Project Approaches to Learning in Engineering Education

The Practice of Teamwork

Luiz Carlos de Campos,
Ely Antonio Tadeu Dirani,
Ana Lúcia Manrique and
Natascha van Hattum-Janssen (Eds.)

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Pontifical Catholic University of São Paulo, Brazil

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University of Minho, Braga, Portugal

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FOREWORD

Engineering is the main pillar sustaining civilized life on earth. Engineers invent the tools that enable us to move faster and produce more than we ever could with our bare hands. To keep our economies going we need engineers to maintain and to innovate our machine park. Therefore it is of utmost importance to continuously train new generations of engineers.

The engineering profession is rooted in practice and in practice engineers have always been working in teams on projects. Utilising projects in the formation of young engineers makes a lot of sense and not surprisingly it is applied in one or another variety in many places around the world. Still there are huge differences between an engineering project and the pedagogical utilisation of projects in an engineering curriculum. In an engineering project all that counts is to find an optimal solution, trading of time, money and other recourses. Sometimes a quick fix needs to be made and if the necessary expertise to solve a particular problem is not available in the team, it is hired from outside. This is acceptable in a real engineering firm, but not from a group of students working in small teams on authentic engineering problems. The students should aim to understand how things work, not just solve a problem and they should be reminded by their teachers that they should utilize the opportunity for building their own knowledge base. Rather than assigning jobs to the ones who are good at it, as is common practice in a real engineering firm, the students should rotate and each practice the aspects where they lack expertise.

This book offers the reader an overview of interesting practices of applying the project method in engineering education. With examples from different study domains and from diverse countries, the book covers a wide range of project applications in relation to various cultural backgrounds. It is a good start the get oriented on the possibilities of learning from projects in engineering and to get inspiration for the development of new varieties of project-organized learning adapted to local needs and circumstances.

Prof. dr. Erik de Graaff, Aalborg University
Associate Professor Delft University of Technology
Editor-in-Chief of the European Journal of Engineering Education

LUIZ CARLOS DE CAMPOS, ELY ANTONIO TADEU DIRANI, ANA LÚCIA MANRIQUE AND NATASCHA VAN HATTUM-JANSSEN

INTRODUCTION

Engineering Education in Europe has been facing many changes, especially due to the implementation of the Bologna Declaration that did not only aim to harmonise systems of Higher Education across Europe, but also to stimulate a more student-centred education. Anticipating the shift from teacher-centred to learner-centred education, a group of teachers at the Industrial Management and Engineering degree programme of the University of Minho (Portugal) started to transform a rather traditional first year semester into a project that was based on a theme related to the future professional practice of the students. The project method as used in the approach was based on Powell & Weenk (2003) and adapted to the local context. Although in the north of Europe, project-based learning has a long tradition, in Portugal it is relatively new and teachers and educational researchers involved in this experience could not yet rely on experiences of colleagues at the same university or other national universities. The project semester though became an enriching and rewarding part of the first year programme and the teachers and researchers decided to make the project a recurring element of the first year. They also started working on continuous improvement of the project semester, by evaluating and implementing changes.

Project approaches such as the one at the Industrial Management and Engineering degree programme of the University of Minho (UM) show that the learning process of students changes. They become more motivated, they learning to solve open-ended, ill-defined problems in a multidisciplinary context, they learn to work in teams and they get a more realistic notion about the professional future as an engineer. They learn in a different way and through the different method not only changes the level of learning –from rather superficial to deep- but also the knowledge and skills. Students are no longer preoccupied about specific technical knowledge and skills, but also work on the development of transversal competencies. Through working in teams on interdisciplinary open-ended problems, students learn more about team work, project management, communication, writing reports, giving presentations, time management etc. The added value of team work was the title of the First Ibero-American Symposium on Project Approaches in Engineering Education, organised by the Department of Production and System and the Research Centre in Education, both of the University of Minho, and the SEFI Curriculum Development Working Group held in Guimarães, Portugal, in July 2009. The symposium served as a platform for the exchange of experiences, research results and discussion of ideas for future

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implementation of project approaches in especially Portugal, Spain and Brazil, countries in which projects are not as self-evident as in countries like e.g. Denmark, Sweden, the Netherlands and Australia. Presenting experiences from less and more experiences contexts, the book seeks to presents experiences and challenges encountered in changing engineering education.

In chapter 1, Campos, Manrique and Dirani describe their experiences implementing a Biomedical Engineering course at the Pontifical Catholic University of Sao Paulo, using the Problem Based Learning (PBL). The curriculum structure, tutor profiles, assessment process and instruments, and analysing the course's first evaluation are some of the main challenges that the team is facing. To overcome these challenges, according to the team, a teaching and staff management model must be developed.

Arvid Andersen describes the European Project Semester (EPS) he created in 1995, in Helsingor, Denmark, in chapter 2. EPS is a program for engineering students, with groups of international students who work, for one semester, on carefully selected interdisciplinary projects in order to meet the real needs of companies, aiming to develop technical as well as transversal competencies. Ten European universities are currently involved in this program.

Chapter 3, by Weenk and Van der Blij, discusses the implementation of Project-Led Engineering Education (PLEE) in the Mechanical Engineering course at the University of Twente, Netherlands, focused on teamwork.

In chapter 4, Lima *et al*. discuss the applicability and present their assessment of the management structure of an interdisciplinary engineering project coordination team, focused on time, team and communication management, conducted since 2004 by the Production and Systems Department of the University of Minho's School of Engineering, in Portugal.

In chapter 5, Du, Stojcevski and Benz present an educational innovation founded on problems, projects and practices in engineering education by examining issues at an institutional, community and business level, showing cases of implementation in a range of contexts and engineering teaching institutions.

In chapter 6, Puente, Jongeneelen and Perrenet describe the project of running a support group for developing teaching skills for lecturers at Eindhoven University of Technology (TU/e) within a concept of technological innovation called Design-Based Learning (DBL).

Chapter 7 describes the implementation of the European Project Semester at the Polytechnic University of Barcelona at Vilanova i la Geltrú, coordinated by Segalàs and Esbri, focussing especially on sustainability in the programme.

In chapter 8, Martins provides a historical description of engineering education in Portugal since the 1950s, covering the effects of the 1974 revolution on higher education methods until the implantation of the Bologna Process. The chapter also discusses difficulties implementing the process in engineering education and the importance of the PBL method within the Bologna Process.

Chapter 9 presents a project developed by Fernandes, Flores and Lima, discussing assumptions regarding assessment in a pedagogical innovation experiment, the Interdisciplinary Project Based Learning method. The chapter examines not only technical issues regarding the way in which assessments are conducted, but also the importance of reflecting on certain ethical principles regarding assessment in the process of learning.

Finally, in chapter 10, Van Hattum-Janssen provides an overview of approaches in engineering education projects, discussing characteristics that aid student learning, changes in the role of educators and their preparation face the new context of teaching and learning.

By presenting these works in progress in this book, some of which have already yielded results that have been assessed, others of which are still in experimental phases, the authors' hope to create an environment of discussion and reflection on the new approaches in engineering education being developed at present.

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AFFILIATIONS

Luiz Carlos de Campos
Faculty of Science and Technology
Pontificate Catholic University of Sao Paulo, Brazil

Ely Antonio Tadeu Dirani
Centre for Science and Technology
Pontificate Catholic University of Sao Paulo, Brazil

Ana Lúcia Manrique
Centre for Science and Technology
Pontificate Catholic University of Sao Paulo, Brazil

Natascha van Hattum-Janssen
Research Centre in Education,
University of Minho, Portugal

LUIZ CARLOS DE CAMPOS, ELY ANTONIO TADEU DIRANI AND ANA LÚCIA MANRIQUE

1. CHALLENGES OF THE IMPLEMENTATION OF AN ENGINEERING COURSE IN PROBLEM BASED LEARNING

A PBL (PROBLEM BASED LEARNING) COURSE PROJECT

Nowadays, there are more than a thousand engineering courses in Brazil and the number of scientific studies involving problem-based learning in engineering is endless. These initiatives are rather recent and mostly restricted at least in some courses of the specific engineering. Within the PBL line, other variations on the methodology have been developed. Eberlein *et al.* (2008) present the characteristics of three common methodologies used in teaching science, comparing and contrasting them in order to enable a possible choice or combination in particular situations. The three methodologies that these authors present are: Problem-Based Learning (PBL), Process-Oriented Guided Inquiry Learning (POGIL) and Peer-Led Team Learning (PLTL), all of them being based on active learning and student-centred.

In Helsingor, Denmark, Andersen (2009) created a programme for engineering students, the European Project Semester (EPS), with groups of international students who work on carefully selected interdisciplinary projects to develop abilities and specializations, in addition to inter-cultural communication and teamwork skills.

Segalàs (2009) coordinates the EPS programme at UPC-Barcelona Tech's School of Engineering of Vilanova i la Geltrú (EPSEVG). This project introduced a PBL curriculum structure at EPSEVG, as well as technical teaching in English and the intercultural factor. Another important aspect was the inclusion of competency in sustainability. The projects of this programme are proposed by regional companies and a student group works on a real project for one semester, guided by an academic tutor and supervised by a professional from the company. The groups include students with different sets of knowledge, from several countries. The programme also involves individual and group seminars throughout the semester. EPS is spreading throughout Europe and, at the end of the course, if their assessment has been accepted, students receive a certificate worth 30 ECTS (European Credit Transfer System), which corresponds to a student work load of 750 to 900 hours.

Puente, Jongeneelen and Perrenet (2009) coordinate a support group for developing teaching skills for lecturers at Eindhoven University of Technology (TU/e) within a concept of technological innovation called Design-Based Learning (DBL).

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Weenk and Van der Blij (2009) work at the University of Twente, Netherlands, with the PLEE (Project-Led Engineering Education) project, focused on teamwork.

At Victoria University, Australia, Du and Stojcevski (2009) are developing an educational innovation founded on problems, projects and practices of the teaching of engineering by examining issues at institutional, community and company levels.

At the University of Minho, Portugal, Lima *et al.* (2009a, 2009b) coordinate a work group of engineering students that is very interactive with the industry.

According to Newstetter (2006), PBL has been used as a means of integrating basic science education with engineering education. In this approach, learning is not linear, but leads students to explore the space of a problem. If different student groups face the same problem, they will probably choose different approaches and will most likely suggest different solutions. In this process, multiple topics and knowledge domains are found, helping students build a more extensive, integrated and flexible knowledge base.

In order to seek solutions for the problems identified in engineering courses, PUC-SP decided to innovate by adopting an active, collaborative and integrative teaching methodology in the biomedical engineering course. The one chosen was PBL – Problem Based Learning. The authors of this chapter that teach in this course have shared their experiences with a number of tertiary institutions in Europe, Asia, Australia, the United States and Latin America, presenting their work at international events.

Within this approach, the curriculum is not organized by discipline; rather, it is divided into multidisciplinary modules, allowing for inter and trans-disciplinarity. The modules are planned units designed to be joined or adjusted to other analogous units in several ways, forming a functional whole. They are thus complete units designed for full-time learning, focused on a central theme encompassing content from different disciplines.

The course is structured to cover five different thematic areas, which are treated in a progressive, complementary and integrated manner throughout the course (five years). The thematic areas are:

1. Medical Images: an area of biomedical engineering that studies the principles, forms and mechanisms involved in obtaining images of the human body.
2. Medical Electronics: an area of biomedical engineering that studies the application of electricity in medicine and health, the design and development of diagnostic equipment, therapies, control systems and data collection systems, as well as analyses of biomedical signals and sensors.
3. Medical Informatics: an area that integrates computer sciences with biomedical information, system development, information management, simulations and data processing.
4. Biomechanics and Rehabilitation Engineering: this area examines the mechanics of living beings, analysing movements and structures from a mechanical point of view, studying and developing prostheses, orthoses and mechanical efforts, as well as materials and their properties.

5. Clinical Engineering and Health Management: a specialised area responsible for applying and managing biomedical technology in health optimization, and managing personnel, physical and financial resources in hospitals, clinics and companies to ensure quality in health systems.

Each area is treated in a specific way in each year of the course, with different concepts and degrees of depth.

- In the first year students are introduced to the area and learn about the basic applications of the associated technology in healthcare.
- In the second year more specific current applications of technology in healthcare are analysed and discussed.
- In the third year applications are presented and discussed with a focus on the development of healthcare technology.
- In the fourth year state-of-the-art technology related to healthcare is discussed and analysed.
- In the fifth year technological research in healthcare and applications in everyday clinical practice are presented and discussed.

This teaching methodology allows students to acquire a range of skills, such as: teamwork, intercultural competencies, effective communication, continuous learning, project and team management, and ethical, social and environmental responsibilities.

This skill set is consistent with a professional profile capable of performing in an innovative way in companies: building specialised, cooperative environments for innovation, developing fundraising projects for research using the different sources of financial support, and seeking technological development and innovation.

This chapter discusses the challenges faced by the team of educators working with this methodology and examines, among other things, the assessment processes that are being implemented in the Biomedical Engineering course at PUC-SP.

IMPLEMENTATION CHALLENGES: TUTORS

The thematic areas are structured into central and associated modules. The central modules are determined by the theoretical and practical content of the thematic areas of each academic period. The associated modules complement the content of the central modules and cover topics such as communication and expression, administration, legislation, entrepreneurialism, bioethics, social inclusion and sustainability.

Each module comprises a group of problems and their themes. The themes must allow for horizontal integration (correlation of a same topic of several contents) and vertical integration (correlation within and between basic and professional contents, in the different phases of the course).

The contents are distributed across different problems in such a way that they will be accessed by the students during group discussions in the guided study. They are distributed throughout the years of the course and learned according to their importance in problem solving.

The problems that make up each module privilege technical, ethical and humanistic aspects, and the most important or common situations, with the greatest potential for intervention.

The pedagogical project of the course defined the tutors as the spine of the course. In order to be a tutor, one must acquire a completely new set of skills, compared to those of lecturers in courses structured according to disciplines. Instead of giving students all of the information and data in classes and notes, they must learn to facilitate learning and guide their students' learning process indirectly. They must allow students to determine, by themselves, what they need to learn and, at the same time, know what resources they will need, especially the school's human resources. Instead of telling students exactly what they should learn and in what sequence, tutors should help them determine such things independently. The role of the tutor must be to ensure that learning is student-centred rather teacher-centred. It is facilitating learning as opposed to offering pre-packaged knowledge. Tutors should constantly give students the opportunity of learning to learn.

During the implementation of the course, challenges arose regarding these aspects of the tutors' role. In the first place, the lecturers on the biomedical engineering course got their own bachelor's degrees in traditional courses, such as engineering, mathematics, physics and medicine. Their schooling, as with the majority of lecturers in tertiary institutions, did not involve issues of a didactic or pedagogical nature. As such, the educators who took an interest in working with this methodology were those who had successful classroom experiences, and not necessarily theoretical reflections about what should be done in tutorial sessions. Tutor training, which took place beforehand, was essential in order to stimulate reflection and raise awareness about these skills. However, it became clear that there was a need for continuing training and reflection on the activities carried out in tutorials.

In order to provide adequate supervision and answer questions about new theories posed by students as they attempt to solve a given problem, it is essential that tutors always seek to remain up-to-date in their knowledge.

> In problem-based learning, you never know what students' questions are going to be, but they all oblige their tutors to be up-to-date. (Enemark and Kjaersdam, 2009, p.19).

The need to solve a given problem and identify its requirements brings students into contact with other ideas and people. Creative and innovative solutions, that do not merely reproduce pre-defined models, spring from this interaction. This means that tutors must aim to foster a capacity for autonomous learning in their students. According to Rué (2009), efficient information and available time management; work, study and research, both individual and in groups; attitudes such as flexibility, imagination, openness to new information and methods; and self-regulation of one's own work are fundamental in order to develop autonomy in learning.

The challenges encountered in the implementation of the course require tutors who are also committed to teaching, research, development and innovation. Such tutors should have an academic background with experience in defining problems, analyses, theories, experiments, syntheses, possible and acceptable solutions, as well as conclusions, assessments and consequences.

PROCESS ASSESSMENT AND ANALYSIS

An education that provides knowledge and skills that favour the routine solving of professional problems – which presupposed a more dynamic style of teaching and learning – is now required of engineering graduates. On the one hand, the curricula of engineering courses in Brazil today, structured in such a way that knowledge is compartmentalized into stagnant disciplines, which do not meet such demands, due to the multidisciplinary education required of today's engineers. On the other hand, assessment methods prioritise the reproduction and memorization of information and the acquisition of minimum requirements for approval, as well as limiting students' studies to that which is considered most essential, instead of relating ideas to one another, establishing of connections with students' past experiences and debating different points of view with other students (Rué, 2009; Manrique, Dirani, Campos, 2010a, 2010b).

The big challenge of PBL is doing justice to basic, advanced and specific professional contents, according to the Curriculum Guidelines for Engineering Courses. To overcome these and other challenges, continuous assessment tools were used and critically analysed by the course coordinators and discussed with the teaching staff, so that their interpretations could be used to improve the course and overcome the challenges that constantly crop up within this methodology.

The system for assessing PBL is important for the improvement and maintenance of the course. If we consider, like Enemark and Kjaersdam (2009), that students need: to develop skills in order to face unknown problems in their future profession; the ability in learn to learn; cooperation and project management skills; practice communicating with tradesmen, businessmen and industrialists to solve problems that arise during projects; and an exchange between teaching and research to encourage innovation, then the course assessments need to address issues related to students, staff, coordinators and the curriculum itself so as to foster the discussion and reflection needed in order to improve the course.

The proposed assessment tools take into consideration new assessment methods involving not only students, but also the teaching staff and the course itself. Assessment sheets, portfolios and tests were developed, and student-teacher meetings were held. The purpose of these assessments and their analyses was to foster continuous reflection regarding all of the guiding principles of the new curriculum, and frequently rethink them. The objective of the different assessment tools employed was to contemplate the formative and summative nature of the assessment processes, set forth below.

Formative assessment should be used to monitor the teaching-learning process and provide continuous feedback for both student and teacher. For students, it reinforces successful learning and allows difficulties to be identified and paths to be corrected. For teachers, formative assessment, through constant student feedback, allows them to rethink the way they go about things. No concepts or scores are attributed to these tools. The tools used for formative assessment at different pedagogical stages were: structured models, portfolios and progressive tests.

The structured models have pre-defined topics that assess the quality of student and teacher participation and the problems used in tutorial sessions. Assessment by problem involves filling in sheets for student self-assessment; tutor assessment of students and the group; and problem assessment by the group. Assessment by module involves sheets for tutor self-assessment; assessment of the tutor by students; and assessment of the group by their members.

