory is present, but not thorough. Provides some justification for approach, but does not acknowledge that other possibilities are feasible	Insightful Clearly articulates design of solution, and draws on data and/or theoretical basis, as appropriate. Acknowledges that other approaches may be feasible, and provides justification for the method chosen
Applying Method to Generate Results	Inaccurate Labels formulas, procedures, principles, or themes inappropriately or inaccurately, or omits them	Appropriate Uses appropriate formulas, procedures, principles, or themes with minor inaccuracies	Accurate Applies formulas, procedures, principles, or themes appropriately and accurately in familiar contexts	Thorough Employs formulas, procedures, principles, or themes accurately, appropriately and/or creatively in new contexts
Conclusions and Evaluation	Illogical Attempts a conclusion or evaluation that is illogical or inconsistent with evidence presented, or omits a conclusion or solution altogether.	Reasonable Presents abbreviated or simple conclusions that are mostly consistent with evidence presented, with minor inconsistencies or omissions	Logical Clearly states and discusses conclusions. Organizes a conclusion or solution that is complete, logical, and consistent with evidence presented	Perceptive Clearly states and discusses conclusions. Considers implications and consequences of the conclusion in context, relative to assumptions, and supporting evidence. Provides reflective thought with regards to the assertions

Figure 7. Critical Thinking rubric (adapted from ABET workshop 2005)

Preliminary results using the *CCTST* are shown in Figure #9 for overall results. The reasoning skills Overall score describes overall strength in using reasoning to form reflective judgments about what to believe or what to do. High Overall scores are attained by test takers who excel in the sustained, focused and integrated application of core thinking skills measured on this test, including analysis, interpretation, inference, evaluation, explanation, induction and deduction. The Overall score predicts the capacity for success in educational or workplace settings which demand reasoned decision making and thoughtful problem solving, (www.insightassessment.com).

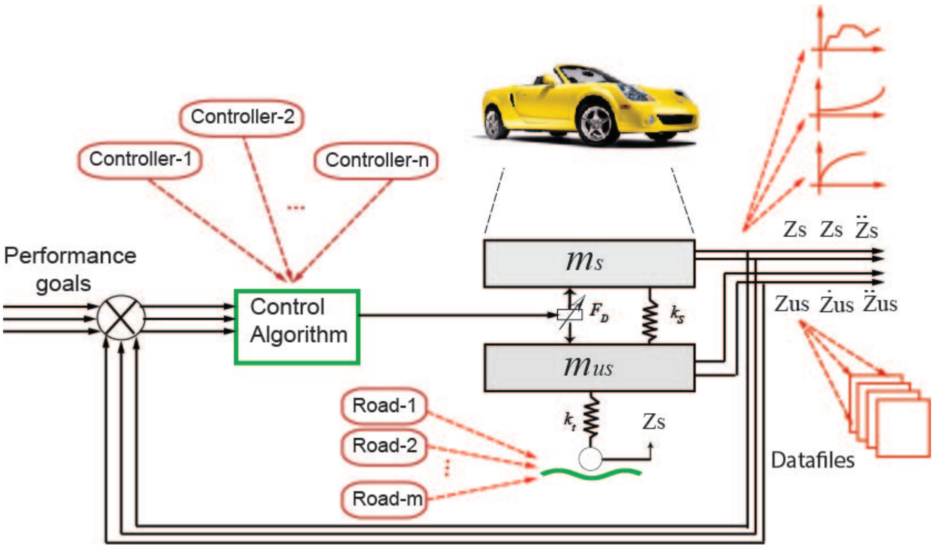
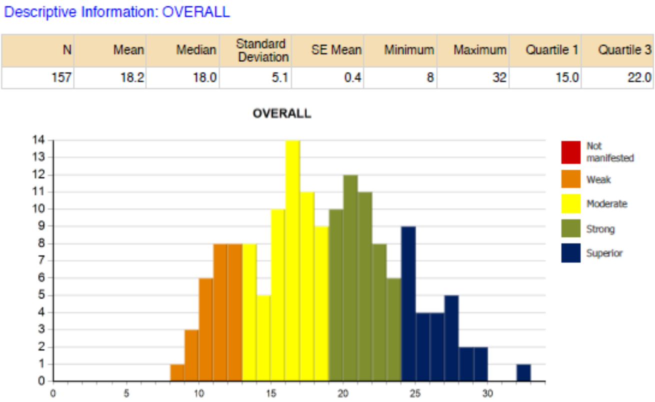


Figure 8: Control system

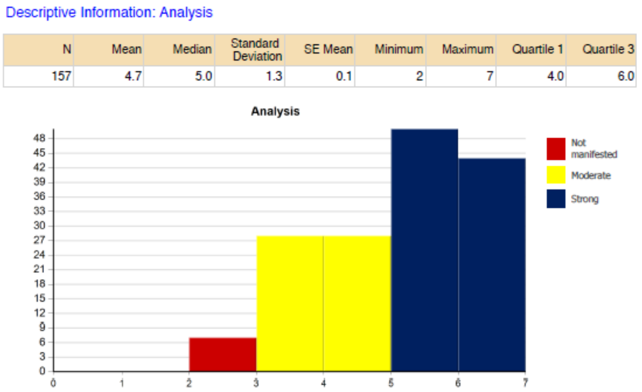

Descriptive Information: OVERALL

N	Mean	Median	Standard Deviation	SE Mean	Minimum	Maximum	Quartile 1	Quartile 3
157	18.2	18.0	5.1	0.4	8	32	15.0	22.0

Figure 9. Overall skill

Figure #10 for Analysis analytical reasoning skills enable people to identify assumptions, reasons and claims, and to examine how they interact in the formation of arguments. Analysis is used to gather information from charts, graphs, diagrams, spoken language and documents. People with strong analytical skills attend to patterns and to details. They identify the elements of a situation and determine how those parts interact. Strong interpretation skills can support high quality analysis by providing insights into the significance of what a person is saying or what something means, (www.insightassessment.com).

Figure # 11, Inference skills enable us to draw conclusions from reasons and evidence. Inference is used when we offer thoughtful suggestions and hypotheses. Inference skills indicate the necessary or the very probable consequences of a given set of facts and conditions. Conclusions, hypotheses, recommendations or decisions that are based on faulty analyses, misinformation, bad data or biased evaluations can turn out to be mistaken, even if they have been reached using excellent inference skills, (www.insightassessment.com).



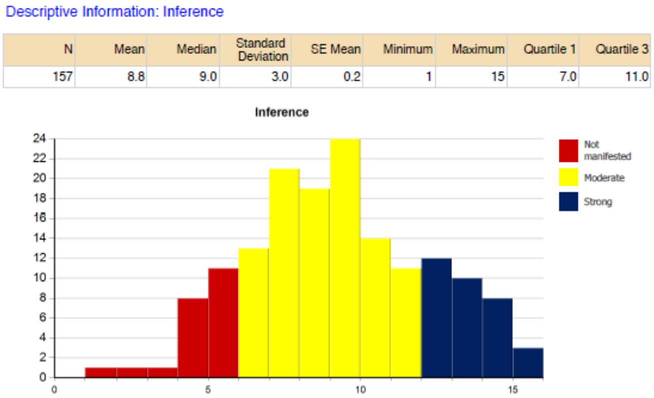
Descriptive Information: Analysis

N	Mean	Median	Standard Deviation	SE Mean	Minimum	Maximum	Quartile 1	Quartile 3
157	4.7	5.0	1.3	0.1	2	7	4.0	6.0

Figure 10. Analysis skill

Similar plots were obtained for other skills: evaluation, induction, and deduction. Even these results are good enough, more time is needed in order to see how the *CCTST* evaluations and learning outcomes are improving through the curriculum. This proposal is not an isolated project, there are several initiatives to develop competences in the students.

According to *ABET* (engineering technology programmes criteria #2 'a to k' and criterion #8) an engineering technology programme must demonstrate that graduates have several outcomes, (www.abet.org). This could be enriched with an occupation specific competencies to trigger meaningful curricular modifications like the competency-based curricula to render them more explicit than generic and thereby help the engineering educations institutions to produce "work-ready" graduates with greater degree of employability for the industry, (Earnest, 2005).



Descriptive Information: Inference

N	Mean	Median	Standard Deviation	SE Mean	Minimum	Maximum	Quartile 1	Quartile 3
157	8.8	9.0	3.0	0.2	1	15	7.0	11.0

Figure 11, Inference skills

For developing Problem-Solving skill, we use a standard research-based problem-solving strategy across several challenges, solve some problems in depth, and help students make connections between the problem statement, the identification of required technical knowledge, and the problem solution, (Woods, 2000).

For developing Teamwork skill, we use a structured approach to teamwork like cooperative learning where the team assignments assure positive interdependence, individual accountability for all the work done, face-to-face interaction, development and appropriate use of interpersonal skills, and regular self-assessment of team functioning, (Woods, 2000)

4.4 Related work

The Institut National Polytechnique de Grenoble (*INPG*), France has a similiar *QoV* experimental test bench. They are using the XP Windows *HMI* provided by SOBEN^{TM} which is very easy but is restricted to: (1)

limited number of road profiles, (2) General state space based controller, and (3) there are not real time plots. They have 4 test benches for academic purposes.

Also, Gipsa-Lab at INPG has a 1:5-scaled baja style racing car, which represents a full vehicle including wheels, engine, steering, breaking system, and the key element a SA suspension system, Figure #12. This experimental platform has two computers: (1) Host computer where the user sets the initialization parameters, configures the desired road profile, implements the suspension control algorithms, and records the acquired data; and (2) Target computer where the control algorithms are compiled and executed in a RT operating system (xPC targetTM). This is an excellent experimental system for research purposes with a open software. Similar experiments can be done to our proposal, but the needed time for learning the use of experimental platform and the needed time for developing and implementing the tests is excessive high for educational purposes.