The portfolio is a collection of a student's work including the different activities carried out during the week. It is intended to be a means for students to learn as they create. It must be both a strategy to facilitate learning and to allow for its assessment. Workshop support portfolios, theoretical support portfolios and tutorial portfolios were produced.

Students include information in their files that present an overview of the strong and weak points of their development in the course. These files contain the results of experiments conducted in the different workshops, their research in books and magazines, the problems solved during the modules, and the exercises and theoretical references studied. In this manner,

> the file is used to encourage them to reflect on their learning objectives and experiences throughout their education and to consider what they have gained from them. (Deelman and Hoeberigs, 2009, p. 90).

The progressive tests are once a year multiple-choice tests for cognitive evaluation. They have yet to be applied, since the first year of the course still has not finished.

Summative assessments are applied to determine students' readiness for advancement. They also help classify them at the end of a learning period (year, semester, month, module), according to how much they have or have not learned. The tools used for summative assessment at different pedagogical stages were written tests, triple jumps and final reports.

The written tests were considered cognitive assessment tools and encompassed discursive, interpretative and multiple-choice questions. Their objective was to evaluate students' individual capacity to analyse and summarise answers to questions based on the content of the units studied.

In the first stage (first jump) of the triple jump assessments, students provide an individual written assessment of a problem situation in the same way they do in tutorial sessions. In the second stage (second jump), they look for and select learning materials related to the situation. In the third stage (third jump) they answer questions about the content of the problem.

From the partial reports drawn up after analysing the portfolios, tutors then write up a final report at the end of the educational stages in which this tool is used. The assessment is the sum of all these tools, indicating, in addition to whether or not the student has passed, any redirection necessary in the development of the course.

This assessment system aims to foster competency in cognitive autonomy and personal responsibility in students. According to Rué (2009, p.162), what makes a student autonomous is:

- having a clear idea of their own learning style and strategies;
- adopting a communicative focus in the tasks they carry out;
- being willing to take risks and make mistakes;
- doing homework and personal tasks, regardless of whether or not they are being assessed;
- recognising the importance of formal concepts and their assimilating.

In addition, Rué (2009) distinguishes three possibilities for the concept of autonomy: one of which emphasises the technical nature of the autonomy of the person learning; another that strengthens the cognitive dimension, and a third that stresses the ability to be the agent of one's own learning, emphasizing a political dimension.

It can be seen in the implementation of the course that not all learning situations foster autonomy in students, in spite of the course coordinators' intentions. Another issue that arises is how motivated and interested students are in being autonomous in their learning when the conditions allow for it. And lastly, it should be noted that even certain potentially favourable contexts for the development of student autonomy do not produce the same effect in all students.

As such, this analysis considers determinant in the implementation of the course: efficient management of the coordinators' assessment process; the time available for students to learn and work on problems; the teaching staff's study and research, group and individual work proposals; and the development of self-regulating tools for everyone's work.

The challenges faced by the teaching staff in implementing the assessment tools presented reveal that the assessment and its analysis are crucial to the development of a course structured in PBL methodology. The purpose of such assessments and their analysis is to foster ongoing reflection on the guiding principles of the new curriculum and to encourage them to be frequently revisited.

Proposed changes to assessment methods tend to be forgotten, altered or omitted.

> Often, maintaining 'old' assessment methods leads staff to pretend that the new model works, when they are, in fact, following the assessment criteria of the old system. This is counter-productive and should be taken seriously, so that the assessment method can be adjusted to the new teaching and learning philosophy. (Moesby, 2009, p. 55).

In the first assessment of the process positive and negative points were identified. Some of the positive points were: the themes approaches were handled in a pleasant, relaxed manner; there was a great deal of interaction in the student work groups; the students were involved in dealing with complex problems and developed an interest in research, acquiring the skills necessary to solve the proposed problems.

Some of the aspects that need to be rethought so that changes may be made to the organization of the course and to better meet educational objectives were: diagnosis of students' previous knowledge in basic sciences and mathematics; a better interaction between teachers in the work groups; students' preparation to understand the new methodology; the planning of practical tutorial sessions and workshops and the process of assessment results.

REFLECTIONS

According to Possa et al. (2008), biomedical engineering courses in Brazil are a recent phenomenon. The thematic areas in the PUC/SP course were thus chosen to cover the areas of activity of biomedical engineers as defined the Brazilian Society of Biomedical Engineering (SBEB, 2007).

One of the challenges we are facing in implementing the PBL curriculum is deciding how to cover the basic sciences in the problems proposed in each thematic area, bearing in mind that the course must be completed in five years. This difficulty is related to the learning objectives that must be met by the tutor's propositions, and which are not easily identified and understood by the students.

To overcome the different challenges presented it is essential that we develop a teaching and staff management model. This model must be consistent with the principles of PBL and the kind of innovative engineer that we want to send into the market.

This management model presupposes that the coordinators of the courses are efficient in the planning of staff activities and determining how much time to dedicate to administrative tasks. It is the course coordinators' role to adopt principles that allow projects to be developed in meetings and committees without taking up too much of the teachers' time. According to Branda (2009, p. 221), these principles are:

1. ensures that everyone has the opportunity to be heard;
2. respect all participants and their legitimate interests;
3. correspond to an interdependent thought system;
4. to speak clearly, without ambiguity or repeating what has already been said;
5. to be willing to express disagreement when necessary;
6. know how to differentiate brainstorming and decision-making meetings;
7. take decision-making based on consensus, such that decisions correspond to the group's needs.

To measure the results of this management, a number of levels of assessment are necessary. The first level, already present in many undergraduate courses, involves assessment of students and course contents, format and organisation. The second level, which is on the agenda of tertiary institutions, is the assessment of the teaching staff and the implantation of the pedagogical project. The last level, which has yet to be included in the evaluation of teaching and staff management results, is the assessment of the course coordination, which deserves special attention from the course educational committees and university administration.

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AFFILIATIONS

Luiz Carlos de Campos
Faculty of Science and Technology
Pontificate Catholic University of Sao Paulo, Brazil

Ely Antonio Tadeu Dirani
Centre for Science and Technology
Pontificate Catholic University of Sao Paulo, Brazil

Ana Lúcia Manrique
Centre for Science and Technology
Pontificate Catholic University of Sao Paulo, Brazil

ARVID ANDERSEN

2. THE EUROPEAN PROJECT SEMESTER: A USEFUL TEACHING METHOD IN ENGINEERING EDUCATION

The EPS Formula

INTRODUCTION

For some years engineering has been in trouble. Fewer students have applied in general and the consequences have been merging and closing down of universities and departments. However, an initiative known as EPS (European Project Semester) was started in 1995 by this author. Students come together to work on multidisciplinary projects in international teams. This has shown to be an effective way to attract students and to give them international experience and develop their enhanced technical skills. Students of both gender from engineering, business and technology feel attracted to participate in this international semester. Many engineering schools have been inspired to provide the same set-up at their own institution. Several universities in Europe i.e. in Denmark, the Netherlands, Norway, Poland, Germany, France, Finland, Belgium, Portugal and two universities in Spain are now offering this international semester course at their universities. Future competition will be fierce and we need engineers in our companies. Industry must find or invent responsible ways to increase production without environmental consequences. This ought to inspire our students to consider a career in engineering. Obviously, the present engineering education needs some adjustment in order to satisfy industry´s requirements and the wishes of future students. The required skills base has changed. A continuous intake of engineering students is needed in our societies to create new developments and to have somebody to take over where others finish. We must persuade people to choose engineering. In that regard a big credit should be given to The Smallpeice Trust, Warwickshire, England. The Trust has for years done a tremendous work trying to attract young people into engineering.

THE NEED FOR AN INTERNATIONAL PROJECT SEMESTER

It is interesting to consider people´s perception of knowledge, insight and creativity. Most people initially believe knowledge to be paramount, and tend not to make a distinction between insight and skills. At a certain stage of an education students should be given time and possibilities to wonder. Work by Tranter and Bond (1997) mentioned in the reference list, has shown the value of Design Project

L.C. de Campos, E.A.T. Dirani, A.L. Manrique and N. van Hattum-Janssen (Eds.), Project Approaches to Learning in Engineering Education: The Practice of Teamwork, 15–28.

Skills to an Engineering early career. This enables the students to make original and creative contributions as responsible team members. This is what we should try to encourage. We already provide students with a good basic knowledge of engineering, economics and management. Further as companies adopt new management structures the need for technical specialists working as consultants will increase. It is likely, as national borders blur, that opportunities to work outside home countries will increase sharply, making mobility part and parcel of a technical career. Many engineers will work in more than one country on short time basis requiring many more skills than we teach them to-day. Engineering has become a more integrated part of the international society. To really understand what integrated engineering work is, one must be involved in group project work, where autonomous learning is facilitated and the ability to work within a team on a project is promoted and emphasised. Engineers should be equipped with the appropriate entrepreneurial and social skills to be able to work successfully across borders with people of different mindsets. Teamwork is group performance with regard to the product produced, the project process executed and the people involved. Project work in that sense is social rather than solitary. Students should be involved actively in order to learn to dare and to do. Perspectives on future engineering education are discussed.

THE EPS FORMULA

The international teamwork semester known as EPS, has developed to become a trademark. A consortium of universities in Europe as well as outside Europe has approved the concept, the structure and the content. Presently 11 universities in ten countries have formed a providers group by implementing the EPS concept at their own universities (http://www.europeanprojectsemester.eu). The team- based -project work carried out during this semester is an interdisciplinary activity that requires a collective effort of specialists with different kind of expertise and cultural backgrounds. It is not enough for engineers just to have a working knowledge of another language. To work in a foreign country requires many more skills. Therefore to remedy many deficiencies in existing engineering courses, the EPS providers have decided to run the European Project Semester Course, designed to train engineering and business students to work in international teams. A team is often defined as a group of people working together to achieve objectives that are shared. It is also a task-tuned group of people deliberately designed. Teamwork on EPS is defined as follows:

> Teamwork is the ability to work together towards a common vision. It is the ability to direct individual accomplishment towards organisational objectives. It is the fuel that allows ordinary people to attain extraordinary results.

The following table shows a typical EPS Timetable:

Week 1: Introduction. Teambuilding/teamwork. Company presentations. Team meetings with companies. Communication. Systematic innovation.
Week 2: Environmental subjects. European law. Group project work.

Week 3: Cross cultural communication and understanding. International marketing. Group project work. Language.
Week 4: Project management. Project review 1. Group project work. Language.
Week 5, 6, 7: Group project work. Language
Week 8: group project work. Language. Submission of interim report.
Week 9: Group project work. Language.
Week 10: Group project work. Language. Project review 2.
Week 11–16: Group project work. Language.
Week 17: Group project work. Submission of Final Project Report.
Week 18: Exam. Graduation.

ASSESSMENT: PROJECT REPORT AND ORAL EXAM.

Project Characteristics

Projects should preferably be real industrial problems. If it proves difficult to persuade industrial firms to provide "live" projects because of worries about commercial confidentiality, it will be necessary to provide College based projects. Doing a group based project together with students from other countries easily compensates for any differences from the home-based degree.

Choice of Project:

Before each semester projects are solicited from industry. This result in a number of project proposals jointly worked out and described on standard form. The proposals are sent to all accepted participants on EPS in plenty of time before semester start. On the project-proposal form is indicated which area of specialisation or study that we find useful on the particular project. All project groups are interdisciplinary and internationally mixed. We now leave it to the students to choose a project of interest and motivation. Normally students choose a project where he/she can use his/her area of study. The home university supervisor is informed of his students choice of project.

Problem Formulation and Team Exercise:

It is very important that all members of the project group understand the project description given to them by the project provider. If necessary the project group should re-write the text and have their own problem formulation conferred with the project provider and the project academic supervisor.

FORMATION OF AND DEVELOPMENT OF PROJECT GROUPS:

All students are asked to return at least three project choices of their own and prioritise them 1-2-3. This gives us at the guest university a good idea on how to form each group with an interdisciplinary and international mix. Although all projects are based in engineering they also contain business, economic and marketing elements. From this experience students learn what work in an integrated context really means. In addition students join team design and teambuilding courses. Here they take a self-perception inventory test and learn the value of diversity of roles in a team. Also the meaning of cognitive and political problems in teamwork is given.

In teamwork teaching, it must be clear what is expected of the participants. Such as: It is expected that you all show responsibility, take initiatives whenever needed. Try to take ownership of your project and your time. Try to develop a we-attitude in your team. Ask yourself how you can join your own effort with the effort of others to achieve a greater success? Remember that the whole is greater than the sum of the parts. Also remember: Dependent people need others help to get what they want. Independent people can get what they want through their own effort. Interdependent people want to combine their effort with the effort of others to achieve a greater success (Covey, 1989). Dependence is the paradigm of YOU. Independence is the paradigm of I. Interdependence is the paradigm of WE.

Typical Group Development Stages:

In order to develop interpersonal skills it is important to know that teams develop following typical and predictable development stages. Knowing this makes it possible to do something about it and take appropriate measures.

Stage 1: FORMING (Uncertainty)

The insecurity phase is where you are building or forming the team. This initial stage is characterised by insecurity and caution, politeness and tentativeness. The group is not really a team yet. Everybody needs attention, help and concern. You can facilitate this situation by socialising with each other. Have a chat with each other under more relaxed circumstances. Tell who you are, where you are coming from and why you have chosen to join this project. Have a beer together in the student pub.

Stage 2: STORMING (Individualism)

This phase is full of storm and resistance. You try to hide and use a lot of energy trying not to come out in the open with your real personal opinion. Sometimes personalities clash acrimoniously. Nobody seems to speak the language as you. Who is actually responsible for this situation? Team members should have a clear understanding of this situation and of the issues in question. They should try to develop a shared understanding of what is going to happen and why. Everybody have to adjust and adapt to the group environment. All members of the group should give up some of their autonomy. The group should try to develop a shared commitment and work collectively to achieve it. Try to take initiative. Think positively and help create a situation where you can agree about something. Try to break the ice with an unexpected proposal

Stage 3: NORMING (Invitation)

Everything seems to be more relaxed. You tend to think that the storm is over, but it might all be harmony at the surface. You tend at this stage to discuss things that you agree upon. You try to escape conflicts although you sense tension. All team members are getting more deeply involved. All feel that time has come for no compromising any longer. Let us get some work done. We have to find solutions to solve our problems. Try to think positively and take initiatives.

Stage 4: PERFORMING (Implementation)
This stage is also called the stage of productive work. The group has now come to a stage where they feel that they know the strengths and weaknesses of each other. Usually you now know who is doing what and why. All team members seem to be engaged and committed. Try to pull your part of the agreed workload.

Research has shown very clearly that we cannot just take a group of highly creative individuals, put them together, and expect them to do better than other teams.

PROJECT MANAGEMENT

Here students learn how to manage engineering projects. Each team is involved in defining, systematising, planning and navigation of their own project. A supervisor is allocated to each team. On compulsory weekly meetings things such as project development, teamwork problems, communication difficulties and, if necessary, cognitive and political problems are discussed. In brief the three P´s i.e. the Project, the Process and People are kept in focus. From those weekly meetings students learn good meeting techniques and disciplined behaviour. Further they learn to work out minutes and to make a good agenda. Abilities such as self-confidence, responsibility and communication in English are improved. Also the ability to listen and negotiate solutions in place is developed. Company advisors do participate in the weekly team meeting as far as their busy timetable allows. Once a month all supervisors meet to discuss matters of concern.

Courses Taught:

During the first four weeks a number of relevant, short, intensive and project supportive courses are taught, see EPS timetable mentioned earlier. All courses are compulsory and equal to 5 ECTS credit points (European Credit Transfer System). The project work is 21 ECTS credits and languages 4 ECTS. In total one semester equals 30 ECTS credit points. The purpose of the short intensive courses is to break down barriers and to promote a common approach. In parallel with the project work students participate in a programme studies held in English. The first four weeks of the semester 70% of time is spent on team-based group project work and the remaining 30% of the time on study programmes. During subsequent weeks 90% of the time is spent on group project work and the remaining 10% of time on study programmes.

Milestones:

By the end of week 4, the first status report is due defining aims, objectives, design specification and also a time plan i.e. a Gantt chart is required. As mentioned earlier also the project development and the teamwork process, is discussed. At midterm, in the beginning of week 8 an interim report is submitted to the main supervisor. The report must contain work results, and a description of the teamwork executed. Also adjustment of the time plan if any and recommendations for further work to be done in the remaining project period. In addition the following four questions must be answered in writing by each team member:

1. What is your professional contribution to the work done?
2. What is your opinion of the group performance?
3. What is your contribution to the teamwork?
4. What is your opinion of the work done?

The final group report is submitted by the end of week 17.

Product and Process Evaluation:

The group project report is assessed by the results produced and the process executed. It is essential that the team can describe what they have learned from teamwork. The participants know from the very start that teamwork on EPS is situations where they are practicing cooperation and communication in multidisciplinary and cross-cultural project groups. Team members also know from the beginning that they are to do self and peer assessments and why, they are taught to focus on the three P´s, the People involved, the Process executed and the Product produced that is the result presented in the submitted group project report.

GUIDANCE FOR PERFORMANCE OF EPS PROJECTS

Project work involves collective activities in which decision-making should proceed through stages of identification, development, selection and implementation. It is important that, at any given time, each member knows what the other members are doing and why. In order to meet the aims and objectives of the team-based project, specified in the syllabus, students are advised to adopt the following procedures.

a) Problem identification, project formulation, aims, objectives, tasks to be carried out and specification.
b) Analysis of available knowledge, techniques, constraints and resources.
c) Synthesis of the relevant components of this information to indicate possible routes to problem solution.
d) Evaluation of possible routes and a decision made upon the optimum route to be adopted (methodology).
e) Production of a planned timetable of goals and milestones to be reached at various stages in the activity in order to meet the problem specification.
f) Execution of the plan with modifications made for obstacles to progress not foreseen at the beginning.

g) Careful documentation of results and evaluation of their importance.
h) Comparison of the results with the initial problem specification and the expected results.
i) Communication of the entire project activity for assessment, in terms of the documentation and presentation requirements.

Project Performance/Implementation

In each stage of the problem-solving strategy outlined above, there are well-defined tasks that must be performed, skills to be learned, and attitudes to be developed and tested. Furthermore, it is crucial that the standard of assessment can be harmonised.