The University of Bundesweher at Munich, Germany has a similar experimental *QoV* model to us. They are researching about chasis control systems looking for optimal solutions in rough roads. They developed an HMI based on C++. This platform has an open code: (1) to interact with sensors and actuators, (2) to implement non conventional controllers, (3) to design new road profiles, (4) to plot simultaneously several signals, and (5) to compare real and simulated results on real time. Similar to Gipsa-Lab approach, the main purpose is research only.

The essential difference of these related works to us is: (1) the HMI which was designed for academic purposes (Plug & Play Approach) based on a teaching technique and (2) the software that support the HMI, which is the result of two PhD dissertations: (Lozoya-Santos, 2013), (Tudón-Martínez, 2014). An important constraint of our proposal is the cost of the Dspace^{TM} card; however, there are cheaper options.

Figure 12: 1:5-scaled baja style racing car at Gipsa-Lab at INPG

5 Conclusions

A proposed educational technology was developed for a tailored Competency Based Learning exploiting a Plug & Play approach. The Plug & Play approach simplifies the used of an experimental *QoV* model where the academic program is based. The Competency Based Learning allow students: to establish a link between theory and practical experience, promote the critical thinking in all its dimensions (inference, deduction, abduction, etc.), teamwork and solving real problems and develop/potentiate the interest for research. Even these are preliminary results that demand more analysis, they are very promising because the high motivation of students and the successful experimental results the validated the learning process and the developing of some skills.

Acknowledgements

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The fieldwork as a strategy for skills development and problems perception

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Extended Abstract

1 Introduction

The curricular structure of Environmental Engineering course, from University of Caxias do Sul, is composed by lectures and disciplines focused, among other things, on diagnosis, planning, management and intervention of environmental issues. All these activities are aimed to prepare students to professional life, enabling the development of necessary skills and competences related on problems perception.

The environmental engineers are professionals that must be able to recognize and identify anthropic problems and their consequences on ecosystems balance and on people's life quality, designing solutions that must be technical, economic, social and environmental viable. Thus, learning the basic concepts on natural functions is crucial, as well as the development of abilities to observe and interpret environmental condition (SCHNEIDER, GIMENEZ, STEDILLE, 2008a; 2008b; GIMENEZ, 2008; MUNIZ, GIMENEZ, 2007; SCHNEIDER, GIMENEZ, 2011).

Among the lectures and disciplines proposed at curricular structure, it stands out those that contribute with the student's comprehension of basic concepts, like Environmental Fundamentals. This lecture has the goal to support the ecosystem concepts and weave their relationship with environmental sanitation, enabling the development of basic professional skills.

In this context, the Environmental Fundamentals III discipline allows students to experience a range of fieldwork and laboratorial activities, using the problem-based learning (PBL) methodology, which enables the development of essential employability skills, since they are faced with the same daily challenges that professional life. It is focused on the contact between students and different regional ecosystems, through observation, monitoring, recording, analyzing and notification of observed cases; and on the solutions proposition for the identified negative environmental impacts (SCHNEIDER, GIMENEZ, STEDILLE, 2008a; 2008b; GIMENEZ, 2008; MUNIZ, GIMENEZ, 2007; SCHNEIDER, GIMENEZ, 2011).

This paper has the purpose to identify the significance of fieldwork activities on environmental engineering students' formation, through evaluating their impression about the activity and used methodology.

The evaluated practice was a three-day fieldwork activity, where students traveled through a pre-established route that involves the following formations: Shadow and Atlantic Forest, Mountain Fields, Nebular Forest, Swampy forest, Dunes, Salt Wetland, Mountain Rivers, Lakes, Lagoons and Ocean. During this immersion, the students were stimulated to observe and compare the structural features of each environment, and to monitor the physical and chemical parameters in aquatic ecosystems (pH, electrical conductivity, dissolved oxygen, temperature, luminosity, nitrite, nitrate and ammonia) in order to identify the influence of anthropic impacts on these environments.

It is expected that students develop the ability to observe the environment, connecting the base knowledge about ecosystems with the impacts caused by human activities, proposing actions to mitigate or repair them. For this reason, it has been chosen the problem-based learning methodology, to allow the development of abilities to solve environmental problems. Using real cases makes the exercises more interesting to students, approaching the professional reality.

After the fieldwork activity, students were divided into groups and stimulated to develop a descriptive report about the visited environments, which should be based on theoretical knowledge, field notes and impressions. Still, the data collected during the practice activities must be presented in a systematized way, as well as its interpretation. Lastly, the groups were requested to describe the environmental impacts observed (diagnosis step) in different natural formations, and the mitigation, preservation and/or conservation actions (prognosis step).

2 Methodology

In order to evaluate the significance of fieldwork activity to the environmental engineering students formation, according to its opinion, it has been applied a data collection instrument, which is composed by 18 quali-quantitative questions. The questions were elaborated in order to understand how significant students considered the fieldwork activities for their vocational training.

The questionaries' application occur in the end of the lecture's period, after to complete the mandatory schedule. The students who participated in the fieldwork activity were oriented to answer the questionnaire individually, sincerely and anonymously.

The results were evaluated and systematized according to statistics' basic rules and are presented on section results.

3 Results

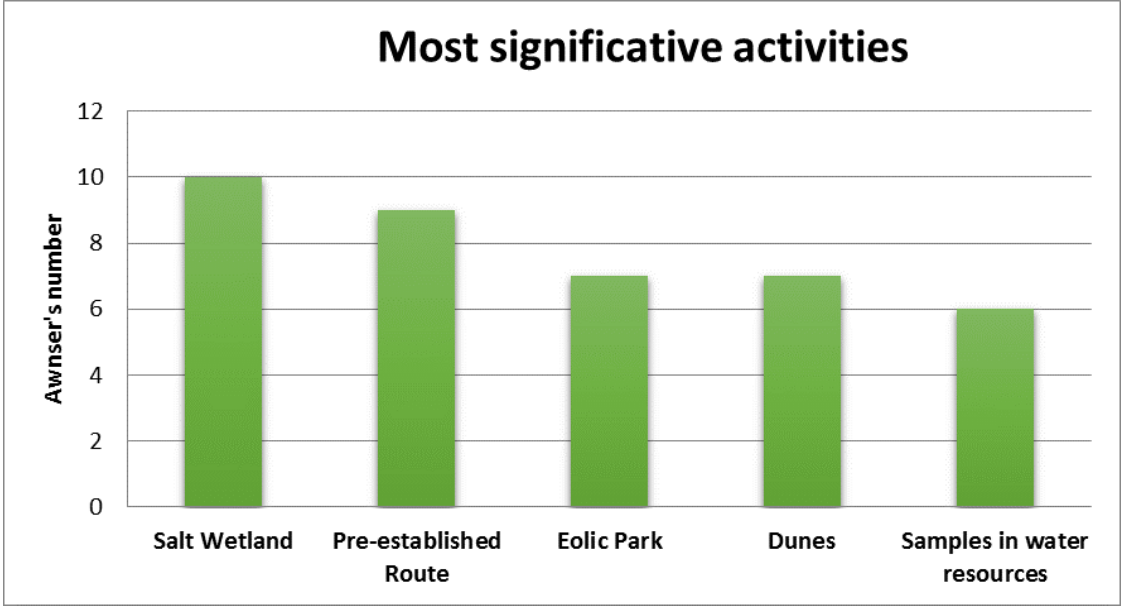
All the fieldwork participants (12) agreed to answer the data collection instrument, whose predisposition to answer it can be interpreted as an indication that students felt engaged by the activity. Approximately 80% of them considered that the fieldwork activity, as a hole, contributed fully to their vocational training as environmental engineers. The remaining 20% believes that the activity just contributed partly to their formation. It is important to stands out that none participant considered the activity irrelevant or unnecessary, confirming the convergence of the activity to the methodological assumptions of the course.

According to students, the activity had a great impact on developing their abilities of integration and interactivity. Still, through its implementation, they affirmed to had develop respect to different opinions and learn how to work with different professionals, since students from biology course also participated in the activity. These are important abilities to all professionals, but especially to environmental engineers, since normally they occupy the role as coordinator in multidisciplinary teams and, in this case, they need to be prepare to work with different professionals.

Specific about the activities held during the fieldwork, the results show that participants had a partial-clear comprehension about the correlation between them and their future performance as engineers. However, this result is acceptable and justifiable, since the Environmental Fundamentals III is a lecture allocated in the curricula's beginning. Nevertheless, in future editions actions must be taken in the order to clarify the correlations.

Figure 1 shows the most relevant activities held during the three-days fieldwork, according to students, who could pointed out three alternatives. The figure shows that there is no big difference between the students' perceptions, which means that all activities were equally considered relevant for the professional development. Still, it is important to stands out that none participants answer that all activities were useless. Salt Wetland was the most significant activity held on during the fieldwork activities, according to students. This answer has been correlated with the specific methodology used in this activity, through which students are challenge to see the Salt Wetland from within it, to observe the environmental impacts from inside and to feel the anthropic pressure from the point, using their senses: seeing, hearing, feeling and smelling.

Figure 1 – Most revelant activities held during the fieldwork.



Related with water monitoring activity, all participants considered it relevant, although less important than other activities, as it can be seen by Figure 1. Nevertheless, the activity achieves its goal: to enable students to identify differences between different ecosystems: Salt Wetland, Mountain Rivers, Lakes, Lagoons and Ocean. It is important to stands out that this activity enabled to discuss and compare the water parameters from different ecosystems, as well as discuss about its weakness related to human actions.

The eolic park activity, as well, fulfilled its function: to demonstrate that even planned engineering work has environmental impacts that must be identified and mitigated. However, some misunderstandings were identified, since few students believes that there is no environmental impacts on local ecosystem because the way to produce energy is *clean*. Even the energy has been obtained through a clean route, there are impacts related to the enterprise implementation and operation.

According to students, the most relevant engineering works constructed at the pre-established route in order to minimize the environmental impacts – since the ecosystems have great relevance across the route – were underpass for wildlife, tunnels, bridges and viaducts. This answer highlight the importance that the pre-established route activity had to students, confirming the data showed on Picture 1. Other works realized, as booms and recovery of local vegetation, were less relevant to students. It is expectable that students who are starting their studies have less autonomy to understand more subtle aspects, as shown.

4 Considerations

The evaluated results demonstrate the relevance of the participants' involvement and the importance of the fieldwork activity to their vocational formation. The results demonstrate, also, the development of necessary skills and ability to environmental engineer performance, although sometimes they are unclear to students.

Activities involving more significant and intense experiences have shown to be more relevant to students. The problem-based learning methodology proved to be effective in the students' wake to environmental problems and to develop their ability to propose solutions.

Discipline's next editions should take into account the necessity to highlight which skills, abilities and competences are important for an environmental engineer, correlating clearly the activities held on during the discipline and the expected results in their professional performance. This indicates that the Introduction of Environmental Engineering discipline can be somehow failing on demonstrating to students the completely professional work field.

The significance evaluation of these activities will continue to be measured in the future, but the questions from data collection instrument will be revalued, in order to minimize the answers'' subjectivity.

Keywords – development of ability, skills and competence, environmental observation, environmental engineer performance.

Session Type: (   ) hands-on session (   ) debate session (**X**) poster session

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Solid waste workshop as a tool for sanitation awareness and inclusion

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Abstract

The characterization of domestic solid waste allows to identify the amount and typology of each residue generated, and thus, to choose the best treatment options possible in one municipality. In this context, the establishment of a solid waste characterization workshop to students of chemical, civil and environmental engineering aims to provide a reflection-action moment to the participants, oriented to residue classification and segregation; and identification of social, economic and environmental impacts associated with inadequate waste segregation. The workshop has been developed by using the precepts of active learning, encouraging students to interact, reflect and make decision across by segregation of municipal solid waste, which are represented by sheets with pictures or clippings of wastes. The workshop contribute with the formation of individuals environmentally conscious, able to reflect about the impacts of their actions on the environment, and to make better decisions based on it.

1 Introduction

The expression "trash" refers to materials that are no longer good and no have aggregate value. It has gradually been replaced by the word “residue” or “waste”, referring to materials with potential for utilization through reuse, recycling or composting. However, due to misinterpretation of the info received by the population, its segregation and discard are still not completely efficient. Many factors play a role on waste generation, among which can be listed: number of inhabitants, purchasing power, climatic conditions, habits, behavior and educational level, seasonality, amongst other (D’Almeida & Vilhena, 2000). Damghani et al. (2008) mention that the increase of residue generation – result of increasing population –, associated with the lack of managing techniques, pose a challenge to the public administrations.

According to the art. 19, subsection XIV of the Federal Law 12,305/2010 (Brasil, 2010) – that establishes the National Policy on Solid Waste – the municipal plan for solid waste integrated management must provide goals for reduction, reuse, waste sorting and recycling, amongst others, in order to reduce the amount of rejects sent to environmentally proper disposal. In order to allow this, the involvement of population is essential, as well as the government, which should create an appropriate management model. The success of any solid waste management system requires environmental education actions, since the decision power rests on the generator. In the case of urban solid waste, the population, as a whole, must be educated regarding the correct segregation, printing a high efficiency level on the system.

Streb, Nagle and Teixeira (2004) assert that, in order to elaborate practices that minimize the generation of residues, it is necessary to know their composition, quality and quantity. Qualitative/Quantitative characterization data allows to identify the amount and typology of each residue generated, and thus, to choose the best treatment options possible. Such information is essential to the physical design of an efficient treatment system, resulting in a qualified management structure (Schneider et al., 2011). According to

Schneider et al. (2009), the determination of the urban solid wastes' gravimetric composition is important in the initial stage of implementing a management system, as well as after its implementation, since the results indicate the progress made and how effective the system turns out to be.

In this context, the establishment of a solid waste characterization workshop aims to provide the students a reflection-action moment, oriented to: residue classification and segregation; and identification of social, economic and environmental impacts associated with inadequate waste segregation. It is expected that these reflections have a relevant impact on generators' actions, mainly upon their freedom to choose to generate – or not – residues; to search for alternatives to reuse; to decide how to segregate waste and how to proceed to send it to the best disposal possible.

The aim of the article is to present a work strategy for a workshop, planned as a reflection-action activity, for the purpose of contribute with the formation of individuals environmentally conscious on the solid waste subject, able to reflect about the impacts of their actions on the environment, and to make better decisions based on it.

The method used as a reference for promoting the students' reflection-action followed the precepts of active learning. According Bonwell and Eison (1991), active learning is generally defined as any instructional method that engages students in the learning process. In short, active learning requires students to do meaningful learning activities and think about what they are doing.

2 Metodology

The workshop has been developed by using the precepts of active learning, encouraging students from chemical, civil and environmental engineering to interact, reflect and make decision related with solid waste issues. The working group consists of 20 students, which are divided into 4 groups. The materials required for the workshop's achievement are listed: tickets with illustrative figures; plastic cups tagged as recyclable, organic, disposable and special; blackboard; chalk; pencil; calculator; and sheets for notes. The course is developed in 4 stages, adding up 90 minutes at total.

At first step, the mediator holds a brief presentation (10 min), addressing the following themes:

- growing of world population;
- typology of the materials;
- waste composition;
- quantities generated;
- the 4R's (reduce, reuse, recover and recycle);
- recycling;
- agregate value;
- legislation;
- urban colleting system;
- waste disposal.

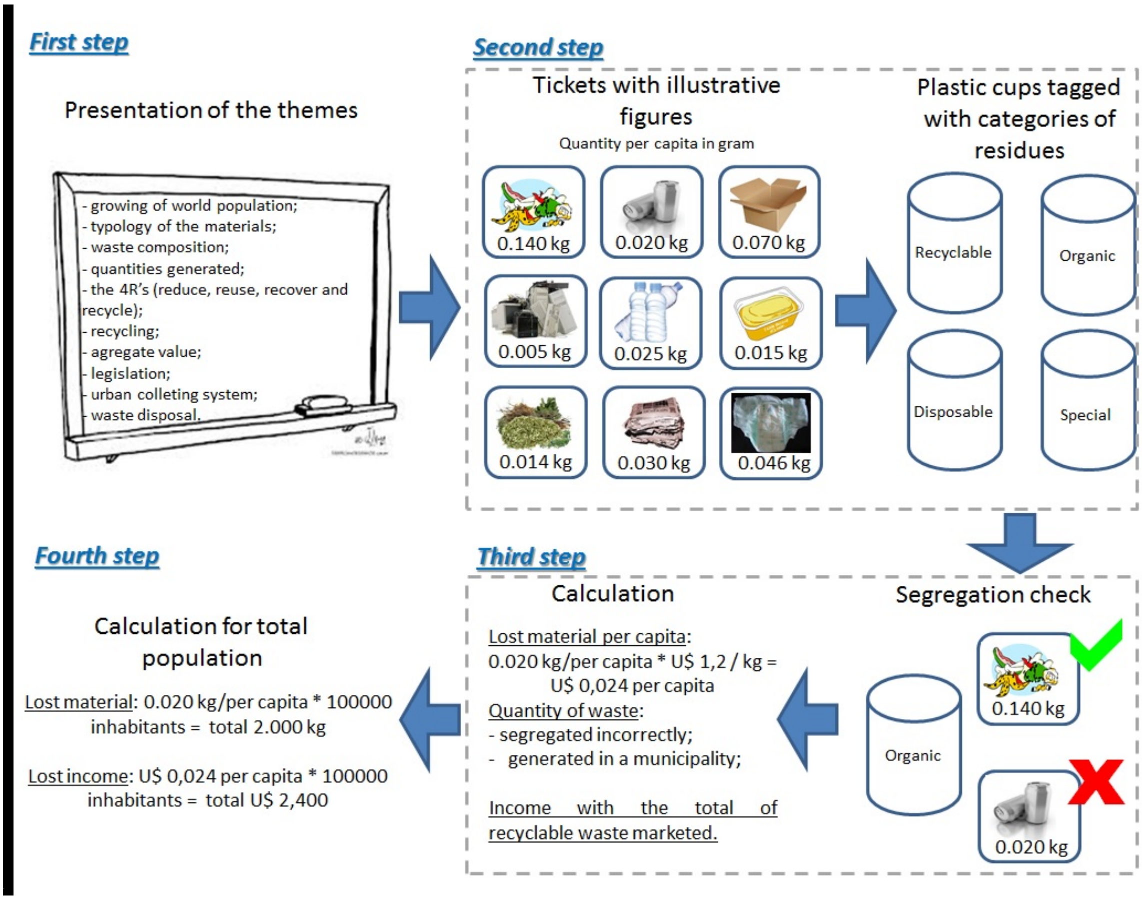
This initial conversation has the purpose to acclimatize the participants on the working theme, as well as level their knowledge about the topic, seeking for better results. At this point, comments, explanations and cases stated by students are allowed and encouraged.

At a second step (30 min), students are asked to segregate the waste, whose different types are represented by tickets with illustrative figures. The categories of residues considered in the workshop are organic, recyclable, disposable (including rejects and mixed) and special. After this activity, it is provided to each group identified containers, for each waste category. At the end of this step, the groups are encouraged to discuss about the composition of the waste and contamination thereof resulting from bad segregation, and performed segregation.