Consideration of Self and Peer Assessment

To follow and assess the group process is difficult but important. During the course the teamwork i.e. the PROCESS performed is followed closely to make sure that the advantage of working in a group is sustained. The difficulty lies in apportioning credit for the team submission to individual team members. In an ideal situation, equal credit is given to each member of the team. In practice, however, each member's individual contribution will vary both in quality and in quantity. For this reason a system of self and peer assessment and a system of point distribution among team members is used to accomplish the apportioning of credit and to achieve a fair spread of marks. A compulsory weekly meeting is held between a project group and its supervisor. This gives the supervisor the opportunity to work closely with the team. Minutes are made of all meetings and a copy is kept in the group Log Book. Every month during the semester the supervisors meet to discuss matter of concern experienced with the project groups.

Supervision:

The main contribution of the company advisor and the academic project supervisor on EPS is to be a coach to help all members of a project group to understand the content of their project and ensure that progress is made. It is also to nurture and facilitate the group work, the project performance and the project process. Above all, it is important that all people involved in teamwork, try to make sure that the advantage of working in a group is sustained. It is important to be especially aware of cognitive and political problems in the team. He must also help the team members develop shared commitments and make sure that they work collectively to achieve them. Students of today take a different attitude towards the lecturer and the supervisor. It is no longer expected of him to be autocratic as such but it is required of the supervisor to be qualified to answer questions. It is crucial that the supervisor shows a real interest in the group. He must pay attention to the group and lead it in the right direction. It is suggested that a good supervisor should possess the following qualifications:

1. Good communications skills in English to prevent ambiguity
2. Show a real interest in people, their behaviour and expectations
3. Show good management skills
4. Show good active listening skills
5. Not be afraid of unstructured situations
6. Understand how to nurture and facilitate teamwork
7. Have knowledge of cognitive and political problems in group work
8. Have knowledge of group psychology and group dynamics
9. Know how to guide and lead people
10. Know what teamwork is about
11. Have knowledge of different cultural behaviour
12. Know how to lead and run a meeting
13. Know how to write a good technical report
14. Appreciate that teamwork is more than just group project work
15. Have a good technical knowledge an background in ct area

Results

The international project semester EPS has demonstrated that to expose engineering students to international teamwork is profoundly useful. To require and expect a team of 4-6 students to execute an Integrated Engineering and Business project is appropriate to their fast-track development. The project examiners were very impressed by the project reports and vivas. But most importantly, the students thoroughly enjoyed the course and the opportunity to work with team members from other countries. They all regard the experience as being beneficial. They all learned things they would never have experienced at their home university in their regular study. They learned that it is immensely important that one is able to tackle problems alone and solve them in a team together with other persons, to seek out information and to communicate with persons having the same or a different cultural and educational background. Each project group comprises 4-6 students to permit effective management and delegation, collective authority and responsibility. A means of assessing fairly the individual performance of each member is important. It is essential for the project supervisor to guide by example and have regular feedback through tutorial discussion sessions. Although this is demanding of time and commitment from the project academic supervisor, we have found this very valuable to all persons involved. In accordance with the milestones indicated, each project group submits an interim report, together with an oral presentation. All members will be expected to answer questions on the report and each student is assessed separately on his/her response to questions. Rotation of presenter ensures equally responsibility and assessment. In total a high percentage of the overall project mark are obtained from these interim assessments. The remaining marks come from the final presentation.

Statements

In the following are given two typical statements one from an international team of four students from Spain, Germany, Poland and United States and an opinion from an EPS partner. The group concluded:

> The EPS, European Project Semester, is a great way to learn efficient team working skills and gain a large amount of practical experience. Too many students seem to go to school to obtain a degree without participating in any practical experience. The practical experience though, is most important, and that is why the EPS is such a good programme to participate in. The semester has contained much project work, but also great amounts of cultural experiences and new friends. This is what makes EPS such a unique programme; it provides students with practical experience in a setting less formal than an actual career setting would be. On the other hand, students are treated as responsible adults who can produce a project with the same amount of quality as professionals. This creates a working atmosphere much better than, say, when a worker is just given a task by their supervisor to be completed in a timely manner. This is more desirable, and thus completed with much more effort than in the later case. Overall, The EPS creates a working environment for individuals to grow; to grow in their team working skills, work abilities, and also in the social sense. These attributes can be applied, in the future, to all aspects of life.

From EPS partner:

> EPS is a unique concept and beneficial to all students who participate in the programme, says Professor Duane L. Abata former President of American Society for Engineering Education (ASEE). EPS is an outstanding opportunity for students to gain valuable international experience, which is very much needed in the global economy of today. The friendships today established among EPS students forms a valuable international network that will last a lifetime and serve them well in their professional careers as engineers of tomorrow. EPS students learn how engineering problems are tackled in other countries. In the global economy this is a valuable experience, an engineering problem does not necessarily has a single solution, but rather, many approaches and differing but effective and creative solutions.

Conclusion

On EPS we say that teamwork is group performance with regard to the product produced, the project process executed and the people involved. Group performance is as we see it a collective performance of people working on a project as members of an international team. Project work in that sense is social rather than solitary. In doing international teamwork on this course, participants learn what synergy means and they learn to value and appreciate diversity and differences, which is necessary to make a successful group-project. After sixteen years with this teaching concept we find it inconceivable to contemplate former learning and teaching methods.

Epilogue/postscript

By the end of 2008 the three year TREE (Teaching and Research in Engineering in Europe) programme ended (www.unifi.it/tree). I participated in the SIG B3 (Special Interest Group). A final report of this work was published with the title: "Facilitating Multidisciplinary Projects in International Teams" (Macukow et al., 2008). From this report the following is quoted:"Modern engineering education should be focused, among others on some generic competencies. Some of these competencies like: Teamwork, interpersonal skills, the ability to work in an international team with students of different disciplines, nationalities and study levels are of special importance. An engineer today must be able to cope with a broad scope of disciplines such as: economics, management, communication, languages and a solid training in interdisciplinary and international teams. Further: "Many higher education institutions organise international teams of engineering students who carry out interdisciplinary projects. The experience gained so far and the opinion of students and employers allow us to draw a positive conclusion. The task is also to work out the detailed principles of creating and managing international teams of students, who on the basis of common tasks and projects, will be able to acquire unique skills and broad knowledge stemming from various disciplines, not necessarily from engineering. Also, the methods of evaluating work in teams should be worked out. Another element to be taken into account, while developing the skills of the supervisors, are psychological aspects of work in international student teams". Most of the work will be based on many years of experience in running the European Project Semester (EPS) at engineering universities in Denmark, Norway, the Netherlands and at the Technical University of Lodz in Poland".

Learning in Teams

It is required of people to-day that they can work in teams. Therefore students must during their study learn how to work in a team. Try to create a benign environment to stimulate learning. Allow time to develop knowledge, insight and skills. Help students develop their critical thinking skills, which will improve confidence and the ability to dare. However, do not spoon-feed students.

Integrated Engineering

Integrated engineering involves the inter-related work of several disciplines. Working in an integrated context emphasises development of personal competences especially the ability to work within groups. A major supporting activity in all engineering courses, in almost all countries, is the use of an extended project based activity. This is now considered to be such an important part of the general technique of learning that it is being extensively employed. This teaching and learning technique is based on the dual concepts often referred to in the educational literature as collaborative learning and Scaffold Knowledge Integration. It is recommended that the project group should do a Problem Formulation Team Exercise to discuss the project brief initially handed to them by the project provider. The result of this discussion should be a description of the problem as perceived by the project group. Thereafter it should be conferred and discussed with the project provider and the academic supervisor. The end result of this work should be an approved problem statement and rules for working together. Based on this the project group should develop and agree a time activity plan, a GANNT chart for their project period. Project management software such as Microsoft Project should be used to plan and run the project. These techniques are particularly appropriate for project type activities. Collaborative learning refers to students working together in teams where they share and distribute the responsibility of learning. Through meetings team members support each other through questioning and elaboration, providing alternative points of view and by sharing expertise. Research has shown that cooperative settings produce positive results in elaboration of ideas, analysis and problem solving. There is now demand of a person to be proficient with open-ended problem solving and to be familiar with multidisciplinary problems to demonstrate teamwork skills. As described in the Scaffold Knowledge Integration Framework, autonomous learning is facilitated by having students work in groups to allow them to serve as social support for each other through sharing ideas providing feedback and providing some critical assessment of other ideas. Assessments undertaken by the students should be designed to make students listen to each other, to make mistakes in a benign atmosphere, to argue, to discuss and to explain their ideas to other students, to members of the academic staff and to industrial experts. Difficulties in the initial stages of group working between students from different cultural backgrounds need careful scrutiny by members of the project supervisor team. Working in cross-cultural and multidisciplinary teams, we have to learn to cooperate with different mindsets. Each of us has our own paradigm. Our cultural codes are different. This is why it can be very cumbersome to deal with international project teams. A number of the key issues are differences between a deal focused and a relationship oriented way of conducting meetings and negotiating between different suggestions. For example a British level of informality and the more formality structured relationships encountered in several mainland Europe cultures can cause strained relationships. Sensitivity to status differences and the rigid hierarchies frequently displayed in a number of universities may also provide initial uncertainty in students. The main contribution of the academic project supervisor is therefore to help the students to understand the content of their project and ensure they are making progress. It is also to nurture and facilitate the group work and the group process. This should be done by holding compulsory weekly meetings with an agenda determined by the project group. It is recommended that the group work is organised with folders. Thomas Kuhn introduced the paradigm shift in his book “The Structure of Scientific Revolution” and showed the significance of first break with tradition with the old way of thinking. Teamwork is group performance with regard to the product produced, the project process executed and the people involved. Project work in that sense is social rather than solitary. Participants learn what synergy means and they learn to value and appreciate diversity and differences, which is necessary to make a successful group project. Students should be involved actively in order to learn to dare and to do. The supervisor must make sure that the advantage of working in a team is sustained.

ASSESSMENT

The need for assessment is obvious. In assessing an integrated engineering project done as teamwork the following elements should be assessed: The product produced. The project process executed, and the people involved. Individual contribution in teamwork is always a key issue when talk is about group project work. To reflect the workload pulled by each member during the project execution and to prevent free riders, team members and team supervisors should be asked to assess this important point. Workload means each team member´s technical contribution in the major field of study. Also their contribution to make things work if something goes wrong. Further the individual contribution to the performance of the work process should be evaluated by asking questions such as: Willingness, understanding, leadership, attitude and initiatives shown. Finally, self and peer assessment, as well as assessment of supervisor qualifications should be considered.

Current engineering education does not respond adequately to the demands that need to be met. Engineers commonly describe themselves in terms of a single discipline, a convention increasingly misleading, as very few engineers work totally within the confines of a single discipline or industry. Changes in working attitudes, and greater emphasis on multidisciplinary and multinational environments, also highlight the need for a completely different approach to education and training. Traditional specialism no longer applies to a world dictated by a bigger overlap of engineering and science.

The accelerating evolution of technology accompanied by a growing amount of knowledge, much of which continuously become redundant, require a new approach to education and training and changes of the curriculum. Engineering education therefore has to provide a learning environment that stimulate deep learning and in which acquiring insight will take precedence over conventional specialist courses. Continuing education has become a more determinant factor in career development and is part of a through-career education and training. Easier access to knowledge through the ongoing advances in information technology should be coupled with improvements in teaching and assessment techniques. Accreditation boards should be aware of the changing conditions and adjust accordingly. They should appreciate the new professional equipped with a broad range of entrepreneurial skills.

CONCLUSION

In making a country a strong competitor in Europe and strong on the global market, we have to make sure that engineering and business students develop the right qualifications. Also the working conditions should be the best possible. Researchers predict that work in the future will merge with leisure making things more blurred. It is expected that engineers of tomorrow will be given a special task to solve, rather than being employed to work from nine to five. The employer will be more interested in short term contracts, buying competence and expertise rather than employing qualified people the way it happens today. This of course requires a solid basic engineering and business knowledge combined with the ability to tackle problems alone and yet solve them in cooperation with others. See reference list: Andersen, A. (PAEE 2009). Keynote on Project Management and Teamwork (Andersen, 2009). It will be an important part of the career of the future engineer. Basic understanding of a broader area of disciplines like economics and management and solid training in teamwork, communications and languages and good understanding of other cultures and their traditions and habits will be required.

Research indicates that an increasing number of people will be employed in the service industry. The manufacturing industry will, to a great extent, be highly automated with greater use of robotics. Engineers must therefore have a solid knowledge and understanding of those technologies. Knowledge of a specific technical field will be of less importance. Environmental awareness and a good understanding of an optimum use of resources will be features of future products and manufacturing processes. Industry must find or invent responsible ways to increase production without environmental consequences. Fast technological development leads to faster product shifts on the market. At the same time, the market becomes more global. No room for failures or mistakes, things simply have to be right first time. That means increasing attention must be paid to the development of high quality products. Product development will take place as an integrated process with collaborating skills such as design, planning, production, sales, marketing and recycling. Greater integration will be required and the developer must be able to overview the situation and make use of specialists and rely on their knowledge. The future engineer must be able to cope with frequent changes.

THE FUTURE

It is important that engineering students acquire an international dimension and it is important to strengthen links with the world outside the university i.e. the industry and the international society. The tendency to go abroad for one or two semesters should be supported, and in particular financially, and we should encourage our future engineers to be mobile. This will help to develop significant communication and contribute to develop our societies. Aims in education must comprise professional as well as personal development goals since true effectiveness requires both elements. The future businesses need persons who are competent, responsible and able to contribute constructively in business projects across borders. It´s extremely important therefore, that companies submit projects and allocate the necessary time to company advisors; this ensures recognition and probably the use of new skills which are to be acquired. Companies with an international organisation and the engineering universities must go hand in hand to develop future candidates with the right skills.

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WIM WEENK AND MARIA VAN DER BLIJ

3. PLEE METHODOLOGY AND EXPERIENCES AT THE UNIVERSITY OF TWENTE

INTRODUCTION

Changes in the society, labour market and new insights in educational sciences have stimulated developments in academic education. Views on student learning have shifted from teacher centred to student centred and learning objectives are no longer the end goal of degree programmes. Nowadays objectives of the programme are formulated as competencies that are to be achieved by the students.

Constructivism advocates that students are active learners who construct their own understanding and direct their own learning process.

Loyens (2007) describes four basic assumptions of constructivism:

1. Knowledge acquisition is a process of knowledge construction in which prior knowledge comprises the frame of reference for the interpretation of new information.
2. Learning involves interactions with others such as fellow-students or teachers.
3. Knowledge construction benefits from meta-cognitive skills such as to plan, monitor, and evaluate one's learning process.
4. It is important that learning takes places in an authentic context, preferably similar to future professional contexts (p.115).

Educational methodologies that fit with constructivism and competence learning are Project-Led Education (PLE) and Problem Based Learning (PBL). In this chapter we mainly focus on Project-Led Engineering Education (PLEE) which is Project Led Education especially for students in University Engineering degree programmes.

In paragraph 1 the PLEE methodology is defined and in paragraph 2 the role of the tutor is considered. Paragraph 3 describes the benefits of PLEE and in paragraph 4 there is an overview of the similarities and differences with PBL. The chapter finishes with the challenges for PLEE implementation.

THE PLEE METHODOLOGY

In this paragraph the methodology of PLEE is explained and illustrated with an example. The definition of PLEE, the PLEE programme and examination in PLEE will be addressed.

L.C. de Campos, E.A.T. Dirani, A.L. Manrique and N. van Hattum-Janssen (Eds.), Project Approaches to Learning in Engineering Education: The Practice of Teamwork, 29–52.

Definition of PLEE

Project Led Education knows a variety of forms and connotations. Powell and Weenk (2003, pp. 29-30) define PLEE as follows:

> Project-Led Engineering Education focuses on team-based student activity relating to learning and to solving large-scale open-ended projects. Each project is usually supported by several theory-based lecture courses linked by a theme that labels the curriculum unit. A team of students tackles the project, provides a solution, and delivers by an agreed delivery time (a deadline) a 'team-product', such as a prototype and a team-report. Students show what they have learned by discussing with staff the 'team-product' and reflecting on how they achieved it.

Features of PLEE

The key features of a project are authenticity and a real problem coupled with a future professional situation and context. A series of projects explores different subjects and themes and develops increasing levels of professional competencies. Van der Blij (2002) defines a competence as:

> The ability to apply integrated complex knowledge, skills and attitude in such a way that the person acts responsible and adequately in a certain context.

In PLEE the students learn to master the competencies specified in the curriculum in the context of professional practice. The theme of each project is related to a few disciplinary subjects. PLEE provides a strong portfolio of context-rich competencies which a professional engineer should have. Figure 1 represents a short description of an example of a typical first-term PLEE project scenario (Powell & Weenk, 2003, p. 37).

The PLEE Programme

Experience shows that PLEE works well in full-time degree programmes in pure and applied sciences and engineering (either Bachelor's or Master's level).

Figure 2 shows a typical schematic timetable of a trimester (Powell & Weenk, 2003, p. 189). Project work and non-project-supporting courses are planned during the whole term, and there are two project supporting courses each blocked for 5 weeks. The project is a substantial part of the student learning activity. The project starts at the level of about 1 day per week, and expands to about 4 days per week. The student study time includes lectures, tutorials and private study. Each element of the trimester is separately assessed.

The curriculum is arranged so that there is a theme in each academic term which represents a part of the complete engineering discipline of the programme. The theme covers at least two (contrasting) project-supporting lecture courses which are not closely related to each other academically, but which are found coupled together in engineering practice. The sum of all the themes therefore covers the curriculum and the discipline in a representative way. It is clear how the lecture courses relate to each other during each term and between different terms.

The **Context**: the first term of a first year 14-week (bachelor's) mechanical engineering programme

The **Theme** of the term: to provide a first motivating acquaintance with mechanical engineering, from which the integration of the subjects is clear to see.

The **Project Assignment**: 'Reduce the internal volume of an empty can by 90%'. Specifications are given to make the assignment very challenging, e.g. volume, costs, quality. This project is meant to give the students experience of the complete design and production cycle for a can-crushing apparatus to be used in the home kitchen. The student team must make a design for a prototype, make the components for it, plan and carry out the production, assemble the apparatus, test it and improve it if necessary. The assignment provides an open-ended, stimulating focus for students to learn about the 'subjects' in the trimester.

Project Supporting **Subjects**: Design, Engineering Drawing and Computer-Aided Design, Production Systems, and Statics.