In a third step (30 min), the potential income from the sale of different types of recyclable waste is determined. The income is calculated with the use of the different waste market values, obtained in waste sorting plants, and its mass value (in grams), given for each illustration. The value corresponds to the per capita total daily generation of the residue. Based on these data is calculated the quantity generated month and year. Furthermore, based on the quantity of recyclable waste incorrectly segregated by students, is estimated the amount of material with recyclability potential is lost. Based on the quantity of recyclable materials generated is calculated the value that could be obtained from the sale thereof.

Finally, in step 4 (20 min), the obtained values to each residue categories, the potential income resulting of their sell, and the loss of material resulting of incorrect segregation are extrapolated to the amount of waste generated by different populations (20,000 – 100,000 – 500,000 inhabitants), which allows the student to identify the different municipalities' environmental impacts, depending on their sizes.

A summary from the steps described above is presented in Picture 1.



Picture 1. Summary of workshop development stages.

3 Expected Results

It is expected that the methodology allow students to develop a sense of responsibility, environmental ethics, as well as the ability to take decisions and to analyses the problem aspects, as well as overcome the much criticized separation between theory and practice (Freitas, 2012). Still, it is expected that the participants develop a critical awareness regarding to the waste discard; the identification of the economic and environmental impact related with the incorrect waste segregation; and which are the ways to contribute with a proper waste disposal. All these actions lead to the success of the local management system, with positive impact on environmental quality and on life's quality.

Keywords - waste disposal, environmental education, waste composition

Session Type: (X) hands-on session (   ) debate session (   ) poster session

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PROBLEM-BASED LEARNING APPLIED TO ENVIRONMENTAL PLANNING AT ENVIRONMENTAL ENGINEERING COURSE

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Abstract

This study demonstrates the application of the learning methodology based on solving problems in the Environmental Planning discipline to the course of Environmental Engineering of a community college in southern Brazil. Search up with it, demonstrate a new working method that will contribute to the development of student skills and identify the methodological validity and its place in the curriculum of the course. Positive results indicate that the proposal is replicable and should be incorporated into the design discipline. The method has allowed the development of skills such as cooperation, communication and teamwork, often criticized for its absence among students.

Keywords: Problem-based Learning, Environmental Planning, active learning

1 Introduction

The development of skills, abilities and competences to work with environmental questions requires a focused learning on the perception and analysis of phenomena, the developing of models, the proposition of new techniques and its application for problem solving. Learning, in this context, should be meaningful and active, by stimulating self-development and autonomy in pursuit knowledge, transcending the traditional teaching based on ready and finished knowledge, which makes part of our culture, science and society (SOARES, 2008).

The Environmental Engineering courses, particularly, require a differentiated student profile, which are challenging courses and institutions to search and apply new teaching and learning methods. The problem-based learning and project-based learning methodologies are tools for significant and active learning, since they have favourable ideas for needs of professional training, and can generate innovative teaching practices, overcoming the limitations of traditional teaching models (BARBOSA e MOURA, 2013).

The problem-based learning (PBL) arose, initially with studies of Barrows and Tamblyn (BARROWS; TAMBLYN, 1980; WHITE, 1996), and consists of an educational method that makes use of real-life problems, what serves as a stimulus for the development of critical thinking, problem-solving skills and learning the concepts that make up the curriculum.

Since in this method the student takes the center stage, the PBL emphasizes learning rather than instruction. It allows students to learn from a problem – real or simulated –, and to interact with peers, search for information, formulate hypotheses, make decisions and issue judgments. The students' involvement in in finding solutions for the problem make them increasingly responsible for their own learning.

Among the strategies that can be used to achieve active learning environments in classrooms, Bonwell and Eison (1991) emphasize teamwork, with tasks that require collaboration of all participants; case studies related to specific training areas; modelling and simulation of processes.

In opposition to the most common education methodologies used by Brazilian universities, which are normally supported by exhibition-dialogue classes, this study presents the results obtained by applying a problem-based learning methodology in an Environmental Planning discipline from the Environmental Engineering course. The work aims to demonstrate a new working method that will contribute to the development of student skills and identify its methodological validity, as well as insertion at the curriculum of the course.

2 Metodology

The tools used into the development of this work followed the conceptual lines presented before, and uses the active learning as a model for the Environmental Planning discipline. The discipline goal is to equip students with different techniques and process for decision-making, in order to promote environmental planning as a key element for environmental management. Still, it aims to develop and improve the critical thinking on environmental themes that are considered relevant for the planning practice. The subject planning is working under different approaches: urban, rural, regional, by watershed, by municipality, etc.

As a tool for developing the active learning principles, it was proposed to students the developing a Basic Sanitation Plan (PMSB, in Portuguese) for a municipality whose reality was different from their residence municipality. Programs, projects and actions that include modifications, expansions and improvements to be proposed for the four basic sanitation components composes the PMSB.

In this context, students were divided into teams to cover the four different areas that make up the basic sanitation: water supply, sewage, solid waste management and rainwater. The students worked with a municipality located on northeastern Brazilian semi-arid region, which suffers with adversities arising from water scarcity due to the local climate.

The first step involved the student by presenting the theoretical background and, sequentially, the development of the plan itself in a 10-week period. At this stage, the challenge was to search for information that could base the diagnosis, immersing into the reality of the target municipality, and the scenarios proposition involving projects and actions to be implemented in short, medium and long term.

Using the most different sources of research, students were overcoming the challenges of limited information available, establishing data correlations with other municipalities and regions, as well as cooperatively establishing relationships with other groups to exchange information. Still, the faculty members who previously developed history knowledge on the challenge subject were consulting. Finally, the activity impact on students' learning was assessed through a survey instrument based on the questions presented in Table 1:

Table 1: Questionnaire

Based on the activities and proposals developed in the Environmental Planning discipline, evaluate:

a) The purpose of the discipline
b) the content developed during the semester
c) The development proposal of a Sanitation Plan
d) The student involvement in activities (self-evaluation in the development of Sanitation Plan, based on participation and knowledge acquired)

3 Results and Discussion

The engineering education, historically, follows the traditional perspective on training engineers. It uses deductive teaching approaches that involves the introduction, by teachers, of the topics normally related with general principles, which are used on derivation of mathematical models, and the illustration applicability of these models. Little emphasis has been given, for example, to the phenomena that models can explain in the real world; to the practical problems that models can solve; or the importance of them to students working life (CASALE, 2013).

The problem-based learning methodology applied to a 24-students class of the Environmental Planning discipline allowed them to explore real-life situations, with emphasis on problem solving and teamwork, developing educational skills that will enable to face the ever-changing world.

The impact of the activity upon learning, evaluated by the research instrument, enabled to indetify two situations: the challenge of relevant information searching for planning in places with little available information; and the awakening to another reality in which the essential element for the sanitation, the water, has its availability restricted.

This model also challenged students to learn how to learn, working cooperatively in groups to find solutions to real problems. Problems stimulate students' curiosity and initiate the learning of concepts, whether the subject or course, preparing them to think critically and analytically and to find and to properly apply learning resources (DUCH, 1996).

With the applied questionnaire, it was possible to obtain feedback from students, who mostly found the proposal interesting, mainly because it is innovative and by enabling the association between the discipline theories to a practical model of learning. It stands out the comments regarding to the model acceptance, since according to students the proposal provided them opportunity to been in contact with a professional situation, by a practical action on problem solving, as well as enabling the constant participation in the discipline.

Another point to be noted is related with the methodology application that allows students to build their knowledge while working in a coordinated group, contributing to develop the social-emotional skill that must be expanded in Engineers. They must to learn how to defend their ideas, but at the same time to be open to new ideas and opinions, so that the group can achieve the proposed objective.

Furthermore, it was observed that the proposed practice contributed to (SIQUEIRA et al., 2009):

1) **meaningful learning:** students were able to relate the learned content to prior knowledge from other disciplines or during the concepts set out at the discipline itself. The Plan elaboration to a city with distinct reality allowed breaking paradigms, established from the emergence of new challenges, which were presented by critical analysis, leading the learner to overcome their experiences (preconceptions, previous syntheses and others) and expanding their knowledge (AUSUBEL et al, 1978; STRUCHINER et al., 1999).

2) **the inseparability of theory and practice:** as the problem situation was presented and conditioned to reality and current needs, students demonstrated the need for theoretical-practical integration, because as pointed out by them, without the prior theoretical knowledge, the problems' solution would be more complex. In general, most felt the need to learn most basic concepts, and that they were presented in a more objective way.

3) **respect for student's autonomy:** a methodological proposal allowed stimulate the learner to take responsibility for their education. This has been exemplified in the implementation of Sanitation Plan, in which students had to develop a product, to judge their relative importance and to bear in front of an audience for presentation of the product elaborated by his group.

4) **the importance of teamwork:** students could understand that his group corresponds to a discussion forum, in which it possible to learn about human interaction, thus becoming an opportunity to learn how to listen, receive and assimilate criticism.

5) **continuing education:** it is known that a discipline or the union of several disciplines are unable to provide all the necessary knowledge to the subject in training. Thus, it is more productive to solve problems that professional practice enabling them to solving the most different problems than acquiring a series of content, which may be obsolete a few years after the completion of undergraduate (VENTURELLI 2003; SIQUEIRA-BATISTA, 2007).

6) **formative assessment:** it is important to note that the involved actors should always take into account the self-assessment, based on the judgment, in a perspective of continuous reflection on practice

(VENTURELLI, 2003). With the survey conducted, it was found that most students assigns itself a nearby middle note to 9 scale of 0 to 10, essentially due to the active role during the course of work.

Positive results indicate that the proposal is replicable and should be incorporated into the design discipline, as with success in engineering courses in many countries (AHERN, 2010). The method has allowed the development of skills such as cooperation, communication and teamwork, often criticized for its absence among students (Veldman et al., 2008).

However, despite the pedagogical practice be innovative, can often pose a threat, as the unknown frightens immediately, but brings new horizons and possibilities for change, which could be identified through the student account.

4 Conclusions

The PBL proposal in the context of the Environmental Planning discipline broke paradigms in the current formation of the Environmental Engineer. Despite the experience of a new learning methodology have brought good results in terms of learning, was not very favourable at the conclusion of the product, which corresponded to the reorganization plan, missing greater integration between the working groups and time of performance.

Still, the change of attitude in the teaching, given the dissatisfaction with the usual teaching method, which has proved inefficient to prepare future engineers is an important aspect of teaching competence, promoting the initiative in the use of PBL as new method and teaching.

As a contribution to the improvement and development of the application of this methodology in the discipline of Environmental Planning and other disciplines of the Environmental Engineering course, it is suggested improving activities, quizzes and its use in other classes, which will show more details how the PBL develops in the teaching and learning processes in the universities of engineering.

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LABORATÓRIO DE ENGENHOCAS: EFFICIENCY HISTORY IN THE IMPLEMENTATION OF METHODOLOGY PBL

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Abstract

A Engineering is one of the most complex areas of study, as well as of great importance for socio-economic development of a country, so a student who enters the course needs to have proactive profiles and creativity to solve efficiently everyday problems, always aiming at environmental responsibility. Based on this, the program "Laboratório de Engenhocas" of University Federal of Pará – UFPA, campus Tucuruí, It aims to encourage students of high school of Public Schools City By Interest by Exact Sciences through the application of PBL Methodology (Problem Based Learning), using experimental methods aimed at teaching in order to encourage them to join in engineering. Due to this, positive results were obtained, among them the construction of a solar heater made of recyclable material, which provided an alternative to the poor society, a Van Der Graff generator developed with accessible materials and a green filter , softening the problem of drinking water in the region. These projects were submitted and approved by FEBRACE (Brazilian Fair of Science and Engineering) . Later the program gained ground in the city of Ananindeua, specifically in EEFM Eneida de Moraes, which were carried out new activities and projects, such as a gas monitoring sensor, to prevent the leakage of LPG, and a motorized wheelchair to disabled people with economic vulnerability, both made with Arduino, a device that helps in basic learning and creation of low cost projects. . These projects were sent to FEBRACE and are under evaluation and were presented at the first fair of Sciences on school with the theme "Technology: Science, Life and Learning". The relevance of PBL methodology is justified since the efficiency obtained by the Laboratório de Engenhocas stands as an active learning model.

1 Introduction

The education of exact sciences intended for high school should be administered so that it can encourage future professional decisions in students, in such a way that creates a solid foundation and fundamental to academic life to follow. However, this concern is not usually relevant in several schools; it is considered only the literal teaching of basic subjects. Much of this is due to the difficulties encountered by teachers to manage interactive lessons that diversify the conventional model of education, especially in Physics, Chemistry and Mathematics that are the basis for engineering and technology courses.

Graduation In Engineering and Technology courses has Enough Emphasis in Physical Sciences disciplines As the Mathematics , Physics and Chemistry and due Upon learning deficit That Behind the student Medium Level , are Difficulties disciplines Fundamentals Course Structure and in many cases is the main reason that prevents progress in the disciplines or even the waiver of them. So, it was necessary to the implementation of educational alternatives to resolve the difficulties mentioned, but also instill in them the duty of social responsibility; one of the alternatives was the use of PBL methodology (*Project Based Learning*).

The PBL is a focused learning methodology that provides the student with the acquisition of critical knowledge, proficiency in problem solving, learning strategies and participation skills. Since it requires proactivity of the student, for it to look for knowledge in the various forms of delivery available and the solution of real problems from the team work , discussion and critical analysis(Campos *et al*., 2011).

Thus, using the methodology, teachers and students of the Universidade Federal do Pará created the Laboratório de Engenhocas, research program and extension, which aims to teach students to learn, be proactive and spark interest in science always applied taking into account the question of environmental responsibility. The program worked together in high schools of the city of Tucuruí , are they the State Preparatory High School Rui Barbosa and State Preparatory High School Raimundo Ribeiro de Souza. Initially a partnership to enable multidisciplinary laboratories of each school and promote their respective science fairs which some selected projects were approved for the Brazilian Science and Engineering Fair(FEBRACE 2014). Upon the successful implementation of the contraptions Laboratory on the campus of UFPA Tucuruí/PA , there was the expansion of the program to the campus of UFPA in Ananindeua in the State School of primary and secondary Eneida de Moraes , whose performance earned on project design who received national recognition after approving again to the new edition of FEBRACE 2015.

The projects proposed by high school students outline goals for solving everyday constant problems of local residents where they were developed. In the city of Tucuruí in the State of Pará / Brazil was presented the project "Water quality in the urban area of Tucuruí and the proposal to create a low-cost filter," which helped to remedy the deficiencies in the quality water supply that the city faced. With the project "Implementation of a Low Cost Solar Heater in the Amazon" was able to use the most abundant source of energy in the region to drastically reduce spending on electricity in a single-family residence with economic vulnerability. Already the project "Proposal for producing a generator of Van der Graaf low cost for the multidisciplinary laboratory of the School EEM Dep. Raimundo Ribeiro de Souza ," prepared by students to improve the Electromagnetism education for students of the third year of school , which helped to decrease the numbers of rejected students. The three projects were approved and presented in FEBRACE 2014. In Ananindeua, two scientific and engineering projects are being developed with an emphasis on quality of life of the city, are they "Automated Intelligent Wheelchair " and "System Detection and Monitoring of Liquefied Petroleum Gas Leak (GLP) and Other "using the Arduino , an electronic prototyping platform, which helps build low cost projects. These projects were presented at the first science fair organized by the school and approved for the new edition of FEBRACE.

The presentation of projects in Science Fairs was used because, according (Milhomem *et al., 2013 apud* Harel *et al.*,1991), people learn best when they are building a work that can be shared with others and upon which to reflect.

The program currently operates in two municipalities submitted and uses the PBL methodology as active learning strategy to create a teaching approach in which students can be proactive and awaken the critical knowledge.

2 Methodology

The Methods used by students of UFPA are to strengthen the link between the University and High School allowing the influence between the two institutions. In the selected schools were made meetings to set a schedule of activities and actions so that students would use the multidisciplinary laboratory, whose facilities were in the leisure and begin to become familiar with the scientific and engineering methodologies. Each student that forms part of the Laboratorio de Engenhocas presented some experiments for the other classes.

With the finalized schedule, the students of the Campus of UFPa in Tucuruí accompanied the High School students in the preparation and presentation of various educational games and scientific experiments made with inexpensive materials, in order to create a sense of environmental responsibility, which, according to (Caixeta& Souza, 2013 apud Pereira 2003, p.235) emphasizes community integration, involving teachers and students in the study of the local reality, in order to search for technical-political and practical solutions to the issues of community interest; it also fosters continuing education that strengthens critical consciousness, creative, technical and ethical, generating new knowledge; and supports the creation and cultural production, integrating the educational activity and the different social contexts of the region. These interactive games addressing various areas of teaching of Physics, Chemistry and Mathematics, which students tend to dislike about these subjects, yet they are the most relevant to the efficiency in the course of an engineering degree.

The partnership between learners of the UFPA/CAMTUC and students of the State High Schools Rui Barbosa and Raimundo Ribeiro de Souza rendered holding three projects approved and presented in the most important science fair in Brazil, FEBRACE 2014, held at the Universidade de São Paulo. In one, was made a qualitative analysis of supply and water consumption in the city, due to lack of treatment and quality monitoring system. The survey results revealed serious problems in the precariousness of water supplied to the population, such as contamination and dirty. Due it has been suggested and implemented the project “Water Quality in the Urban Area of Tucuruí and the Proposal to Create a Low-Cost Filter”, that is the creation of an efficient device in the process of filtering the water, using accessible materials, are they coconut fiber, acrylic blanket (Perlon), sponge, chlorine tablets (Cl) and activated carbon screen. The filter assembly process all these materials are set within a structure composed of adapters, plugs and PVC gloves threadable. Figure (1) outlines the filter frame

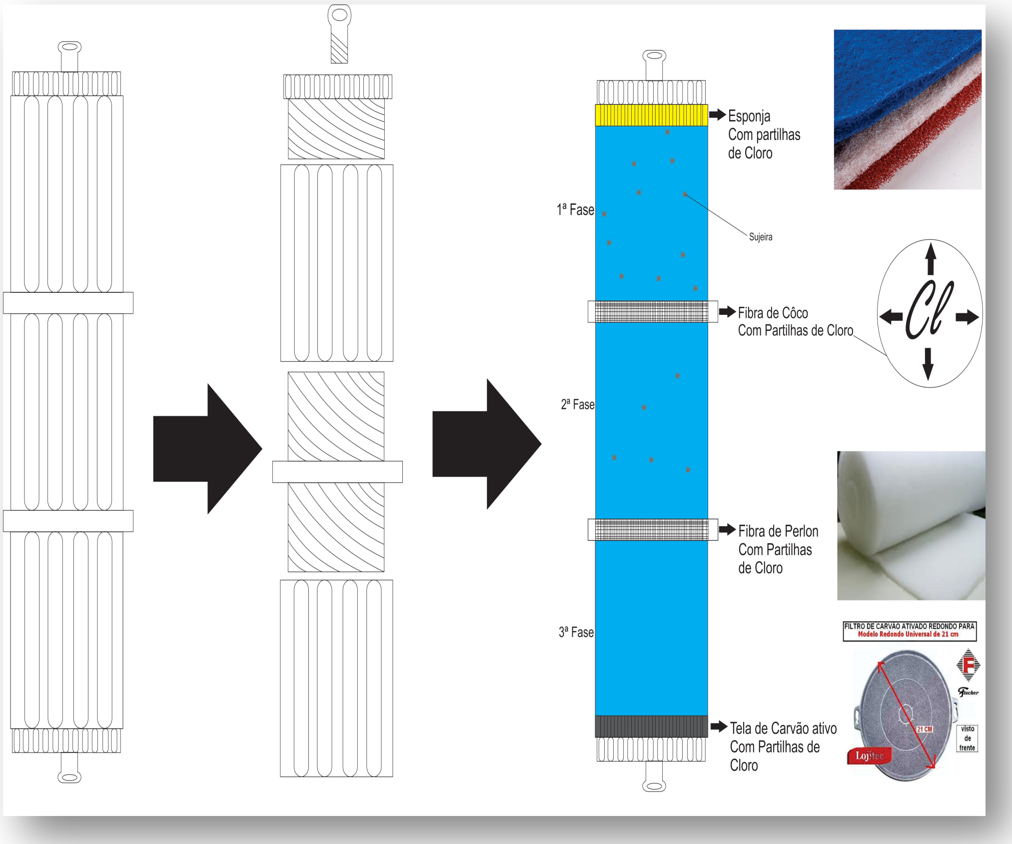


Figure 1. Filter Schematic Structure.