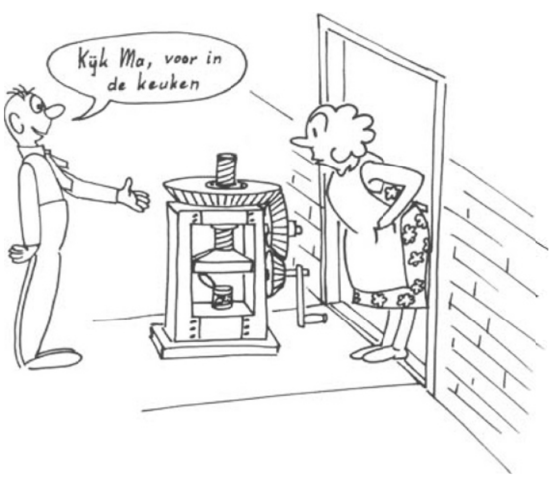

Figure 1: 'Look, ma, something for the kitchen!'

Non Project Supporting **Subjects**: e.g. Mathematics, Communication,

Activities: The student team gets the project on the first day of the first term and is immediately confronted with a real problem representative of professional practice. It will need to make well-reasoned choices and compromises in order to reach a good-quality 'solution' within the time allowed.

Figure 1. An example of a typical first-term PLEE project scenario.

Examination in PLEE

Experiences with PLEE demonstrate that it is quite possible to examine all aspects of the student learning activity in a proper manner (Peters & Powell, 1999; Powell 1999). Non-project supporting courses are handled in the conventional manner using written examinations or oral examinations, according to local custom. Table 1 shows the four aspects of the project that can be assessed. Often all four elements are part of the final mark. How the different elements are weighed is determined before the project starts. Sometimes it is obligatory that all parts are sufficient, sometimes a percentage is given to all the elements and compensation within the project is possible.

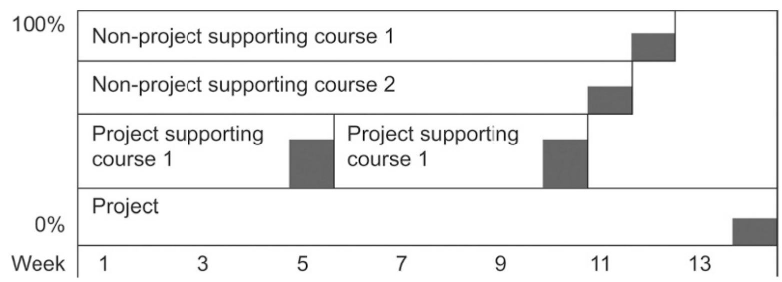

Figure 2. Schematic typical study period in 1 trimester.

= examination

Table 1. Individual and team aspects for project assessment

	Process	*Product*
Individual	Reflection on own learning process	Presentation, part of team reporting
Team	Reflection on team co-operation	Final Report and Prototype

Examining the project work depends on a clear scheme: it is good practice to use a team of examiners to read the team-report on the project, listen to the team's oral presentation of the work done, and cross question individual students about the work done by other members of the team. In this way the examiners can form a judgement whether each student understands and can defend all of the work the team has done.

The Dutch review of Mechanical Engineering programmes is satisfied with what UT has done:

> The Faculty [UT-ME] indicates that the problem of individual assessment in teams/projects is still difficult... The committee judges the different forms of examination (team reports, individual examinations, written and oral) and the integrated approach as positive' (VSNU, 2000).

PLEE in Practice

As described in the paragraph ‘The PLEE programme’ all, or almost all, trimesters have a substantial open-ended project which handles a problem representative of professional practice.

Eight students work in teams about 40 % of the available learning time on the project.

The emphasis is on the student learning time (the time needed to master a given topic) and not on the conventional class contact time. About 60% of the learning time is spent on handling the materials of the lecture and other courses; the rest of the time is spent on the project.

All the students are responsible for the complete project, including the parts which they are not personally working on. All the student teams work on the same project. The theme and subjects of the project will change each term.

Most Universities start with the main features of PLEE but make adjustments to their own situation. That is one of the reasons Project-Led Education holds a variety of forms and connotations. Some have a more traditional curriculum with a small project at the end of each term or year. One of the main goals of such projects is integration and application of knowledge. Others prefer a combination of projects and problem based learning, but all the different forms agree with the four mentioned basic assumptions of constructivism: construction of knowledge, interaction, meta-cognitive skills and authentic context.

TUTORING AND SOFT SKILLS IN PLEE

Two important differences between PLEE and classical education are the role of the teacher and the emphasis on soft skills.

Tutoring in PLEE

As stated in the previous paragraph PLEE consists of courses next to the project. The teacher has the role of expert in the courses. In the project the teacher has the role of tutor in supervising the work of teams as well as the role of expert. It is important to distinguish between these roles. In both roles the tutor should be able

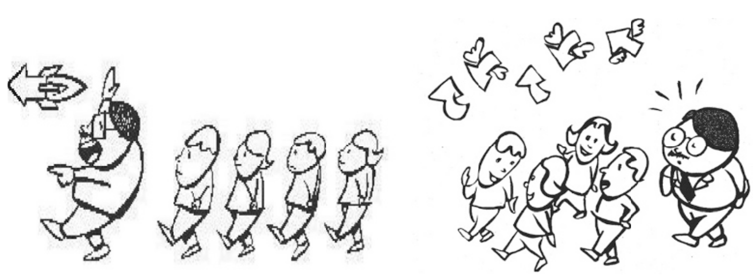

Figure 3. Different teaching methods (Powell & Weenk, 2003, p. 150).

differences in position of a traditional lecturer and the tutor. In traditional education it seems as if teachers 'walk in front'. Teachers and tutors 'walking behind' student teams are preferred (Weenk, 2000).
Compare the tutor and a volleyball coach during the match:

- The coach is not equal to the team players nor being the leader;
- The team players invest energy in active way; the coach is observing;
- The coach is seated outside the boarding, while team players are jumping and smashing;
- If the score is going lose, the coach is enabled to ask for time-out;
- Always discussion, feedback and if necessary changing some players.

Most lecturers are unfamiliar with the tutor role. It is not easy for lecturers to adjust to the role of tutor. Teachers at the University of Twente are supported in learning to be a tutor in PLEE by short tutor workshops. Role-playing and simulations help to understand and develop appropriate tutor competencies.
The work done in teams must be made functional. Supervision is directed towards the teams getting things going and keeping them going. It is important for teams to function well even without the tutor in the vicinity. Getting real work going and structuring it is the function of team meetings.

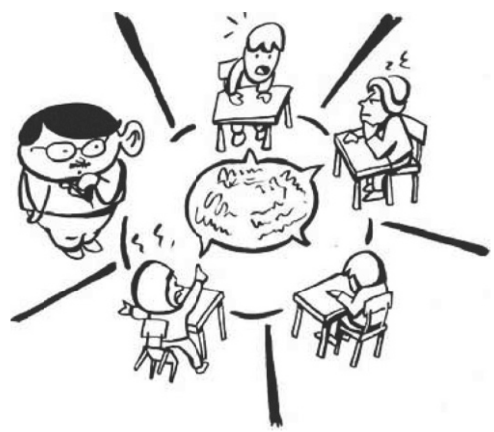

Figure 4. The teacher monitors student team discussion (Powell & Weenk, 2003, p. 98).

Asking questions and providing students with feedback fit the tutor role. Asking the right question and giving feedback at the right time not only challenge the team, but avoid having students getting stuck during their learning process and ending up treading water.

Tutors observe individuals, give feedback just-in-time, in order to keep the students going in planned direction, and speed. Tutoring involves listening carefully to what students know and then reacting to the student signals by suggesting new or better approaches. Above all the tutor does not tell the students what to do nor does the tutor solve the problem for the student or student team. Pictorially the teacher develops a smaller mouth and a larger ear.

It is important that project teams take decisions independently and justify the choices they make. Students who have not previously taken part in project work have to learn how to do so. That involves working together, planning and task distribution, taking part in meetings, giving presentations, and so forth. Therefore the tutor may fulfil the next sub roles in the project (based on Powell & Weenk, 2003).

Setter of the assignment. A characteristic of project work is that there are certain learning objectives so that the student and the project team have to plan, communicate and work together, make adjustments, agree to compromises, and so forth in order to achieve the outcome. The learning objectives set the limits of the freedom of the students project work.

Stimulator. The tutors can motivate students through their own attitude and get the most out of the exercise in terms of a learning outcome. They can do this for example through:

- showing interest and giving attention to students team work; depending on what team members need, the tutor becomes either a listener, or an opponent who challenges through asking questions.
- asking the team members regularly about the why and the how, encouraging creativity and setting them to go into things in more depth.
- helping the team through a difficult period if things are not going too well; and with projects which last a long time that is very likely to occur at some point.

Monitor of the learning process (facilitating co-operation). Learning to work together in project teams does not always run smoothly. The tutor will be able to observe that from confusion on the activities and strategy, poor preparation of the meetings and the team climate. The tutor can support the good development of co-operative effort for example through:

- ensuring that the team makes a good start. The tutor must be present at the first meeting and introduce him/herself, the project and the mutual expectations of the students and the tutor.
- insisting on drawing up agreements arranging the activities between the meetings.
- seeing to it that the team works hard and focused according to the procedures agreed on and that every member contributes to a satisfactory extent.
- checking that the chairperson takes turns and coaching the discussion leader in preparing the meeting, Chairing a meeting is a learning experience for everyone.
- observing to see that the team is working together in a useful manner and that team co-operation is discussed in a constructive manner.

Evaluator of the process. The tutor can support team process evaluations on different times and in different ways. This is to improve the quality of the work in the course of the project. During the last ten minutes of a meeting the tutor can comment on the way in which the meeting ran, what has gone well and what could go better. The tutor can discuss for example the work done and project team opinions about the way the meeting went. The team members try to find the weak spots for themselves and think about own solutions.

Expert (specialist). In some programmes the role of tutor is fulfilled by (PhD) student assistants. In many programmes however, the lecturer is the tutor. In discussions with the team, the tutor tries to avoid explaining and teaching, so that the team is forced taking the active role. When the team is really stuck the tutor may give a short explanation of a difficult point on request of the team. The tutor uses judgement based on academic and professional experience to guide students to reach solutions to open-ended problems. There are no ‘perfect’ or ‘unique’ solutions to proper PLE problems or projects. Staff may from time to time feel exposed to unfamiliar situations where they have no ‘ready-prepared’ answers to team questions, and feel uncomfortable about this. This need not weaken their position; such exposure places them in much the same position as the students, but the staff can draw upon their wider experience-in-general when handling the student questions or commenting on student proposals.

Teacher and tutor in soft skills. In the above described role of the tutor it becomes eminent that the tutor has a very important role in supervising the process of project work. During the project work the students learn, next to the knowledge and skills necessary for attaining the result, the so called soft skills.

Soft skills in PLEE

According to Weenk and Haijkens (2008) ‘soft skills’ is a sociological term which refers to the cluster of personality traits, social graces, facility with language, personal habits, friendliness, and optimism that mark people to varying degrees.

Table 2. Tutoring soft skills

Soft skills	*Discussion aspect*	*Typical (PLEE Tutors') specific questions*
Planning	definition of problem research issues time-work schedule planning	What is the problem statement? What are you going to research? Who will do what and how and when? How will you re-adjust the planning?
Organising	division of tasks team organisation adjustment of tasks	How will you determine who does what? What will you do individually, in subteams or full teams? How will you mutually adjust contributions?
Co-operating	rules norms co-ordination productivity	What rules has the team agreed on? What are sanctions for exceeding certain rules? How has mutual adjustment between subteams been settled? What agreement has been made on producing output?
Evaluating	procedure product evaluation process evaluation result	What agreement about evaluating project work? What progress did the team make on tackling problems? How is co-operation going within the team? What is done with the evaluation results?

Van Woerden (1991) summarised many project team soft skills. He subdivided the skills and provided questions for PLEE tutors to consider in case they wished to contribute to the development of an effective project team. In Table 2 some examples of these skills and questions are summarised.

Today's competitive global market and changing work environment demand that engineers possess 'soft skills' in addition to technical skills, and must be able to understand project goals and have the ability to accomplish them with available resources. Currently, engineers learn leadership and management skills while working, learning 'soft skills the hard way.' In order to meet the demands of this changing world, engineering programmes are challenged to come up with innovative ways to teach classes so that graduates are prepared to take on the challenges twenty-first century engineers face (Kumar, 2007).

Looking at the tasks and activities of the tutor it is clear that this person has a very important contribution to the learning process of the students and that this is consistent with the four mentioned basic assumptions of constructivism: guiding the students in knowledge construction, stimulating co-operation with team members, supervising meta-cognitive skills and making students aware of similarities of the project context and situations in the labour market, the authentic context.

The benefits of PLEE

In this paragraph a number of questions on the benefits of PLEE will be answered, mainly based on the experiences with PLEE as described by Powell and Weenk (2003 pp. 30-79).

Does the student learn more or less in PLEE compared with the classical approach?

Comparing different methodologies is difficult because the aims of the classical approach are different from those of PLEE. Therefore some separate skills are considered.

- *Soft skills.* One of the major reasons for changing from a classical curriculum to PLEE is the need to broaden the competencies of the students during their passage through the degree programme. After completion of one project the student has learned much about the necessary 'soft skills', and effective study skills are becoming well-developed. In this sense one can claim with reasonable certainty that the students will learn more about 'soft' skills' because these competencies were but little developed in the old-style programme.
- *Academic skills.* In the special sense of developing competencies in analyzing and solving open-ended problems, where the integration of the various elements of the programme is required, the answer is a clear 'yes'. The team work is accompanied by more-or-less continuous deliberately-stimulated reflection: this

strongly supports the learning process. In the sense that the students have learned to learn, and to articulate what they know and what they do not know (and to focus on issues), then again 'yes'.

- *Hard skills.* Comparing the academic progress in the first term of the programme between the PLEE approach and the classical approach the students will have learned about the same technical material. Motivation and enthusiasm will have encouraged student learning (especially in project-related courses). Experience (Powel & Grunefeld, 1999; Milgrom, 2001) confirms that academic progress in the development of the 'hard' competencies really is quicker under PLEE.

Experiences in Twente give the impression that PLEE might be less good at handling the mastery of all the abstract concepts, perhaps because students tend to see mainly the relevance of concepts for application in the assignment.

How Does PLEE Affect Student Motivation to Learn?

The engineering student wants to learn to think like a professional engineer and behave like an engineer. PLEE brings in an element of realism from the beginning by an open-ended problem. The problem bridges several lecture courses or disciplines; it is not narrowly defined, so the students must make and defend choices made during their work; the involvement of the students helps to establish their 'ownership' of the problem and its solution. The excitement of completing good work on time, and interacting with a tutor who can show the relevance of practical experience ('how does...? and 'what if... ?') as well as guide on the theoretical aspects gives a boost to the learning process and motivation.

What Do Staff Think About PLEE?

Although there were initially a few reservations about the depth of study which students could reach in a project ('surely all this effort on attractively-presented written work takes time away from the serious learning business?'), this was soon dispelled by the serious in-depth approaches which students demonstrated. And after three years, those entering the graduation phase were well-motivated to choose what they wanted to do and ask the professors opinion about it: previously the students were much less well-prepared for this new step.

What Do Students Think of Their PLEE Experience?

Below some student comments on their PLEE activities and results. (Powell & Weenk, 2003, p. 30-31).

> 'At the end of the trimester our team had designed a can-crusher (see box 1) and demonstrated that it really worked – and we picked up the first prize for

the best solution to the problem. We saw how the different parts of the syllabus really fit together.'

'We got stuck at one stage, and spent quite some time working out why we were stuck. We talked through what we wanted to ask the teacher. He did not tell us what to do, but he did suggest several approaches we had not come up with. That helped us a lot'

'We split up the problem into sub-tasks and reported back individual work to the team every week. This meant that we worked at a reasonably good rate during the complete trimester. If we had left most of the work until the last few weeks, we would never have finished on time.'

'We worked quite hard throughout the trimester. In the first project it took longer to pull the report together than we had expected. In the second project we allowed more time for this.'

'The first project exam was rather nerve-racking. The examiners asked questions about what was in – or should have been in – the report. But they asked explanations from those team members who had not done the specialist work.

'It soon became obvious that there were differences in understanding some showed a tendency to take on more of the work and others who were often absent. This led to some friction between team members for a while. In spite of the disagreements, we enjoyed working on the project and learned a lot about how machines worked, and how to construct them. We remained motivated, and because of that we were able to deliver the report on time. Eventually we built a prototype, which we were very proud of. '

The Dutch Review Committee on Mechanical Engineering Education commented on the changeover from a classical curriculum to PLEE at the three Dutch Technical Universities offering Mechanical engineering, Twente, Eindhoven and Delft: 'the motivations to change from a classical approach to a project-based approach were:

- to stimulate and motivate students and to acquaint them at an early stage with the profession of mechanical engineering, in particular the aspects of analysis, planning, design and manufacturing, etc;
- to increase the efficiency of the system in terms of the duration of the study;
- to improve teamwork and communications skills of the mechanical engineer;
- to arrive earlier than before at a point where the student can make a well-founded decision as to whether or not to continue the study of mechanical engineering at a university level.' (VSNU, 2000)

The Committee came to the conclusion that this approach was successful in this task.

'The Review Committee noted a great enthusiasm among the students and staff at the three universities for this change in educational methodology.... It appeared that the early selection procession during the first year is more effective than before .... The students are more motivated during the first few years and communications skills have improved.' They also noted that this 'revolution' in the education of engineers during the past few years has enthused the staff again for their educational task – the main 'raison d'être' for the universities.' (VSNU, 2000).

PLEE AND PBL

Problem Based Learning is another method besides PLEE that fits constructivism and competence learning. PBL is not a form of PLEE but a different educational methodology. In this paragraph the PBL methodology is explained as well as the similarities and differences with PLEE.

Definition of PBL

As defined by Howard Barrows and Ann Kelson, 'PBL is both a curriculum and a process. The curriculum consists of carefully selected and designed problems that demand from the learner acquisition of critical knowledge, problem solving proficiency, self-directed learning strategies, and team participation skills. The process replicates the commonly used systemic approach to resolving problems or meeting challenges that are encountered in life and career.'

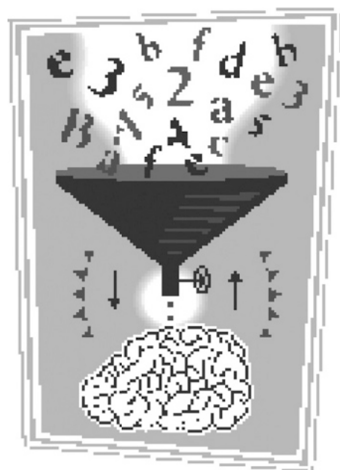

Figure 5. Knowledge construction (Vlas, 2010).