Figure 2 – External Structure Mounted.

The contact of students with practice exercised in afterschool program allows for ease of knowledge acquired in the classroom and induces them to be creative, innovative and exercise environmental education. In this case, they are related directly to the concepts of chemical reactions, acidity and alkalinity of the water.

The Municipality of Tucuruí is located in the northern of Brazil, located on the equator whose territory receives high levels of solar radiation during all seasons of the year. This source of natural energy and clean, despite abundant, is little used and should be an energy alternative to reduce the impacts caused by excessive use of electricity. Thinking about it, it was proposed the implementation of a solar heater made with sustainable materials in order to be installed in a single-family residence with economic vulnerability and needs of such improvements due to the presence of elderly. The project entitled "Implementation of a Low Cost Solar Heater in the Amazon" aims to take advance of the excessive incidence of thermal energy and help needy residents financially unable to acquire the industrial electrical equipment, replacing it with almost the same efficiency and significantly reducing energy costs account, in addition to the significant environmental gains achieved through the heater parts, since in its composition the first prototype was used 300 bottles PET's, 300 packaging Tetra Pak and 70 meters PVC pipe, which were collected by selective collection and task forces of collections.

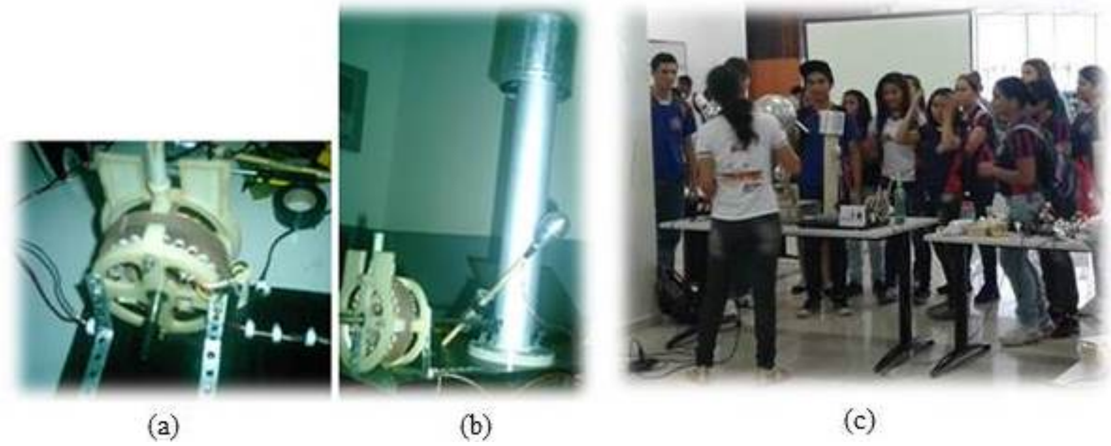
Figure 3 – End Plate of Solar Heater.

FEBRACE 2014.

gure 4 – (a) – Motor Coupled in the Structure. (b) – Model Generator Final. (c) – Presentation for High School Students.

The Figure (3) demonstrates the end results of assembly of the prototype that is 7 meters to 60 centimeters in length. The structure installed remains in operation reaching the expected effectiveness. It is extremely important that the educational advantage Low Cost Solar Heater provided on topics such as thermodynamics, fluid mechanics, hydrodynamics and heat transfer which were discussed experimentally, as well as reductions in spending on electricity and decreases environmental impacts.

Also in Tucuruí, a pedagogical study was conducted to find out what the subjects that most disapprove students and propose solutions to make them accessible. Among the most rejected, the teaching of Electrostatic was highlighted as worrying by students but also by the difficulty teachers with didactic. Thereupon, the students UFPA with the students suggested the project "Proposal for a production of a Van der Graaf generator of low cost for the Multidisciplinary Laboratory of State School Raimundo Ribeiro de Souza", in which a Van der Graaf generator would be constructed and accessible only with reusable materials such as aluminum pan, blower motor, wood and PVC pipe. Mounting of the equipment follows the standards of a Van der Graaf generator industrial, however as this costs high price, the construction of a using these materials becomes viable and intelligent because it can get similar results.



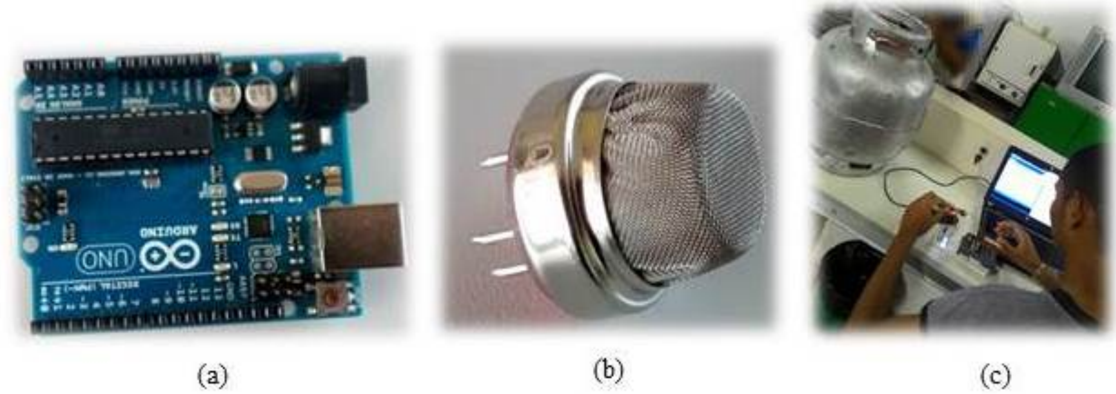
The three works were portrayed nationally recognized after being approved and presented in 13ª FEBRACE 2014. The Students, now Scientific Initiation Scholarship from CNPq, follow in front with the continuations and development of more innovative projects to solve environmental problems.

Due to excellent experience of the Laboratório de Engenhocas in Tucuruí, was planned for an expansion to the other schools and in other municipalities in the state of Pará, to application of PBL methodology as a form of active learning and to continue the work and research carried out in the program. The town of Ananindeua embraced the project in partnership with the State School Eneida de Moraes where teaching them and schedules already made in the municipality of Tucuruí Schools were promoted, pursued the same educational goals that occurred in the previous city.

The new projects created has as characteristic the alignment between the idea of quality of life and the application of technology in day-today, such as in the tittle “Smart Automated Wheelchair’’, which employs an automated wheelchair based on Arduíno electronic prototyping platform, allowing a better locomotion to people with disabilities or reduced mobility, mainly for the ones that uses the wheelchair with difficulty due to the absence of special systems to wheelchair user and poor streets infrastructure. The needs components are a Joystick (overall control gadget), an ultrasonic sensor (obstacle sensor and meter), infrared sensor (proximity meter), a Arduíno and a simple wheelchair. On the work plan an average cost has been drawn, approximately 78,7% under the purchase cost of a commercial automated chair.

The Arduíno, according to (Fernandes et al., 2013 apud Souza et al., 2011), is a hardware platform of easy utilization, ideally suited for creation of devices that allows the interaction with the environment, using as input temperature, light, sound sensors, and as output leds, motors and displays. That is why it has been used as a base to the proven projects. A emphasis to its application in the initiative ‘’Detection System and Monitoring of liquefied petroleum gas (LPG) leak’’, in which has been developed a monitoring system of gas leak, applying the Arduino platform, with specific safety purpose of the people involved and decrease of leak gas incidents statistics. The System identify the gas concentrations and send the data collected to an application in the Smartphone, constantly updating, and any concentration gas change can be noticed. The prototype consists in an Arduino kit, gas sensors, a Shield Ethernet (Arduino Accessoryable to connect in internet) and a sounder that will issue an alarm, alerting a gas leak occurrence and sending, in real time, the information to the Smartphone.

It is important to highlighted that both projects are in progress process, and them value the Family integrity in their homes, workplace and public space, keeping that people protect and prevented from the difficulties in urban mobility, accidents, fires and explosions. Even the projects are in deployment phase, the two has stands out, the “Smart Automated Wheelchair’’ has been presented at school Science fair on the theme “Technology: Science, Life and Learning’’, the ‘’Detection System and Monitoring of liquefied petroleum gas (LPG) leak’’ has been submitted and approved to the FEBRACE 2015 next edition.


(a) (b) (c)

gure 6 – (a) – Arduino Board; Fonte: Autor; (b) – Gas Sensor, Fonte: Autor; (c) – Presentation for High School Students.