PBL has been developed by the University of Maastricht (among others). PBL, as the name implies, begins with a problem for students to learn more about. Often these problems are framed in a scenario or case study format and are designed to be 'ill-structured' and to imitate the complexity of real life cases. Assignments vary widely in scope and sophistication, but in general PBL deals with small scale problems relating usually to a small number of issues within the theme for a trimester. Assignments or tasks which are primarily based on knowledge and understanding and not on solving complex open-ended problems may lend themselves more to problem-based learning (PBL). They involve a quick individual expert diagnosis of a problem. This makes PBL particularly suited to the study and practice of medicine, law and psychology.

The Procedure Used in PBL

A team of up to 20 students meets for a few days during typically a 1 to 2 week period, in order to reach collectively a good understanding of a problem. In PBL the emphasis is on making a diagnosis, providing an explanation or an interpretation of a situation. Although the problems and solutions are new for the students, in fact they are well known to the experts.

Duch (2001) describes a standard PBL cycle for the students for attaining the solution of the problem. The students:

- organise their ideas and previous knowledge related to the presented problem
- discuss and pose questions, called 'learning issues', in order to define what they know - and more importantly - what they do not know.
- rank the learning issues. They discuss what resources will be needed in order to research the learning issues and divide tasks to attain all the answers
- reconvene and explore the previous learning issues, integrating their new knowledge into the context of the problem. They are encouraged to summarise their knowledge and connect new concepts to old ones. They continue to define new learning issues as they progress through the problem.

Students soon see that learning is an ongoing process, and that there will always be (even for the teacher) learning issues to be explored. Students ideally have adequate time for reflection and self-evaluation. Using PBL, students acquire lifelong learning skills which include the ability to find and use appropriate learning resources.

The PBL Programme

The students work during one or two weeks on a task. After that a new problem is introduced. The tasks are organised in a certain theme. After a certain period examination takes place in which all the knowledge and understanding of the previous period is tested. Figure 6 shows an example of a PBL study period.

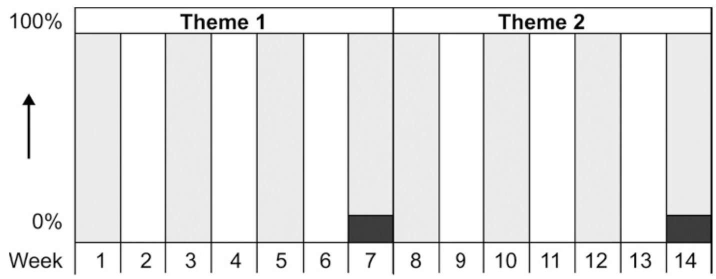

Figure 6. Schematic example study period in 1 trimester.

= examination point

The Role of the Lecturer in PBL

Almost always lectures are a part of PBL. During the lectures the lecturer is the expert. But during the team work the lecturer must supervise guide and support students, not lecture, direct or provide easy solutions. The degree to which a PBL course is student-directed versus teacher-directed is a decision that the lecturer must make based on the size of the class, the intellectual maturity level of the students, and the instructional goals of the course.

Similarities and Differences Between PLEE and PBL

The EduTech Wiki Sites (2010) give an elaborate exploration of the similarities and differences between PLEE and PBL. The breadth of the definitions of PBL and PLEE, their conceptual similarity, and the use of the shorthand term *PBL* result in some confusion in the literature. At first glance the characteristics of PBL seem the same as in PLEE they are different in emphasis and form. Fundamentally, problem- and project-based learning have the same orientation: both are authentic, constructivist approaches to learning. The differences between the two approaches may lie in the subtle variations.

Similarities

As defined in the literature, project-based learning and problem-based learning share several characteristics. Both are instructional strategies that are intended to engage students in authentic, 'real world' tasks to enhance learning. Students are given projects or problems with more than one approach or answer, intended to simulate professional situations. Both learning approaches are defined as student-centred, and include the teacher in the role of facilitator or tutor. Students engaged in project- or problem-based learning generally work in cooperative teams for extended periods of time, and are encouraged to seek out multiple sources of information. Often these approaches include an emphasis on authentic, performance-based assessment.

Differences

Despite these many similarities, PBL and PLEE are not identical approaches. PBL typically begins with an end product or 'artefact' in mind, the production of which requires specific content knowledge or skills and typically raises one or more problems which students must solve.

PLEE goes a step further and much wider. The problems or projects are larger, and the inter-relationships between several different subjects and domains are explored.

The PLEE approach uses a production model: First, students define the purpose for creating the end product and identify their audience. They research their topic, design their product, and create a plan for project management. Students then begin the project, resolve problems and issues that arise in production, and finish their product. Students may use or present the product they have created, and ideally are given time to reflect on and evaluate their work (Ruangrit, 2009).

The entire process is meant to be authentic, mirroring real world production activities and utilising students' own ideas and approaches to accomplish the tasks at hand.

Table 3. Differences between PBL and PLEE

	PLEE	*PBL*
Assignment	Open ended	Closed
Authenticity	New real life authentic question, the solution is unknown	Real life authentic problem, the solution is known
Duration	10 weeks or more	1 – 2 weeks
Knowledge	Inter relationship between subjects	One subject at the time
Skills	Disciplinary skills, engineering skills and soft skills	Disciplinary skills, problem solving skills and soft skills
Team process	Co-operation	Task division
Team work	Up to 8 students	More than 10 students
Method	Disciplinary methodologies for research and design (production model)	Standard strategy for learning (inquiry model)
Result	A new solution, often a product or a design	Answer to the problem
Organising centre	The solution is the organising centre for the curriculum	The problem is the organising centre for the curriculum

In table 3 some differences are summarised as two extremes on a continuum. In reality the differences are much more blurred (Mettas & Constantinou, 2006).

Mix of PLEE and PBL

It is possible to mix PLEE and PBL, provided there is a clear vision. The Technical University of Eindhoven started out with problem-based learning, and then switched to a mix of PBL and PLEE and has now a methodology called: Design Led Education. ITESM (Martin Perez, 2002) has a mix of case studies, PBL and PLEE. In practice, the line between project- and problem-based learning is frequently blurred and that the two are used in combination and play complementary roles.

CHALLENGES FOR PLEE IMPLEMENTATION

As has become clear in the previous chapters PLEE is complex and it is not limited to a single course in a programme. A change to PLEE involves a large-scale innovation covering the complete degree programme and will affect the organisation, the staff and the students, which is very challenging.

Innovation Phases

The three conditions for successful innovation which Havelock & Huberman outlined in 1977 are still valid: The infrastructure for the innovation must provide a recognition of needs at all levels, a correct analysis of the problem to be solved, a usable solution at the right level for implementation and sufficient resources. Bringing in PLEE must be planned, guided and progressed with the necessary authority, so that its implementation can be embedded and institutionalised and there must be consensus among those most involved about the aims of the innovation process (bringing in PLEE) and how to reach the objectives.
Fullan (2007) describes the process of curriculum innovation towards a new concept as three broad phases:

1. Initiation phase: the result is the decision to proceed with the change (adopt)
2. Implementation phase: the result is the first experiences with the application of the new method (implement)
3. Institutionalisation phase: the result is the incorporation of the change in the organisation (consolidate)

Plomp *et al*. (1992) represent the phases of curriculum innovation in figure 7.

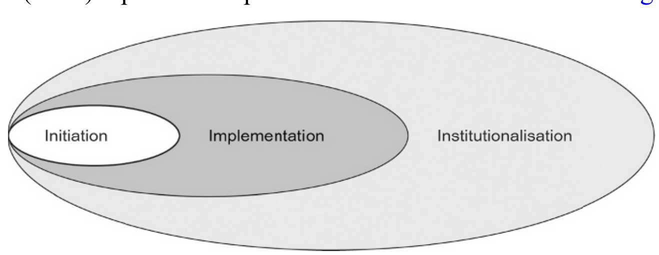

Figure7: Schematic representation of innovation phases.

The initiation phase starts with the conviction of the Faculty Management that the problems about the current handling of the old curriculum are sufficiently serious to justify a large-scale re-design and that PLEE seems to be a promising basis for solving (some of) the problems.

Ruijter (2002) identifies 4 reasons why PLEE is a good choice for innovation within an 'engineering system':

- it is suitable for educating and training relevant engineering competencies.
- students respond well to more varied learning activities (compared with the traditional approach).
- the social commitment to team work stimulates participation.
- students respond well to the relevance (to engineering practice) of the PLEE learning activities.

In most cases the best start of the implementation phase is when the initiative comes from the Faculties under the general support of the Executive Board of the University. When a given Faculty proposes a coherent structural change it is more likely that the change will be implemented, either gradually or in a more abrupt way, depending on the local cultures. The support and recourses for the innovation must be considerable at all levels within the Faculty.

Pilot-scale trials leading to a larger-scale impact are good. Small-scale experiments involving teams of teachers and teams of students can be highly informative and motivating within the wider context of the structural use of PLEE, thereby influencing the three criteria for innovation stated by Havelock & Huberman (1977) just mentioned. However, very small-scale efforts at the level of a single lecture course and a single teacher are unlikely to be successful.

Difficulties of PLEE

It is very important that both strong aspects as difficulties will be considered during the implementation phase. Of course PLEE knows some difficulties, fortunately they can be overcome by careful planning and by the added-value PLEE confers over and above the classical approach.

The Necessary Costs

Naturally there are costs involved with the implementation of PLEE. However, there is little evidence that 'in the steady state' PLEE is financially much more expensive than a classical approach. Powell and Weenk (2003) give the following checklist:

> Overall planning of PLEE prior to decision to implement, and planning for academic implementation.
>
> Administration: timetables and deadlines; regulations and procedures; recording inscriptions (registration for course and programme), fees paid, and exam results.

Staff information to change their focus from the old system to the new system; tutor training; student training in meeting skills, project planning, team-work

Accommodation for examinations (several small rooms in place of a large exam hall); student team project rooms or units with facilities in a large room.

Staff time for defining a project for each academic term, and the work-up process using a staff team; staff training for examination of student team; staff time for exam preparation and conducting the project exam; tutor liaison meetings; documentation on how to organise/run/prepare X; and what to do when something goes dramatically wrong.

Preparation of documentation for internal (Faculty/University) approval to start.

Monitoring of staff allocations and expenditure against agreed budget.

Evaluation of a project after completion (p.94).

The New Programme

The use of the PLEE approach does require some change of coverage of the curriculum.

Not all of the old curriculum can be handled, the emphasis on abstract principles might be less explicit and soft skills are included. A cut of 20% in the old core curriculum is the *maximum* likely to be necessary. The reduction can be adequately achieved by reducing the quantity of lectures, making tutorials more effective, incorporating learning within the project itself, modernising treatment of old craft-based courses and omitting some courses altogether. Making the choices of what to leave out will always be controversial at the time of doing so; afterwards, with good study results, one wonders what all the fuss was about.

Kolmos & Algreen-Ussing (2001) report a successful transfer to PLEE at Esbjerg by reducing the course time by 70% and by upgrading the project work from 15 to 50%. The new curriculum for Industrial Design at the Technical University of Eindhoven (Powell, 2004) goes a big step further: the university considers the students as co-workers. These students work on a highly individual basis (in project teams), follow hardly any scheduled lectures and have discussions with their mentors during which their progress is assessed.

Beliefs of the Staff

By far the biggest challenge for university or faculty management is to convince the staff to abandon an existing comfortable practice, even if, in that practice, student understanding or student progression is unsatisfactory. Objections to the change are to be expected.

- Attention to soft skills takes the place of content of the old curriculum Engineers need the soft skills as a part of their necessary competencies. And when the students learn to study effectively they learn engineering more effectively as well.
- Teachers haven't the skills to practice the social science of tutoring team-work.' Once the teachers see how PLEE is to be handled they respond well to a good training session on the relevant soft issues.
- In a team of eight students, only two will do the work the rest will sit back and do nothing. The workload for the assignment, the social pressure of team members, the tutor and the examination prevent the so called 'hitchhiking'.
- Students can't do a project in year 1 because they know nothing about engineering and must get a good dose of theory first'. A project has two functions: to apply or integrate knowledge already given in lectures, and to generate new knowledge.

In Twente incoming (first-year) students find the team-based project an excellent motivation for finding out what engineering is all about the students learn the fundamental subjects in the courses in parallel with the project and the project-related subjects in combination with the project on a 'just-in-time' basis. The students learn about the same amount of disciplinary knowledge and skills during the first year as under the classical system. A great deal depends on how seriously the culture change will be taken: having the old approach and the new PLEE approach side-by-side is unlikely to be convincing for staff or for the same cohort of students at bachelor-level.

The staff will have new roles, tasks, timings of activities, and broader competencies in place of the narrow competencies in their 'super-specialism'. In a change from classical education to PLEE there is a number of substantial differences which need attention. The new staff role is much more geared to encouraging the students to extend themselves and to encouraging the development of a professional way of handling situations. Appropriate training can help staff to handle the changes.

Without staff agreement and training, attempts to bulldoze through a PLEE-style reform will lead to an overload of frustration. Not all the staff will be convinced of the PLEE methodology at the start of the implementation. But the changeover is likely to be successful when 70% is willing to change, the rest will follow.

The next challenge is to make the framework of the programme flexible, so that changes can be made rapidly in the light of developments.

Beliefs of the Students

At the start of PLEE students may have objections too. Diverting to a quite different way of working that is used in most schools or emphasised in most university literature relating to academic matters is difficult. The students will have to get on with other students who can disturb their academic progress and planning. They will have to learn how to take responsibility for their own learning process and learning progress and how to co-operate in a team.

The new curriculum needs to have enough incentives, besides the challenging assignments, perhaps using progression rules and carefully formulated regulations, to encourage students to work on the non-project-related lecture courses rather than concentrate on the intrinsic interest of the project and related courses.

The flexibility of the study path is decreased, e.g. there is no time to catch up if an individual student is seriously ill or must be absent for long periods with good reason. The student may feel disadvantaged if one or more other team members will not work properly, or there is a poor team atmosphere. And what happens if tutors are unhelpful or give conflicting advice? An averaged exam mark for the project discourages the above-average students, who feel unjustly rewarded or insufficiently challenged.

Students do not usually experience strongly the differences between the classical and the PLEE approach if the university introduces PLEE step-wise, starting in year 1 and developing years 2, 3 and 4 as the cohort progresses.

Sometimes they look with envy at the older year students, it was easy for them, just following courses and getting the answers of the lecturers, not the challenge to be director of their own learning process and co-operating with other students to come up with new solutions for complex problems. On the other hand some older year students are envious of the first years because they did not have so much freedom for creativity and challenging education.

The Redesign of the Curriculum

The Faculty Management cannot do all the detailed work of re-design itself, but it can delegate the authority to do so. When there is a later agreement on the proposal for change, a decision to develop and implement PLEE, then the Faculty has ultimate responsibility for meeting the criteria, in order to reach the desired end-point (Powell & Weenk, 2003).

Redesigning a curriculum is sometimes harder then designing a new one. It is wise to make a small team responsible for the redesign: the Curriculum Development Team preferably advised by an educational consultant. The key questions in the redesign of the engineering curriculum are: 'What are the expected competencies of the graduates after the degree programme?' 'At what level do we expect them to be able to do this?' 'How can we measure and demonstrate that the graduates have these competencies?' These questions demands clear answers. From these answers the Curriculum Development Team can design a strategy on how to transform the incoming student with a known profile into a graduate with the desired competencies. Choices will have to be made on what to leave out of the existing programme (e.g. aspects of knowledge, or only the out-of-date or non-functional content) to make room for PLEE, especially if the overall time for the programme remains unchanged (Powell & Weenk, 2003).

The necessary Equipment to Support PLEE

Project rooms were considered essential for PLEE. A place is needed where the student team can learn project skills, planning skills, check with the tutor, inform tutor of progress, undertake tutorials, exchange ideas, and provide a focus for the project. Experiences at Industrial Design at the University of Twente demonstrate that separate project rooms are not essential. In a large hall, students have the possibility to arrange the tables in such a manner that they can work undisturbed by other teams. Lectures are provided in the same hall; the students stop their project work and arrange their seats so they can see the lecturer. Glasgow Caledonian University has a large hall has many niches with laptop connections and a digital white board in each niche. This also seems to work very well.

Contact is essential for project team work. Conventionally this occurs face-to-face, but there is growing experience (see for example Van der Veen, 2001; Martin Perez, 2002; Milgrom & Jacqmot, 2002) of effective electronic contact in distance learning projects.

Success Indicators for Implementing PLEE

The change from a traditional curriculum towards PLEE is a complex process.

Faculties that want to make the change over face an enormous challenge. Fortunately there is agreement on several principles that have to be met to make the implementation a success.

According to Senge (1990) the capacity for innovation depends on five disciplines. Ruijter (2003) applies these disciplines to explain the process of curriculum innovation.

1. Personal mastery: The only way for organisations to learn is the learning of the individuals.
2. Mental models: New concepts are only transferred in practice when they are not too different form the deep rooted insights and beliefs about education.
3. Shared vision: A fundamental change will only occur when there is enough agreement about the necessity to change.
4. Team learning: A good team is the right mix of talents and is aware that team work is essential for winning.

As mentioned above the adoption of the methodology by the staff is essential for the success of the implementation. Reinforcing factors for this adoption, besides the above mentioned disciplines are:

- Understanding of the why (shared problem), what, when and how.
- Clarity of goals and procedures
- Visible leadership and back up by the management (means, time, assistance)
- Regular communication between all stakeholders
- Influence in the decision making and the process
- Reward (e.g. publication, being an example for other faculties)

These success indicators are part of the culture and climate of the organisation. The change over from a traditional curriculum to PLEE is a change in beliefs and the success of the change is influenced by the culture.

'The [Dutch] Review Committee on Mechanical Engineering Education noted that the ambience [in University of Twente] is open and adaptable to change. The atmosphere in the Faculty is characterised by congenial relations and enthusiastic support of the students, the academic and support staff. Attention is paid to problem areas.' (VSNU, 2000).

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AFFILIATIONS

Wim Weenk
Senior Officer in Staff Development and Educational Consultant
University of Twente, the Netherlands

Maria van der Blij
Senior Officer in Staff Development and Educational Consultant
University of Twente, the Netherlands

RUI M. LIMA, DINIS CARVALHO, RUI M. SOUSA, ANABELA ALVES, FRANCISCO MOREIRA, DIANA MESQUITA AND SANDRA FERNANDES

4. A PROJECT MANAGEMENT FRAMEWORK FOR PLANNING AND EXECUTING INTERDISCIPLINARY LEARNING PROJECTS IN ENGINEERING EDUCATION

INTRODUCTION

Traditional teaching methods being adopted in higher education across European Universities are not contributing effectively to the real needs of today's world. The current challenges that the world is facing, concerning the new economic paradigms, centred on eco-sustainability along with global and unbalanced competitiveness, demand new answers from the universities. The professionals that universities must create should be prepared with the right set of hard and soft skills so they can rapidly contribute with new energy to the existing enterprises and other organizations.

The Bologna process, besides the objectives of making the European higher education more comparable and more compatible, includes also the objective of finding solutions to the reality described above - Heitmann (2005). The Bologna process emphasizes the importance of student-centred approaches, promotes the implementation of more effective active learning practices and considers as a fundamental issue the reduction of the gap between learning outcomes and real world needs. This process also advocates that greater efforts should be made to create learning activities with "meaning" for students to provide additional motivation to the students as they are able to understand the reasons why they should learn the proposed course subjects. In this sense, meaningful learning requires the acquisition and development of competencies which will be materialized from the contextualization of the contents, Heitmann (1996).

One of the methodologies used to achieve the previously described objectives is based on interdisciplinary project approaches. A project can be looked as a field of application of more theoretical stuff, and can also act as a driver for better comprehension of theory. Interdisciplinary projects bring up the necessity to understand the interaction between different curricular units (CU) and develop project elements to address this issue. Powell & Weenk (2003) presented an interdisciplinary project approach, the Project-Led Education (PLE), which is based on a project supported by some of the curricular units of a semester

L.C. de Campos, E.A.T. Dirani, A.L. Manrique and N. van Hattum-Janssen (Eds.), Project Approaches to Learning in Engineering Education: The Practice of Teamwork, 53–76.

(PSC - Project Support Courses), developed by teams of students. All the teams develop the same project theme in order to create similar evaluation conditions. Nevertheless, the proposed project is open enough to allow quite different solutions, allowing thus the development of student's initiative and their ability to take decisions with incomplete/redundant/fuzzy information. These teams should be large enough to impose difficulties both in the project and in the coordination team. These are conditions to improve the development of several additional transversal competencies such as: team work skills; leadership skills; project management skills; communication skills; and so forth.

These learning project approaches are different every year, and can be characterized by different ways of implementation during a pre-defined time period, where a coordination team and several students' teams are engaged in medium/large projects as close to reality as possible.

Managing this process is equivalent to manage different operations every edition with scarce resources during a pre-defined time period. This "one of a kind" characteristic is the fundamental difference between project management and operations management, and reinforces the need to manage these processes as projects. In these projects, the following subset of PMI (2004) PMBOK Guide's project management knowledge area processes get a higher attention from the coordination team: management of one team of staff and several teams of students; management of physical resources like class rooms and project rooms; management of communication between stakeholders; management of time; management of risks.

The main objective of this paper is to present a management framework, centred on time and team management, for project coordination teams, oriented to project led engineering education initiatives. To accomplish this, there is a sub-objective of characterization, in several project oriented learning initiatives, of the following project management knowledge areas: team management, time management and communication management.

The development of a framework of reference for the management of such projects is based on the analysis of several cases of interdisciplinary project-based learning in engineering that have been undertaken during the last four years with students mainly from the Integrated Master Degree on Industrial and Management Engineering (IME). Three of those PLE editions were implemented in as many different semesters of the IME course, and the corresponding projects will be identified as follows: IME11 (1st year, 1st semester); IME41 (4th year, 1st semester); IME42 (4th year, 2nd semester). The IME41 project involves all the six curricular units (CU) of that semester while both IME11 and IME42 include four out of five CUs of the corresponding semesters. The total work load of the project should be based on the total ECTS (European Credits Transfer System) - DGES-ECTS (2010), allocated to the PSCs (Project Support Courses). This is not an easy task because every PSC has some competencies developed outside the project theme, which are not considered for the project evaluation process. It can be said that total load ranges from 12 to 25 ECTS in the first year project and from 15 to 30 ECTS in the fourth year projects.

Another initiative in project based learning at University of Minho is designated as Innovation and Entrepreneurship Integrated Project (IEIP) and it is a multidisciplinary optional curricular project with teams of students from four different technical backgrounds, all of them from the fourth year of an engineering integrated master course. These four different Engineering Integrated Master courses are: the already referred IEM; Polymer Engineering (PE); Industrial Electronic and Computers Engineering (IECE); and Mechanical Engineering (ME). Two editions of this innovative experience were already completed in 2007/08 and 2008/09, involving four teams of six and eight students respectively (two students from each master course). They have worked during the entire semester, on proposals to improve industrial products and production systems. The problems to be solved by those multidisciplinary groups of students were presented by local companies willing to get real improvements in their products and processes. This project had different workloads allocated to each master course, ranging from 7.5 to 12 ECTS.

Next section describes the project management framework for the coordination team, based on project management concepts. Other sections show the applicability and evaluation results for this management framework.

THE PROJECT MANAGEMENT FRAMEWORK

Project Life Cycle

The interdisciplinary projects of the Integrated Master in Industrial and Management Engineering of the University of Minho, Portugal, are characterized by similar types of activities. Before the beginning of each PLE semester, several informal brainstorming sessions take place in order to prepare the incoming project – the main purpose is the definition of the project's theme. Neither the number nor the duration of these sessions is predefined, but usually they start in the months before the semester begin. During this phase the project manager is also appointed.

After this, and to manage the entire semester, the coordination team builds up a schedule for a horizon of 18 weeks. This schedule includes not only the specific activities of the coordination team, but also the activities involving both staff and students. In the beginning of the semester, during one to two weeks, students must execute a mini-project with the objective to simulate the whole semester process. Table 1 presents some activities developed during the execution of the project, along with the correspondent number of occurrences (semester basis), for each of the four project oriented learning initiatives.

Some activities occur every week (e.g. PSCs classes and tutorial meetings) while others are distributed along the semester (e.g. staff meetings and teachers' feedback). Table 1 shows that the number of occurrences of some activities varies significantly depending on the PLE project and, naturally, this implies some differences in the effort associated to project time management. However the time spent on each type of activity is not so different from project to project, except, eventually, for the IEIP case, due to its nature.

Table 1. Activities involved in the project oriented learning initiatives

	IME11	**IME41**	**IME42**	**IEIP**
Staff Meetings	10	4	4	4
Milestones (for students)	10	6	6	6
Teachers Feedback Events	7	3	4	3
Extended tutorial meetings	2	1	4	3

The higher number of staff meetings, milestones and feedback events associated to IME11 demands an accurate monitoring and control of the time spent. The duration of each staff meeting should be, approximately, one hour. The agenda is defined in the previous meeting and includes the expected duration of each topic. During the meeting a time controller (in every meeting this role is attributed to a different member of the coordination team) monitors the time spent on each topic and immediately announces any delay. Thus the president of the meeting can take the adequate action (conclude the topic, if possible, or postpone it to the next meeting). Despite this time management effort, sometimes the one hour duration is exceeded (e.g. in the IEIP staff meetings, probably due to the dimension of the coordination team – 15 members).

The time management associated to students' milestones is simple but, mainly due to the number of occurrences along the semester, it is somehow laborious - Alves *et al.* (2009). One of the staff members should verify if all the students' teams have met the correspondent deadlines and if they have delivered the expected elements (reports, presentations, prototypes, etc.).

The feedback activities referred in Table 1 are of two types: presentations' feedback and reports' feedback. During the semester, and depending on the PLE project, there is a minimum of three multimedia presentations (initial, intermediate and final) and two written reports (final preliminary and final). Typically the presentations' feedback is not time-consuming and it is usually provided in oral form to the students. On the contrary, the reports' feedback demands a lot of time, except for the final report (this report is assessed but no written feedback is provided). Each PSC teacher should perform a detailed analysis of each team's report and write down a full set of relevant comments/corrections/suggestions. Each teacher has its own time management approach to deal with these activities but, occasionally, some teachers do not meet the deadline. However, the semester coordinator, which is also the project manager, should continuously monitor the execution status of all the activities, in order to avoid deadlines' overcoming (both by teachers and students).

In terms of time management, the extended tutorial meetings are similar to the staff meetings. The time controller and the president ensure that the meeting with each team of students does not exceed 20 minutes, approximately.

An estimative of the time spent on project supporting activities, by project manager, teachers and tutors, is presented in Table 2, including some of the activities listed on Table 1.

Table 2. Estimate of time spent on project supporting activities

	IME11	IME41	IME42	IEIP
Project Manager	One hour per week	One hour per week	One hour per week	One hour per week
Teachers' time for project support	Approximately 1,2 hours per week per PSC	Approximately eight hours per week	Approximately eight hours per week	Approximately eight hours per week
Tutors' time for project support	One hour per week per team.	One hour per week per team.	One hour per week per team.	One hour per week per team.

Specifically on the time management knowledge area, and based on the analysis of the referred data, it was possible to foresee the project life cycle with five main phases illustrated in Figure 1 Preparation; Set-up; Start-up; Execution; End.

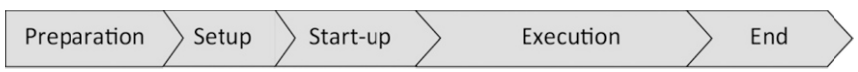

Figure 1. Project Life Cycle Framework – Project Main Phases.

Preparation phase starts 0.5 to 3 months before classes begin. During this phase, based on informal communication, a few team members start to contribute for the definition of fundamental aspects of the project: project theme; human resources; project support courses. This is the phase with lower workload demand for team members.

For the project specification it must be defined a project theme that is challenging and actual for both the students and the staff for increasing motivation. So in this context, some of the team members propose ideas that will be considered during *setup* phase in formal meetings of the coordination team. In the cases previously described a project can be purely academic (IME11 and IME42) or can have interaction with the industry (IME41 and IEIP). In the first case the limit conditions are imposed by course contents of the semester. In the other cases there is an additional constraint related with industry partners that must be found and also that must agree with objectives and main contents applied to the project.

Human resources and project support courses are closely related because teachers of courses associated with the project will be part of the team. Additionally there will be team tutors (also teachers) and, usually, researchers also. It is desirable that staff team members have prior knowledge and experience in the methodology. Nevertheless, in all editions there are teachers that participate for the first time. There is a key role decided during this phase which is the team coordinator that will act as a project manager. He or she should be a teacher with good organization skills and with in-depth knowledge about the methodology. The coordinator should maintain a high motivation and the project under control, both from the staff and students perspectives.

Setup phase starts 1 week to 1 month before the beginning of the semester and has the following main objectives: project theme definition and specification; milestones definition and planning; project and PSC assessment process definition; project process evaluation definition; project guide elaboration. During this phase the coordination team builds up a coherent plan for the entire semester that is materialised in the project guide. This guide works as a project charter for the project, describing the main objectives, the scope, milestones and evaluation process.

The *Start-up* Phase has the duration of 1 to 2 weeks, beginning at the first day of classes with a project presentation session. Depending on the project, students' teams will be created before this session (IEIP), at the end of this session (IEM11), or during the following few days (IEM41; IEM42). This phase can comprise students' training, mainly on first year edition. *Start-up* phase is based on the idea of one week simulation of all semester process and also to get teams working on the project right from the first day of classes. At the end of this phase, students' teams make a presentation of their own project objectives and organization model that will act as a guide for project work.

The *Execution* phase has the duration of 16 weeks with classes, tutorial meetings, deliveries, presentations and feedback sessions. Each PSC has classes for both theory and project support during the entire semester that can be mixed each week. The tutors are expected to have one hour meeting per week to support students' teams on aspects of transversal competencies development and project management processes. The coordination team should also prepare and control project milestones, and in some occasions prepare formal feedback to deliver to the students. During this phase students' assessment his fundamentally formative and the summative aspects corresponds to approximately 20% of final grade.

The *End* phase has duration of 1 to 3 weeks. At the beginning of this phase, teams have to deliver final reports. In one case (IEM11), this final report is followed by a written test. Prototypes can be delivered jointly with the reports or with the presentation of project. In all cases the project must be presented and discussed with the entire coordination team and only after this event students will receive their final grade.

There is no intention to create a detailed work breakdown structure (WBS) for this type of projects in this framework, but it is possible to describe some of the main types of activities that should be included. The main activities envisaged on the analysis developed in this work are: theme definition; project support courses definition; human resources management; evaluation process management; assessment process management; milestones management; internal resources management (non HR); external resources management. It is clear from the above text that some of these activities have sub-activities spread along project phases. As an example, theme definition has one sub-activity related with generation of ideas during the *preparation* phase and others for theme selection, definition and specification during *setup* phase.

Project HR Management

All project based learning initiatives presented above (IEM and IEIP) undertaken at the Engineering School of University of Minho require coordination by academic staff. The characterization of the staff project teams is presented in Table 3. These teams are more or less constituted by the same people, changing one or two persons from one year to another, e.g., in the coordination team of IEM11, almost all members have been the same, except the CC teacher. This brings the additional difficulty of explain the PLE project and accept the decision of participate/not participate of the responsible teacher of this CU.

Typically the coordination teams for those initiatives include lecturers, tutors as well as researchers from the educational field. Sometimes the same staff member accumulates both the role of PSC lecturer and of tutor of a given team of students. According to Alves *et al.* (2007) and Fernandes *et al.* (2007) tutors play an important role in this process since they get very closely involved with different tasks and aspects of the students' teams.

Table 3. Characterisation of the Coordination Team

	IEM11	**IEM41**	**IEM42**	**IEIP**
Elements of the Coord.Team	11	10	11	15
Teachers	6 (teachers of several PSCs from different departments and from different schools)	8 (teachers of several PSCs from different courses. IEM course director is one of them)	6 (teachers of the five PSCs)	11 (teachers of several PSCs from different departments; one company representative)
Tutors	6 (3 are also teachers of PSCs)	4 (3 are also teachers of PSCs)	5 (1 is also teacher of 2 PSCs)	4 (1 from each department)
Education Researchers	2	2	2	2

These coordination teams are characterised by a matrix organisation, where each element is associated with different knowledge areas and has a high level of autonomy. According to Lima *et al.* (2007) the members of the coordination team also have to deal with project management and personal interrelationships issues. Project management has to do, mainly, with the schedule coordination, deadline achievement and project's tasks planning and organization. In the personal interrelationship area, the main challenge is the management of conflicting situations due to: divergences on opinions, ideas and individual objectives; attitudes and position confrontation; lack of communication inside the team. To deal with these difficulties, which occur during the entire project, adequate strategies are demanded. Understanding and overcoming these difficulties are two important components both of the learning and the coordination process.

Each coordination team needs a project manager which is the semester coordinator nominated by the Course Director. However, there is no hierarchy in the coordination team - the project manager should negotiate all important decisions. Project manager, as described in PMI (2004), acts like a coordinator in a loose matrix organisation type. The results of the project cannot be totally assigned to the project manager; nevertheless, he has the responsibility to build a coherent pedagogical model and motivate colleagues to embrace it. He must be prepared to deal with conflicts, absences to scheduled meetings, delays in tasks' delivery and to deal with teachers that, by nature, are more sensitive to criticism from colleagues. Some resources, like project rooms, are dedicated to the project but must be allocated to all the projects of the semester and that must be negotiated with both the IEM course director and the director of the Production and Systems Department director.

The project manager also has to manage the students' teams and solve all problems related with them, like schedule training sessions provided by the Courses Council and assure that the students go to these sessions in the IEM11 or assure that, in the final of the semester, the project rooms stay clean and the laptops are returned to the department. During the semester there are several activities and milestones to be delivered by the students where the presence of project manager is fundamental - Alves *et al.* (2009); Carvalho & Lima (2006). The compilation of final grades for the project is a task of project manager and this compilation involves a grading model which is somehow complex - Moreira *et al.* (2009); Fernandes *et al.* (2009).

From the point of view of knowledge area of human resources management these project approaches are based on teams of 10 to 15 members that include teachers, tutors and educational field researchers. These teams are characterised by a loose matrix organisation. In this type of organisation the project manager act more a project coordinator that have to negotiate all important decisions. In order to build real team's spirit, team members should identify themselves with the organisation. In this context members should be part of the decisions and should contribute for project management processes. So, these teams must share activities and roles, both pleasant and unpleasant. Presence in most of the project events is a step for accomplishing the objective of team's spirit building. As an example, members should actively participate in staff meetings and act like chair, note keeper and time controller in accordance with a rotational schedule. After contributing for project guide construction, several members should aid and participate on project presentation execution. During execution phase team members should participate in assessment and feedback activities. Acting simultaneously with different roles and with commitment to the team objectives is the foundation stone for team's spirit development and high performance achievement, in these interdisciplinary project approaches. Figure 7 represents the main roles that staff members must interpret in different situations during the project. Most of these roles were explicitly referred previously in this work, but roles referred as "outside" were not.

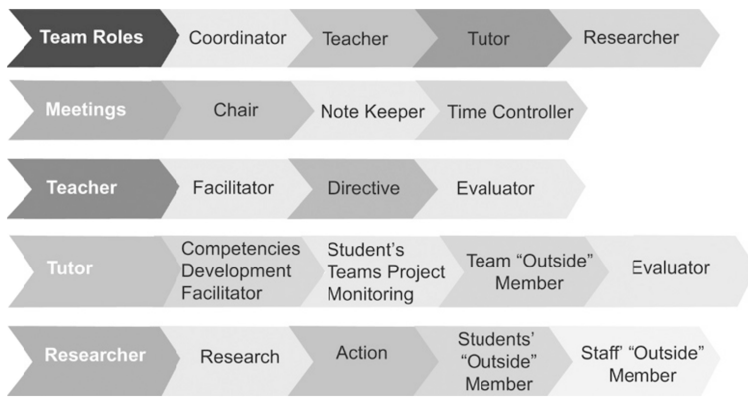

Figure 7. Roles of different staff team's members.

As an example, tutor is an "outside" member of students' teams because he (she) should simultaneously be close enough to understand teams' main conflicts and problems and far enough to restrain any temptation to execute activities for the team. Researchers have similar roles because they must be close to students to understand fundamental learning issues. Furthermore they execute some activities of the staff team but they are not involved in teaching activities and don't have responsibility on students' assessment.

Project Communication and Information Management

The communication and information management in this type of projects includes mainly the staff team internal communication, the communication between the staff team and student teams, the communication inter and intra-student teams, the communication between student teams and the company representatives when applied, and the communication to the outside community. There is a concerned not only with the exchange and understanding of information between all the elements, but also with the preservation of the necessary privileges and restrictions to data availability.