To the projects confection process, the students took a “leadership role, editor, spokesperson and participating member in teamwork. The purpose was place them in real situations, even it was simulated, of professional life, which the managers operate, make written reports, oral presentations and work in group" (Filho et al., 2008), in order to promote the pedagogical progress on education method and motivate researcher character in students, to solve society problems, as confirmed by the direct participation of the UFPA learners, allowing the sharing and engagement with the knowledge gained on university.

The accomplishment of those scientific and engineering projects –with social-environmental intention- has become essentials to examine the results of PBL Methodology. In them it was possible to note the researcher instinct of each one, the force of teamwork and the benefits of an active learning, which, based on acquired knowledge, could be presented at school Science fairs, at first, and afterwards in the more relevant Brazilian Science and Engineering Fair.

3 Results and Conclusions

The ideal of a more interactive education based on active learning proposed by extension program Laboratório de Engenhocas and applied in two municipalities proclaims pedagogical innovation which comprises the use of science and technology associated with environmental responsibility. This methodology applied in schools was important as it demonstrates to the students that it is possible to acquire knowledge of attractive and motivating way, besides achieving the aspects made on the list of objectives outlined in the program still the beginning.

At the beginning of project implementation in 2012, several presentations of scientific and educational games experiments were performed, serving 48 high school classes and an average of 960 students. During this period there was the approach of school children with the University, due to the fact that students UFPA presenting the experiments.

The campus of the Federal University of Pará in Tucuruí has graduate courses in Civil Engineering, Mechanical, Electrical,Computer, and Health and Environmental. All of these areas of knowledge are quite present in the three projects carried out from 2013 to 2014, which some phases of their methodologies occurred on campus. This brought the students with the university in many cases revealed the campus, since many of the students did not possess knowledge of its existence. After the construction of the projects and,subsequently, the national recognition, the city campus was popularized and motivated students from the municipality itself to join in one of the courses, given that much of the university are from other cities in the region and not Tucuruí. In turn, living in step -by-step assembly of projects alone, attracted students involved in the project for the branch of Engineering, obtaining the approval of the entrance exam students in Naval Engineering, Civil Engineering and Electrical Engineering.

In Ananindeua was continued the same initial schedules made in Tucuruí and then the construction of projects. As the activities are still in progress, it cannot report conclusive analyzes, although the students perceive clearly the educational maturity, interest in environmental issues, initiative and proactivity, characteristics inherent in a graduate in engineering.

The role of tutors and teachers in active learning process were also beneficial because the teacher should not teach directly but to create teaching tools along with the students to make the environment conducive to learning. And so, through the lived experience of students in the preparation of projects various chemical, physical and mathematical concepts, They Could Not only hear but Also observe the operation in practice, setting more the content displayed, showing educators That You can make the lessons more attractive and exciting science from the pursuit of knowledge if the student earns, the teacher earns too.

Most projects and experiments in this article were made with alternative materials, recyclable and low cost. In addition, they intend to solve social problems inherent precariousness of the population. After the implementation of three projects in Tucuruí there were significant results as improvement in the treatment of water in some neighborhoods, reducing the impact caused by electricity consumption and diversification in the form of education of the students rejected by content. Because the projects in Ananindeua map targets for improving the population's quality of life, for the ease of movement of the wheelchair in economic vulnerability and the prevention of domestic accidents with the control of the gas leak. The environmental and social education shouldn't also be considered a form of active learning, because through it you can solve common problems Either Obtaining knowledge.

Overall, the program Laboratório de Engenhocas aims to promote and disseminate science and technology, leading to education in an accessible form, acting directly with schools to attract students to ace areas of science applied. It works like a real talent scout, since we should not lose outstanding scientists, engineers and professionals simply because there are no access to information, educational foundation at the beginning of a graduation or minimum consideration the social and environmental problems. Education, represented here, is required so that there is an evolution of the apprentice taking a proactive stance, critical, responsible, innovative and that can contribute to solving societal problems. Therefore, after the development of several scientific and engineering projects, attracting many students for engineering, diversification of the conventional way of teaching and education professionals who crave the development of science with the society, the contraptions Laboratory wins Featured as an eminent model of active learning, as well as praises in education in engineering from relevance in the use of PBL methodology.

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Active learning based on interaction and cooperation motivated by playful tone

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Abstract

The Derivative Circuit, presented in this paper, can be characterized as an active learning strategy that integrates the students in an activity of intense interaction, cooperation and collective thinking. Promotes peer review, also to learn, and the playful motivating studies, discussions and reflections about the development of significant learning about derivatives. In addition, provides an opportunity for students to develop communication skills and behaviors to work in teams, such as respect, active participation and improvement of knowledge, as they learn with colleagues and share with them, what they know.

Key-words: Active and significative learning, Mathematics to Engineering, Differential and Integral Calculus, Interaction, Cooperation, Recreation.

1 Introduction

The understanding of the derivative has been one of the main factors that affect the learning in Engineering courses. In the high school there are different approach levels in Mathematics and most students start studying Calculus disciplines, in general, bringing more gaps and lags than solid knowledge about basic math. These are essential to be recognized when they need to be applied. In addition to difficulties in arithmetic and algebraic processes, they make up a reproach scenario and even dropouts in engineering courses, caused by discouragement and feelings of inability to overcome such difficulties.

The derivative is a structuring concept to be constructed in the beginning of Calculus studies, because of its meaning and its wide range of applications. So, the lack of knowledge about the derivative rules, may hamper the proper understanding of the Differential and Integral Calculus and its important applications in Engineering.

The derivative learning involves knowledge and arithmetic and algebraic skills, which allow the application, with understanding, of derivative rules, in particular the chain rule. This is a mystery to students because they don't understand the concept of composite function.

Thus, the learning derivative requires a special attention from teachers and students. For this purpose, we created a pedagogical strategy of interaction in teams to the knowledge and application of derivatives, with discussion and reflection on the arithmetic procedures, algebraic and on appropriate mathematical communication, which requires the formalism of their own language as an expression of ideas and the meanings intended to transmit.

In section 2 we present some reflections on aspects included in the "Derivative Circuit" as an effective educational intervention for learning Differential and Integral Calculus. Then, in section 3, the "Derivative Circuit" is described.

2 Active learning with interaction, cooperation and peer review components and having playful as motivation

Knowledge is built on interaction, where the subject enhances own ability to know, while producing knowledge itself. (PIAGET, 1978)

Thus, the act of learning distinguishes learning as active and meaningful, that, according to Ausubel (2003), produces new knowledge anchored in the knowledge structure already acquired and which results from a process in which the teacher creates conditions for the student to interact. Similarly, as Moares (2007), for whom the concepts never are ready, because they can always be enriched, it is understood that new knowledge is learned by constant reconstruction of those already built; that is, to learn something new you need to interact with something already known, and transform it, making it more complex and broad.

Then teaching should plan environments which these cognitive actions, afforded through activities, pedagogic approaches and interventions that may help the student to do their jobs, and learn from them, to develop own ideas and modify them as you zoom knowledge. (SAUER, LIMA e SOARES, 2008)

Interaction among students promotes cooperation with the sense of acting, operate with each other, sharing ideas, meanings and knowledge, own and of the other by modifying both. A process of interaction and cooperation brings the dialogue, which values all kinds of knowledge and also the knowledge of the other.

Pais (2006) and Moraes (2007) highlight the importance of dialogue and joint so there is interaction and exchange of knowledge in the classroom. With this, the teacher will create a favorable environment for the student to discuss, confront and defend ideas and argue, based on knowledge and theory, expanding and rebuilding previous and new knowledge.

Then learning in interaction in class is engage, interact, question and discuss possible to overcome difficulties. Thus, it is a process that involves different languages. In Mathematics, the written and spoken language, with recognition and appropriate use of mathematical symbols, adds new knowledge to those already developed, uniting them in the construction of new concepts.

To the process of teaching and learning joins assessment that integrates and complements, providing a diagnosis that allows rethink and reshape methods, procedures and learning strategies.

By understanding the assessment as a process of understanding of the advances, limitations and difficulties, in addition to measuring performance scores, teacher and students, are involved, and the design is then a mediator evaluation, to Hoffmann, "... means provocative action of the teacher, challenging the student to reflect on the concepts studied and lived situations, to formulate and reformulate their own concepts, heading gradually to scientific knowledge and new discoveries." (HOFFMANN, 1996, p. 121)

By including student participation, we approach of what Fernandes (2009) calls alternative formative assessment as being more interactive, considers the reality of the teacher and the student and is to regulate purpose and improve learning. Being more participatory and more transparent, requires the evaluation as a formative process of mutual accountability between teacher and students.

According to Perrenoud (1999), the teacher needs to engage students, encouraging mutual appreciation of their own skills. For this, we need to plan, to study it and propose forms of assessment to consider the responsible participation of the students. In this is considered the participatory analysis of production and student records, which allows intervene immediately in observed reality, providing value the collaboration among peers, the strategies used by students and improve learning.

Finally, it is worth highlighting the playful as another educational resource that has the power to improve the self-esteem of students and promote a relaxed and engaging environment, serving as a stimulus for interaction, because it generates interest and pleasure in relating with colleagues. Delivered from a more formal learning situation, and with the support of colleagues, everyone feels more comfortable discussing, saying that they do not know and what do not know to ask for and give hints, tips and ideas.

To promote teaching strategies with such possibilities, we leverage the concept of Vygotsky's theory (1979), about the zone of proximal development, defined as the difference between the current development of the student and the level that reaches when solving problems with aid, indicating that the student can do more than he could do for himself. And, the best, opens the opportunity that tomorrow he can do alone what today he is able to do in cooperation.