The projects presented in this paper typically involve 7 to 9 lecturers (some of them acting only as tutors), 3 to 4 researchers and 30 to 50 students. The communication network can be quite complex not only due to the number of people involved but also because of the complexity of roles and complexity of privileges/restrictions to data availability. Managing all the communication, documentation and information in this type of projects can therefore be quite demanding. Different levels of confidentiality must be preserved and managed in the network of teams and with the outside world. Examples of restriction are:

- In some cases the company/product information must be preserved from the outside world while being available to all students and staff members. On the other hand the company may not be interested in part of the important information shared among staff members.
- Each students' team may want to preserve to themselves some data that may be or may not be shared with their tutor or with some other staff members.
- Students' teams must keep updated information and data available to every member and to their tutor, keeping the track of document changes, keeping accurate plans, etc. On the other hand most of such data must not be available to other student teams.
- The staff team must feed all students' teams with some critical updated information: re-planning information, changes in resource availability, feedback information, assessment information, etc.
- Researchers require information that may or may not be available to students, tutor or other lecturers.
- Usually companies have no interest in receiving much of the information that is shared among members of the coordination team.

A list of the main types of tools and types of documents used for communication and information sharing is presented on Table 4, for the Project Led Education projects reported on this paper.

Table 4. Main tools and types of documents used for communication and sharing of information

	IEM11	**IEM41**	**IEM42**	**IEIP**
Documents	Project Guide Tutor guide Instructions for Reports Templates for Evaluation Bibliographic referencing rules Templates for the peer evaluation	Project Guide Instructions for Reports Companies documentation sent directly for related team	Project guide Instructions for reports List of topics to be deal with	Project Guide Instruction for Reports Company documentation Rules for company access
Repositories	Moodle forum accessible by the	Moodle forum accessible by the	Moodle forum accessible by the	Moodle forum accessible by the

	students team and teachers	students team and teachers Students used "Microsoft Groove" and "Yahoo Groups"	students and teachers	students team and teachers
Email	Based on direct email; using the moodle participants list	Based on direct email; using the moodle participants list	Based on direct email; using the moodle participants list	Based on direct email; using the moodle participants list
Elearning	Moodle discipline environment configured for the project Different teachers use different platforms to communicate with students: Moodle and Blackboard	Moodle discipline environment configured for the project Different teachers use different platforms to communicate with students: Moodle and Blackboard	Moodle discipline environment configured for the project Different teachers use different platforms to communicate with students: Moodle and Blackboard	Moodle discipline environment configured for the project Different teachers use different platforms to communicate with students: Moodle and Blackboard
Informal	Direct contact is facilitated by proximity	Direct contact is facilitated by proximity	Direct contact is facilitated by proximity	Direct contact is facilitated by proximity

In terms of information management it may be said that special attention must be paid to the communication channels and what information should be exchanged with students' teams. Students' teams tend to be very demanding - they want to get information as accurate as possible at the precise moment when they need it. This may not be easy especially when companies are involved. Special attention must also be given to the internal organization of students' teams since they must learn how to plan and manage their formal meetings as well as keeping accurate records of team decisions and task assignments. In order to help them in managing their projects students must deliver results on several milestones along the semester, which keep teams alert without losing the track of the project.

PROJECT MANAGEMENT FRAMEWORK APPLICATION

The characterization of PLE's organization model, presented in this paper, is based on the 2008/09 edition implemented in the first year of IME at University of

Minho. The organization model description is structured according to the following aspects: stakeholders, i.e. students and faculty staff; courses; project.

Stakeholders

This project involved 38 students of first year of IME. Most of these students accessed to IME at University of Minho through national contest to higher education and a minority are transferred from other courses at the same university. Students who accessed by national contest have an average mark of 168.9, the minimum 158.4 and the maximum 188.0 (scale 0-200), and 29% of them entered in their first option. Their ages range between 18 and 23 years old. For the development of the project, the students were organized into 6 teams, varying from 5 to 7 members.

The coordination team of the first year, first semester 2008/09 included 12 members. Nine of these members are teachers that have different roles: 3 of them are lecturers and team tutors, 3 are only lecturers and finally 3 are only tutors. The coordination team also includes the course director and two educational researchers. There was an additional member, a teacher of a non supporting course that assisted to the all process and participated as an observer. Most of these members have been participating in different editions of this project and a large number of these also had training on Project-Led Education methodology.

Preparation Phase

The implementation of PLE in Integrated Master's Degree of (IME) is supported by the first four courses represented in Table 5. These are considered as project supporting courses (PSC) and the fifth course - Introduction to Economic Engineering (IEE) - in this table is a non-supporting course. The five courses of the semester represent a total of 30 ECTS (European Credits Transfer System), as indicated in Table 5.

Table 5. First year, first semester study plan of Industrial Management and Engineering

Course	*ECTS*
Calculus C (CC)	6
Computers Programming I (CP1)	7
General Chemistry (GC)	5
Introduction to Industrial Management and Engineering (IIME)	6
Introduction to Economic Engineering (IEE)	6

The Project was introduced as a value added to the learning process of the first year students. The technical competences acquired by the students come from specific courses' contents and from the interdisciplinary project. Additionally students develop transversal competences mainly through project activities: project management competences like time management and organization skills; team working competences such as responsibility, leadership and problem solving;

writing and oral communication skills and, also, personal developing competences like critical thinking and creativity.

The linkage of interdisciplinary contents in an integrated way is supported by the Project. As the Figure 3 illustrates, each PSC had different contents included in the project, being CC, the course with minor participation. This means that some subject contents of each PSC was assessed by the contents included in the Project and specific contents not assessed in Project.

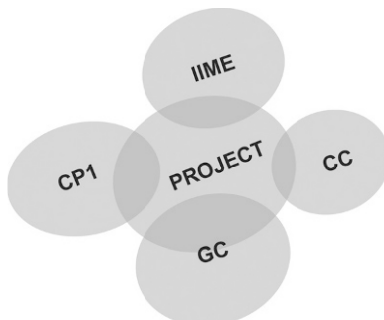

Figure 3. The four PSC involved in first year first semester IME PLE.

Student assessment in IME PLE courses is based on continuous assessment of the PSC specific contents and on project assessment. The final project grade has a 40% impact on students' final grade and continuous assessment 60% (Fernandes, Flores & Lima, 2012). Each PSC defines its own way of assessment based on small group tasks or work assignments and written tests. The criteria and the methods for the assessment of each PSC were, also, defined by the responsible teacher of each PSC. In the 2008/09 IME PLE edition, the number of assessment items (tasks and tests) defined by the teacher responsible for each PSC, is indicated in Table 6.

Table 6. Number of Assessment items for PSCs

PSC Assessment Item	***PC1***	***IIME***	***GQ***	***CC***
PSC Tests	4	2	2	2
PSC Tasks	1	6	2	3

Coordination team members are asked to freely suggest project themes at an early stage. Themes are then picked-up from the pool of ideas and subject to discussion during a coordination meeting. Themes are object of scrutiny by project supporting course (PSC) lecturers. This procedure contributes for validation of the eligibility and relevance of project contents within the context of each single PSC. A selected project theme normally emerges as a result of: a) adequacy to PSC contents (and vice-versa); b) coordination team members individual perceptions on the relevance of the project theme; and c) project holding adequate dimension for a full semester work by a team that can vary from 5 to 8 students. Therefore themes vary each year.

Definition Phase - Setup

After agreement on the project theme, all student teams work on such theme during the whole semester. The theme scope is normally wide enough to allow for significant diversity in both problem solving approaches and solutions.

The 2008-2009 first year first semester project intended to design and detail the: "Production of batteries for plug-in electric cars: specification of the battery system and the production system". The objectives of the project were:

1. Specification of the battery system for a plug-in electric car. This included: a) specification of relevant vehicle parameters; b) specification of the battery system: battery type, power, charge time, dimensions, weight, expected lifetime, environment impact, limitations of the chosen battery, etc., and c) electric vehicle autonomy.
2. Specification of the battery production system. This included: a) target market; b) monthly production; c) number of workers; d) suppliers; e) materials supply; f) Production management; g) equipments; h) layout; i) costs; j) proposals of eco-sustainable measures within the production system (such as rationalize de use of water, energy, materials, waste, etc.).

Teams were instructed to develop fully rigorous specifications. Their final work should show and prove the development of PSC-specific technical competencies. Students were informed of such PSC competencies in the beginning of the semester. The PLE approach intends to develop not only PSC-specific competencies but also soft skills, which are not well developed using traditional teaching approaches. Among these, there is a special emphasizes on teamwork skills; project management skills; communication skills and conflict management skills. The project development process also stimulates critical thinking and creativity while rewarding teams and individuals with initiative power.

Additionally, it is necessary execute some tasks: documents support to PLE development such as the project guide for the students, project description, semester schedule, first week plan and a short description of pilot project and its objectives. The tasks execution is discussed and allocated to all members of the coordination team. Normally, the first meeting includes a balance about the last year project, to search the process continuous improvement.

Teams were introduced to the project theme by way of a short description on the relevance of cars for personal mobility, the global dependency on fossil fuels, the 2008 spotted energy crisis and consequent increase in fuels cost, the global phenomenon of climate change, and greenhouse gas emissions (GHG). Basic statistical data on Portuguese high dependency on energy imports (about 83%) were also given, showing the country's vulnerability to oil prices fluctuation. The Portuguese government holds a strategic agreement with

Renault-Nissan group for the introduction of electric cars from 2011 onwards. This has set a high spotted relevance for electric cars thematic, and a renewed motivation to teams.

Start-up

For coordination team members the start of the semester begins two weeks before the start of classes. In the first meeting of the coordination team, everything has to be prepared: the session where the PLE project will be presented to students; PSC related issues, i.e. learning outcomes, week-by-week contents planning, assessment, etc.; the selection of the project theme; detailed schedule of the first week of the PLE where student teams develop the pilot project, establish the project milestones and the evaluation system.

The PLE presentation session is scheduled as the first event of the semester for the new students. This includes an introduction by the Course Director followed by the coordination team leader who presents PLE. This presentation launches the project theme, the overall project plan and the following PLE aspects: advantages and challenges of the PLE methodology; skills to develop in the course of the project; presentation of the members of the coordination team; tutor role; PSC classes plan; week schedule; monitoring project progress and milestones; assessment system. During this session the teams are formed and one tutor is allocated to each team. After the session, the students have the first meeting with the tutor. Each team is allocated a space (a permanent project room), a laptop computer, individual lockers and keys for the project room. Teams are afterwards instructed in teamwork and multimedia presentations. The teams then begin to develop the pilot project which they have to present in about a week time. The pilot project includes the construction of a Web Page (using a simple html editor) whose contents are the initial ideas and context for the project. This pilot project requires the development of many smaller tasks in a short timeframe. Therefore the teams have to organize themselves, split the tasks among team members, sequence them and assure that all runs smoothly to successfully accomplish the task. Therefore the pilot project works as a shortened experience of what will be the teams work during the full semester. At the end of week 2, the student teams have to come up with, and present, the project plan. At an early project development stage, teams have to be working and understanding the PLE methodology.

Execution Phase

The project plan has 19 weeks, with 9 to 17 hours of classes per week, one hour with tutor and 2 to 4 hours of additional support, in a total of 5 to 18 contact hours per week. The project schedule is presented in Figure 4. The figure also shows the 10 milestones of the project. After Christmas' holidays (week 14 and 15) there are no more classes and the teams concentrate their efforts in concluding the project work and some subject-related assessment activities.

Student-teacher hours	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Week 15	Week 16	Week 17	Week 18	Week 19
Classes	4	17	17	17	17	17	17	17	17	17	13	13	17			<17	<17	<17	<17
Tutor	1	1	1	1	1	1	1	1	1	1	1	1	1			1	1	1	1
Total	5	18	18	18	18	18	18	18	18	18	14	14	18			<18	<18	<18	<18

Figure 4. Project Aggregated Plan - classes' plan, tutor meetings and milestones.

Project progress is monitored along the semester. Ten milestones enable the coordination team to acknowledge the team progress. In each milestone, teams are expected to deliver documents and/or presentations which are subject off scrutiny by some or all coordination team members. Teams underperforming are spotted and specifically tracked for project progress in following milestones. Table 7 presents all milestones, delivery times and expected deliverables.

Table 7. Milestones of the Project

Milestone	*Date*	*Requisite*
1	2008.10.02 2008.10.03 (Week 2)	18:00 – Pilot Project – Deliver a specification and a presentation file 14:10 – Pilot Project presentation
2	2008.10.10 (Week 3)	18:00 – Deliver a document (max. 2 pages) with the internal strategy to manage the team
3	2008.10.21 2008.10.22 (Week 5)	18:00 – First report delivery (max. 25 pages) 14:10 – Project progress presentation
4	2008.10.29 (Week 6)	14:10 – Extended tutorial
5	2008.11.18 2008.11.19 (Week 9)	18:00 – Intermediate report 14:10 – Formal presentation
6	2008.11.26 (Week 10)	14:10 – Extended tutorial
7	2008.12.19 (Week 13)	18:00 – Deliver a balance document (work done and future work)
8	2009.01.09 (Week 16)	18:00 – Preliminary version of the final report (max. 60 pages)
9	2009.01.23 (Week 18)	18:00 – Final report (max. 70 pages) + prototypes
10	2009.01.28 2009.01.29 (Week 19)	10:00 – Final exam (written test) 14:10 – Final presentation, discussion and poster delivery

On milestone 2, the team should deliver a document which describes the management strategy that the team will use to control the progress of the project. The coordination team uses that document to check if teams understand the meaning of team working and the eventual need to develop and explore strategies that will help bypass difficulties arising during the project. Extended tutorial – milestone 4 and 6 - is a special meeting, held twice in a semester, between each team and all the members of the coordination team. This meeting intends to give a more broad feedback on the work done by the team, and clarify any doubts relating the project that could persist within the team. The balance document – milestone 7 - helps teams to acknowledge their project status, i.e. what was already achieved and what remains to be done and when. The final exam - milestone 10 - is an individual exam on the respective project team contents. It is normally based on the project report delivered in milestone 9. This exam assesses the individual involvement and responsibility within each team. The project ends with a final presentation followed by discussion. The PLE has a final social activity which brings together students and teachers in an afternoon snack offered by the Course Director, to discard the stress accumulated during the semester.

End Phase

The IME PLE assessment has two major components: c1 - continuous assessment of PSCs; c2 - project assessment. The assessment weights of each component can vary yearly; in 2008/09 c1 weighted 60% of the PSC final grade while c2 weighted 40%, as previously referred. Early editions of IME PLE also used a 50/50 weight. The c1 component includes work assignments and written tests. The c2 component derives from the Project grade (team): Reports (60%), Prototypes (20%), Presentations and Final discussion (20%), which is transformed in an individual grade by multiplying the respective grade by: a) the peer assessment factor; and by the individual written test grade (20%). The assessment model was built in a way to help students regulate their own learning, however the authors identify that most project items are assessed only in a later phase of the project, although project related feedback is given extensively during the semester.

FINDINGS FROM STAFF'S VIEWS

In this section, findings are presented based on the staff members which were part of the coordination team of PLE in the academic year of 2008/2009.

At the end of the PLE semester, the coordination team members were asked to reflect on their experience. A set of categories emerged from the oral discussion between staff members, namely, the staff workload, the project's theme and interdisciplinarity and also student learning outcomes and the PLE methodology in general.

Each of these categories will be explored in further detail in the next subsections.

Staff Workload

From the discussion of coordination team members, the staff workload was one of the main concerns shared by most of the participants in PLE.

The single teacher not involved in the project (IME PLE observer) stated "I never thought it would give so much work" and "You do not know the workload involved if you are not on it". She also mentioned the great amount of emails exchanged amongst team members and the number of decisions that had to be taken.

The teacher of CC regrets that the respective course truly "awakened" to the PLE project in a later stage of the project. This teacher also indicated the "excessive PLE-related workload, both for students and teachers… especially in the final stage of the project", but he is positive about joining IME PLE next year and on the need for teacher stability to allow a successful contribution of the respective course on the IME PLE. He points out that the main advantage of the PLE is the integrated perspective that students acquire in regard to the PSC courses that make up a semester.

IIE teacher said that "it is possible to do the same with less effort" and that "…we need to be more efficient to reduce the coordination team workload". He spotted excessive use of coordination team meetings and identified some project issues that could have been discussed and decided through an alternative way of communication, reducing the number of meetings.

One tutor referred her difficulty to account the workload related to project coordination tasks. For her "what needs to be answered is: "Is the relation between staff effort and students' results positive?... is it worth it?"

Another tutor suggested that the "use of project tasks to assess PSCs" should be stimulated, and that "PSC teachers are not making it yet… resulting in a heavy workload both for PSC and Project". Another teacher agreed with this conclusion and added that "this is only possible if the PSC are well integrated within the project".

The GC teacher spotted "many moments of heavy workload within IME PLE", but also "…assessment is readily done..." therefore valuing the new assessment model instead of traditional teaching, where assessment through written exams tends to be more spread over time.

Project Theme and Interdisciplinarity

As said before, the selection of the project's theme is based on its relevance and importance but, also, on its adequacy to PSC contents, especially GC. So, it is more or less expected that courses like CC had some difficulties in integrating the theme selected in the contents prepared for the semester. This was perceived by the coordination team members, in particular, IIE teacher referred "When we think about the Project theme, we think how we integrate

GC and IIE and we do not think how we integrate CC, then the difficulties with integration arise."

This requires a continuous effort to try to involve and readjust all program contents as one of the tutors noticed "Need to readjust the program contents: understand the project and look for the best possible way to integrate contents, even changing the syllabus or the contents order. It is a fundamental effort of the teachers. But this is a difficult task, mainly when the teachers involved weren't responsible for the CU, like the NSC teacher (IME PLE observer), who admitted that "Initially I thought that I couldn't integrate the biggest part of the IEE contents but now, after what I have seen, I think I could." However, for this teacher it is difficult adapt the curriculum contents to the project: "I can't reformulate the syllabus contents, I can't teach *Costs*".

IIE teacher referred that these difficulties arose because the first year IME PLE didn't have an Integrated Project course. He says "We need one thing and the courses give another. An Integrated Project course is missing in the first year and I am increasingly convinced of that."

Other IIE teacher concludes that it is important to direct the project more "I think we have to define some concrete things in regard to the project. It could facilitate the content application. However, this change might put in risk one of the main characteristics of the project – being open."