These are the main pillars that support the strategy of the derivative circuit. We expect them to be identified in the reading of the description, as follows. We tried to by arguments to support this learning strategy, noting that it is important to learn to live and cooperate by sharing knowledge and engaging in the individual development of each colleague and the whole class group. It is this learning that build knowledge, skills and behaviors to live professionally and socially, and to evolve in the larger context of personal development.

For these reasons we present the derivative circuit as a significant learning strategy.

3 Derivative Circuit

As a learning strategy, the circuit can be applied in different situations. In the way described here it has been applied when the study of derivative in the discipline of Differential and Integral Calculus I, to the Engineering courses at the University of Caxias do Sul. With this, we have the opportunity to resume the derivative rules, aiming to understand how a function law operates for processing its derivative, also deepening the understanding of a composite function and of the chain rule.

In the previous lecture the completion of the circuit, students are reported on the learning and evaluation activity, as an invitation to participate in a challenge. In the description, then, there are the circuit guidelines, as they are presented to the students in this description of a class that consists of four groups formed with approximately 10 students.

"This activity, in teams, aims the derivative calculation by means of a challenge in teams, according to the guidelines that follow:

1. The class, divided into four teams, solve, within the framework derived from randomly chosen functions. Each resolution will be assessed by 1 point (1.0) and at the end, the team with the most points will receive the maximum score, equal to 2.0, which is equivalent to two points on the second note of evaluation in half . The remaining number of points converted proportionally, making note of each of the other teams.

2. Each team in each round, is represented by two components exiting the function to be derived from an envelope and present it as well as its resolution on the board.

3. While the resolutions are shown in Table (COLOR 1), others have the task of monitoring the resolutions in an attempt to help its partners and trying to find possible errors in resolutions of the opposing teams.

4. Each resolution must be written with appropriate language and symbols and correct calculations.

5. Each resolution can only be shown in the table by two representatives. These can interact with your team, the team table, and return to the table at once, for the improvement of what is presented without taking any form of annotation. (COLOR 2)

6. After that, other teams, designated by the teacher should evaluate each resolution, to be correct and proper writing. If there is nothing to add, should be written only "right." The team evaluates the resolution will be represented on the board, one of its components. (COLOR 3)

7. The teacher follows the entire process and discuss all final resolutions, writing additions or adjustments, if necessary. (COLOR 4)

8. The scores will be awarded at each resolution, as follows: for the staff of the resolution, with (1.0) or (0.5), as they are or not any comments the evaluation team or the teacher. And for the team that evaluates, with loss of points, (1.0) or (0.5), depending on whether or not to provide relevant comments.

9. Each team may use, at your desk, a computer and your reference material, as deemed necessary.

10. Each team can not repeat any of its representatives on the board, until all have not participated.

GOOD FUN AND VERY LEARNING FOR ALL! "

In these guidelines, some variations can be considered according to the number of students in class. It can be used kraft paper fixed on the walls and four color pens, if the frame does not contain all of the teams. These, according to the experiments performed in order to have better results in terms of participation and learning should have eight to ten components.

Also, as a challenge factor, it is possible scoring unlike resolutions, with 1.0, 2.0 or 3.0 points in accordance with their degree of complexity.

4 Results and Final Comments

The circuit, as described in the previous section, has been promoted with the main intention to involve more students in the derivative study in Calculus I. The good results could already be seen from the first applications of this activity, observing the good reception of students, not only taking an interest in gaining skill in resolving bypass operations, but also trying to understand and engage with its many applications. Thus, it has been possible, concurrently with the development of the circuit, the realization of important discussions about the applications of derivatives, such as determining the slope of a curve, its high and low, among others. At such times, like Avila (1991) we see that makes sense to the student the importance given to the concept of function.

On the performance of students, it can be said that is a significant increase in approvals in Calculus I, from the realization of circuits. An approval rate of around 50%, has today around 65% of successful students. And this is due, rather, to better learning of derivative calculation, as these are structuring content and interfere in the final grades of student performance.

The best confirmation that we have, that the strategy promotes involvement, preparatory study for the challenge and better learning conditions, and higher notes, is based on the evolution of writing production. In the assessment that complements Note 1, students have more quality in mathematical communication and better performance in processing algebraic, besides being the fittest in the application of derivative rules.

As host and feedback on the implementation of the strategy, we can talk about the satisfaction and joy of the students in the circuit class, the curiosity of some arriving in the discipline already knowing the challenge by other colleagues who have passed the course, and students who pass the challenge and at the coursing Calculus II or Calculus III, when they find us as teachers, ask if there will be a circuit at some point of the semester.

In fact, the circuit can be applied to other content, as it is proposed, as in the study of limits, especially in indeterminate forms, or methods of integration and content involving procedures which comply with rules or development of routines, such as the use of tables. And, reformulated, can be applied to other activities such as problem solving. This will be the next challenge, planning a game strategy with challenges to the troubleshooting applied Mathematics for Engineering.

As teachers and researchers in mathematics education, interested in mathematics learning strategies in Engineering, we have concern and interest in learning the knowledge that is taught, for the planning, creation, experimentation and analysis of educational interventions that promote meaningful learning .

In addition, in all math classes are required knowledge of basic math, so it is said to be basic math. That is, it is necessary to build new knowledge starting from others have built in a permanent process of construction and reconstruction, that enhance the preconditions to anchor new concepts with understanding. All this cognitive frame is critical because there is a large network of relationship between the mathematical contents, which are interconnected and complement each other.

If the teacher does account that basic mathematics is commitment of students, which is also, but do not give attention, seeking to know the difficulties and integrate the (re)construction also of concepts or rules and required basic properties, the same history of difficulties, failures and evasions runs its course, instead of the students follow, improving the learning of Mathematics and the success in the course.

We understand how to meet the objectives proposed for this article, presenting an educational intervention that contributes to the learning skills training in Engineering, discussing and describing it, like it is presented to students as a way to share and allow their implementation and thus, effectiveness confirmation in the reduction of dropout and retention rates, especially concerning education and learning Differential and Integral Calculus.

In the context of the discussion to be held in the ALE 2015, we believe that we can move forward and collaborate to identify key features of pedagogical interventions of active learning as a way to qualify the training in engineering.

Continuing beyond the Ale 2015, the proposed partnerships between teachers of different universities and the possibility of setting up a discussion forum on proposed active pedagogical interventions and didactic experiments, successful or not, is also what we suggest as effective action to reduce retention rates and evasion, and to meet the parameters of quality training.

We strongly believe that a better education in any of the forms and levels, passes essentially through the professionalization and improvement of pedagogical skills of the teacher. Standing and walking together, discussing, sharing and developing, also in partnerships, teaching experience and teaching resources can promote a significant advance toward the best quality in Engineering Education.

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Completely Fair Teaching Method

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Extended Abstract

The title of this paper comes after the process scheduling algorithm currently running in Linux, called CFS (Completely Fair Scheduler). We present an active learning activity that we use to learn about process scheduling algorithms.

The experience was carried on in the context of an introductory course about Operating Systems at the Computer Science degree from the university UPC BarcelonaTech. In this course there is a topic especially difficult to learn: scheduling algorithms. Presenting it as a frontal lecture has given us bad results in the past: students are bored during the lecture and remain confused after it.

We present a different approach based on Cooperative Learning which is flexible enough to manage on large groups of students. We use the technique of jigsaw to learn three of the most typical algorithms. We carried on the activity in a classroom with 48 students and we found it was easy to add new algorithms and students without changing the structure of the class. Time wise we spend on this topic two sessions in classroom (about 2 hours each) plus an extra 2 hours of study out of the classroom for the students to gain enough competence in the subject.

In the jigsaw technique each student is member of two groups: the heterogeneous group and the expert group. Our first two hours session will run as follows: At the beginning of the session we create the heterogeneous groups (i.e. by letting the students group themselves in groups of three people). Next, in each group the teacher numbers the students from 1 to 3 and each number will study one of our algorithms. We focused on three scheduling algorithms: (i) First Come First Served; (ii) Shortest Job First and (iii) Round Robin. Students with number 1 would study (i), students number 2 would study (ii) and so on. We distribute the material and each student studies the appropriate section (approximately 40 minutes). Next, we create the experts groups, each group will only have experts in one algorithm. It is good to try to construct as many groups as possible with 3 or 4 people. In our case, we create 12 groups of 4 people each. Groups of experts must debate about their algorithm, expose their doubts and teach among themselves what they had learned. At this point, they can ask the teacher for help and clarifications. This takes approximately 1 hour and at the end of the expert groups meeting we should be very close to the end of the first session of 2 hours.

In our second two hours session the students go back with their heterogeneous group (in our case we had 16 groups of 3 students) and they teach each other what they understood in the expert group. Each group has one expert in each topic, therefore after a while (approximately 1 hour) all of them know the basics of the three algorithms. Once again, teacher has to be there to answer any cognitive conflict that could appear in the meanwhile. Eventually all 16 groups must be prepared to proof their competence in all the three algorithms.

We spend the last hour on providing them with formative assessment. To do that we prepare several Gantt diagrams that we project on the screen's classroom. Diagrams represent allocation of burst of CPU from several processes and each group has to work as a team to find out which policy has been used in each diagram. A fast feedback is very important. The faster we give them the answer, the better. Thus we use our Campus learning platform, based on Moodle, to prepare an on-line test that students can fill with their mobile phones and the correct answer is shown to them immediately.

To evaluate the impact of the new teaching approach, at the end of the assessment we ask the students to answer two more questions (anonymously this time). We want to know what was the best and the worst of the active learning sessions. Most of the positive answers agreed with the benefits of working in groups or at least doing "something different". On the other hand, there was a consensus in the negative answer, they complained about the arrangement of the classroom where the tables and chairs could not be moved to make it more comfortable for them to work in teams.