Learning Outcomes and the PLE Methodology

The discussion involving students' learning process and outcomes in PLE is already a common theme amongst the coordination team meetings. However, in the 2008/09 PLE edition, one of the new participants in PLE processes, a teacher who played the single role of a tutor during the semester, expressed that her expectations in regard to students learning outcomes and the PLE methodology itself, hadn't changed. She believes that PLE brings some disadvantages for first year students "as they arrive to the University and have PLE right in the first semester, so they assume that University is this. They think that they will always work in teams and everything will be easy, that they don't have to get involved in the courses and that they will always get their way through by sticking to their teammates". She also referred that, in her opinion, "students seem not to get the message behind PLE" because, as she lectures these students later, in a course which takes place in the second semester, and verifies that "students seem not to be capable of transferring the knowledge and skills developed earlier, during PLE, to other different contexts". For instance, "they should already know how to make a written report and I don't see them doing that successfully when I ask them to make one, for my course".

This point of view, however, was not shared by most of the coordination team members in the meeting. Many arguments and specific examples were given by other teachers and tutors, present at the meeting, in order to clarify that what actually might be happening in the second semester does not have necessarily to be related with PLE or even a consequence of its implementation. The coordinator of the semester stated that “when students reach the second semester, they become more relaxed. They are used to being under great pressure and, suddenly, they find themselves in a learning process which is less demanding, so they kind of sit back.” Another teacher reinforced this idea saying that “it was the effect of worn-out.”

Other teachers pointed out the positive outcomes which have been demonstrated by PLE students in previous years. The NSC teacher (IME PLE observer) was surprised by the quality of students’ written reports and oral presentations. She said “I was quite amazed by their level of their autonomy during the discussion with the rest of the class.” Besides this, one of the IIE teachers also called the attention for the opinion of some senior students, from the fifth year of IME, in regard to PLE students’ performance, as he stated that “they were completely surprised by the quality of the presentations of first year students. They remembered their own first year at the university and they recognised that they didn´t make such outstanding presentations or master the courses contents with such a grasp as these students did.”

Strategies for the Improvement of PLE

The coordination team members were also asked to identify a set of strategies for improving the PLE methodology. Based on their fundamental reflections, a few items were identified. These items are presented in Table 8 and cross linked with the categories previously mentioned.

Staff workload reduction could be based on 4 items from this list. Item 1, reducing the number of staff meetings would, undoubtedly, contribute to this reduction. Considering the total number of meetings and the comparison with other PLE approaches, it was found possible to accomplish this goal without reduction of project results. Furthermore, as described by Alves *et al.* (2009), this reduction could also result from a lower number of attendees in each meeting.

Item 4 could contribute to the change of focus of assessment procedures. In case of implementation of this change proposal, courses’ continuous assessment should be based mainly on project tasks instead of specific content assessment through tests. This should be bounded to a reduction on the number of continuous assessment tests (item 5) to maintain a balanced workload for students.

The reduction of the number of project reports is a consensus change (item 7). This should be replaced with something simpler like, for instance, the presentation of an argumentative strategy to sell the main project idea of the student’s team.

Investing more time on the design and planning of the project, as well as identifying more detailed course requirements for each project phase (items 2 and 10) could facilitate the selection of the most appropriate project theme, as the interdisciplinarity between courses’ contents could be explored more deeply between lecturers. This could result in more clear objectives and more adequate plans.

A clear interpretation from this list of items is the special focus on student learning and methodology improvement. Besides the positive results achieved by this project approach, in regard to student learning and competencies developed, the team of teachers is motivated to propose a few improvement changes. Most of the proposals are directly related to assessment and deliverables (items 3, 4, 5, 7, 8). It is a general perception from this team that learning is strongly influenced by deliverables and assessment activities. So, an improvement on the number and type of assessment elements could make a strong contribution for the improvement of student learning. Furthermore, some members of this team also believe that project requirements should be more detailed and clearer (item 10), which together with a better comprehension (item 6) of the project approach will be a benefit for students results. Finally, an increased level of interdisciplinarity is expected from the inclusion of the only NSC (item 9).

Table 8. List of strategies for the improvement of PLE

Strategies for the Improvement of PLE	*Staff Workload*	*Theme & Interdisciplinarity*	*Learning & PLE*
1. Reducing the number of staff meetings	X		
2. Investing more time in planning		X	
3. Consider project milestones deliverables as elements of course's evaluation	X	X	X
4. Each curriculum unit should reduce one test	X		X
5. Students should make a better use of feedback			X
6. Each students' team should get a print copy of the Project Guide			X
7. One report less	X		X
8. Anticipate the first version of the final report			X
9. NSC included in the project.			X
10. Identify detailed course requirements for each project phase		X	X

It should be noticed that some of these suggestions can have a less positive effect on other issues discussed. For example, investing more time in planning, preparing the theme and related contents can increase the teachers' workload. So, it is necessary to find ways of implementing these strategies that do not put in risk other aspects of the PLE approach. For instance, in item 5 – students should make a better use of feedback – the student teams can deliver a short essay indicating that the changes proposed by staff were included in the report. This essay should be designed in such a way that it would not be necessary for staff to read most of the report again.

CONCLUSION

The coordination of projects like the ones presented here is not very different from other projects with different teams to manage, a limited number of resources and time. Project management of these types of projects faces challenges that overcome the traditional role of the teacher. Thus, teachers that want to embrace in this type of approach have to be prepared for this.

Characterization of team management and communication management in these project oriented learning initiatives allowed the identification of different roles for staff stakeholders. Interdisciplinary projects for a whole semester need a coordination based on a real team spirit. Clarification of these roles and sharing them between coordination team's members help feeling the project from different angles, and to share responsibilities and decisions. Sharing responsibilities and decisions help to interact with commitment and to achieve higher interdisciplinarity.

Building a characterization of time management activities for project oriented learning initiatives can help coordination teams to identify and develop time management processes. These processes should help staff to keep the project under control. Among these there are several main processes that can be classified in learning facilitator activities, organization activities and communication activities.

PMI (2004) presented several project management knowledge area processes that can help project managers to select, develop and execute adequate processes for each project. Nevertheless, the project lifecycle for a specific domain is not known a priori and can be different for each team or project manager. Based on four cases of interdisciplinary project oriented learning initiatives it was built a project lifecycle for this kind of projects. This project lifecycle includes five phases with different durations and capacity demand that can be adapted for each project instance: preparation; setup; start-up; execution; end.

This framework allowed clarifying and formalising project management life cycle processes of these similar learning project approaches. This can be used for re-evaluation and reorganization purposes of these approaches. Furthermore, it can be used for new project approaches as a possible way to manage processes. It is now clarified where human resources are used during project management processes, what are the main types of activities developed and also what are the interactions between successive phases of the project life cycle.

Valuable inputs for management of this type of learning projects could be done in several domains: team building; information management; communication management; risk management; etc. It is now commonly accepted that people can make management decisions to be highly effective or to fail. So, understanding teams that perform well and trying to build organization models based on those cases is one way to develop this area. Furthermore, investing time on augmenting the effectiveness of management teams could help to get better learning results with less staff effort. This could be done based on improved processes of information and communication management and also on reducing risks.

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AFFILIATIONS

Rui M. Lima
School of Engineering,
University of Minho, Portugal.

Dinis Carvalho
School of Engineering,
University of Minho, Portugal.

Rui M. Sousa
School of Engineering,
University of Minho, Portugal.

Anabela Alves
School of Engineering,
University of Minho, Portugal.

Francisco Moreira
School of Engineering,
University of Minho, Portugal.

Diana Mesquita
Institute of Education/School of Engineering
University of Minho, Portugal

Sandra Fernandes
Faculty of Psychology and Education Sciences,
University of Coimbra, Portugal.

ALEX STOJCEVSKI, XIANGYUN DU AND TOMAS BENZ

5. EDUCATIONAL INNOVATION AND CHANGE FOR PBL

INTRODUCTION

The emergence of knowledge society brings in new characteristics of knowledge construction and learning process – technology-bounded, multi-dimensional, unstable, innovative, collaborative and complex. Professional competences and expertise become progressively more difficult to identify when problems are becoming increasingly ill-defined and cross-disciplinary with involving a growth of various integrated issues like technology, environment, economy, culture, sustainability and society. This gives rise to challenges to universities, in particular, engineering universities, which traditionally have been playing a role of dissimilating technical discipline focused and stable knowledge based on individual learning.

Questions have been posed to universities in the globalised society: How to help students gain contextualised knowledge and competencies which are connected with relevant cultural and collaborative environment instead of merely learning generalised knowledge and fixed skills? How to prepare students for their professional life with sufficient readiness to solve the complex and ever-emerging new problems collaboratively and innovatively? In many instances educational research report that traditional classroom based and lecture centred education has not always successfully produced satisfactory answers to these questions or even addressed these issues. Therefore, it is essential for engineering education to innovate its pedagogical theory and methods.

Problem and Project Based Learning (PBL) has been well identified as an innovative pedagogy in engineering education. PBL has been employed as educational philosophy and methods to provide the possibility for students to achieve interdisciplinary, sustainable, transferable skills, while at the same time exposing them to the complexities of global and cultural issues. In late 1960s and early 1970s, PBL started from being an alternative of lecture based pedagogy which focuses on improving teaching and learning. In the past two decades, it went through a developing process with including a broad variation in terms of across contexts and across discipline based PBL. High diversity can be observed at the current stage where aspects of sustainability and culture become essential.

This paper discusses a theoretical understanding of innovation in engineering education. This is followed by exemplification in relation to the development of PBL through introducing of its contextualised variation. Examples and cases of

L.C. de Campos, E.A.T. Dirani, A.L. Manrique and N. van Hattum-Janssen (Eds.), Project Approaches to Learning in Engineering Education: The Practice of Teamwork, 77–88.

PBL practice from diverse contexts are illustrated for the reflection on sustainable innovation in engineering education from a PBL approach.

THEORETICAL REFLECTION ON INNOVATION IN RELATION TO ENGINEERING EDUCATION

Innovation is one of the catch words that have been well used in both daily life and professional discussions. The major reasons for the strong focus on innovation fall into two folds, as summarised by Lundvall and Nielsen (2007)]. Firstly, successful innovations lead to less effort to manage things or better products and services with the same efforts, and secondly, innovations provide best solutions to fundamental social and human problems related to health, environment, energy shortage, sustainable development, etc.

Many literature agrees that innovation does not take place in isolation but depends on extensive interaction with the environment. According to OECD report (2007a), although technological development such as good use of internet can bring people worldwide into the knowledge economy, innovation clusters around specific regions, notably those with vibrant communities, skilled people and universities. High-tech companies choose to base key parts of their operations in knowledge- and innovation- intensive regions with a concentration of research, skilled and creative labour, and infrastructure to innovation.

In this context, being the resources of the knowledge and innovation, higher education institutions are playing an increasingly important role in that they build human capital and enhance the social and cultural fabric that ensures the occurrence of innovation (OECD, 2007a). Therefore, the innovation of high education institutions can make great contribution to the development of human capital by improving teaching and learning (Lundvall, 2007; Puukka & Marmolejo, 2008). This can also contribute to social, cultural, and environmental development in the region, which will consequently make the region more globally competitive (OECD, 2007b).

The global needs for innovation give rise to challenges to the university in terms of producing innovative graduates with sufficient readiness to participate in solving the complex problems of professional life. These needs, in particular, give new tasks to engineering universities. In relation to engineering profession, the traditional involvement of only mathematics, science knowledge and technical skills is not enough. Engineers today are expected to master a combination of disparate capabilities – not only technical competencies concerning problem solving, technological production and innovation, but also interdisciplinary skills of cooperation, communication, management and lifelong learning abilities in diverse social and cultural settings, which involves open-mindedness and innovative thinking throughout professional life (Lehmann *et al.*, 2008).

Innovation studies started to emerge as a separate field of research in 1960s and have been developed into a well-established research area in many disciplines like economics, human geography, etc. The terminology of innovation was firstly employed as an academic concept in economics study by one of the most original social scientists of the 20th century, Joseph Schumpeter. With a focus of researching on the role of innovation in economic and social change, Schumpeter defined innovation as „new combinations of existing resources (Fagerberg, 2006). He also distinguished innovations between 5 types: new product, new methods of production, new resources of supply, expectation of new markets, and new ways to organise business. Based on this, later scholars classified these types into product innovation, which refers to knowledge about how to invent or improve products, and process innovation, which refers to knowledge about how to produce innovation products (Lundvall & Nielsen, 2007; Fagerberg, 2006; Lundvall 1992). In their work of innovation performance in relation to knowledge management, Lundvall and Nielsen also point that knowledge creation/production process is

> a process of joint production, in which innovation is one kind of output and the learning and skill enhancement that takes place in the process is another (Lundvall & Nielsen, 2007).

Scholars of innovation studies also agree on what innovation is not – it is not a linear model as often assumed, starting from scientific research results, to technological innovation and market introduction. Instead, many empirical works observed a changing and interactive process with loops that vary in different contexts (Lundvall & Nielsen, 2007; Lundvall 1992; von Hippel, 1988).

Currently an increasingly growing body of scholars has been devoted to the study of innovation from cross- and inter-disciplinary perspectives. However, in educational area, this concept has been well-used but without clear and agreed definition. Inspired by the discussion of innovation from an economic perspective, the following 5 aspects are proposed in this paper for the understanding of innovation in higher education (in particular, engineering education):

- New skills / competences (not only technical competences, but also process competences such as communication, management, collaboration, etc.)
- New pedagogy (methods of teaching and learning)
- New contents (teaching and learning materials)
- New application and assessment (resources for applying and methods of assessing learning outcome)
- New ways of thinking/organising education

In the rest of the paper, these five aspects will be related to the discussion of the variation of PBL practice with respect to innovation in engineering education. The concept of innovation will be used based on this understanding.

CASES OF INNOVATIVE AND CONTEXTUALISED PRACTICE IN PBL

In this section, three cases will be discussed to exemplify how PBL has been implemented differently as innovative pedagogy at three engineering universities. Questions will be addressed: In which ways PBL practice can lead to successful innovation within a certain context? In which ways the effect of innovation can be maximised in the change process towards PBL?

Case 1: PBL at Aalborg University, Denmark

As a strategy for educational innovation, the application of Problem and Project Based Learning at Aalborg University (AAU), Denmark started in 1974. Instead of focusing on lectures, PBL is mainly based on problems and/or projects with a diversity of learning resources such as lectures, facilitation, group discussions, seminars, workshops, laboratories, company visits, etc as shown in figure 1. Implemented at the university level since its establishment, this PBL model at AAU was and it involves not only the change of curricula, but more importantly the fundamental understanding of teaching and learning at a philosophical level.

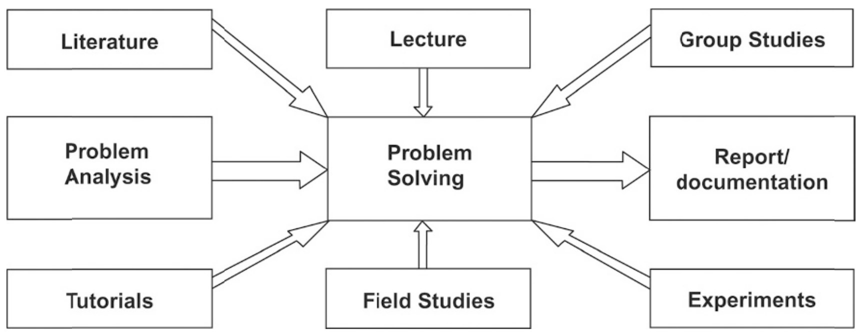

Figure 8. The Aalborg Experiment – Project innovation in university education.

The fundamental elements of AAU-PBL include: 1) the semester *theme* that can describe certain problems and cover relevant subjects, 2) the *problem* as a starting point for a project that can vary among professional areas, 3) the choice of *projects* (which last approximately 5 months) that can be based on open or rather controlled discipline formulations depending on the educational objectives, and 4) the *team work* (with approximate 3-7 students in one team) that will encourage students to develop process skills such as collaboration, management of learning and peer learning. In order to pass each semester, students are expected to conduct a project and earn 30 ECTS (European Credit Transfer System). Approximately half of the students' time is spent on project work (which takes up 15 ECTS) in teams, whereas the other half is spent on traditional lectures. The projects are formulated within the framework of the given theme and related to the overall educational objectives. Each team works on a unique project. Very often students formulate their project proposal with the help and approval of the facilitator.

The effect of AAU-PBL can be evidenced from both students, the university and the industry. For students, it improves students learning in terms of competence gaining both technical and process aspects, also in the way that students can gain transferable skills and authentic work experiences. The university benefits from gaining feedback and access to instructive cases and ideas for research and teaching, as well as decreased drop-out rates and increased on-time completion rate so that it accentuates the institutional profiles (Kolmos & Du, 2008). Enterprises benefit from getting a clearer picture of what the university stands for and how the students might fit in as prospective employees.

The evaluation of engineering graduates from industry evidenced the positive effect of AAU-PBL innovation. In 2002, a national report from Danish government board of job market documented that 59% of the private employers prefer candidates from AAU rather than candidates from other engineering universities because AAU graduates proved to have better skills in team work, innovation, project management, and acquiring new knowledge (Kandidat, 2002). In 2004, a survey conducted by Danish Industry (Ingeniøren, 2004) among 125 of the 500 engineering companies evaluated the performance of young engineers in their workplace. The results show that graduates from AAU and from another traditional university have no significant differences in professional knowledge and skills; however, AAU graduates have visibly better performance in skills of project and people management, communication, innovation, knowledge of business and life. In a recent survey of engineering companies in 2008 (Ingeniøren, 2008), AAU has been identified as the most innovative education institution (compared with six other universities with engineering educations) and AAU engineering graduates have been regarded by employers as the most innovative young professionals.

Further, OECD report on regional development and innovation used PBL at AAU as a good example of linking university with industry, linking students with the local economy, and contributing to the improvement of human capitals by providing innovative gradates with good skills and competencies (OECD, 2008;Puukka & Marmolejo, 2008).

Case 2: PBL at Heilbronn University, German

A humble start In classical curricula of engineering education in Germany you could find lots of written tests, some oral exams and one or two oral presentation in a seminar. In the late 90s a group of teachers at Heilbronn University started their ‘private’ trial and error in finding new ways of teaching because they detected a lack of interest and success at a growing number of students. So they increased the percentage of practical training in their lectures and built up a community discussing their ideas and concepts known from other Universities.

There was some small improvement in the results but motivation did not change drastically. So the next step was to change from well defined training units to problems or projects which were related to a single subject. In the beginning of each semester a growing number of teachers presented the problems or projects the students could select from. The students had to work out their solution during the semester. Lectures provided the theoretical knowledge to solve the problems. The examination board step by step changed the curriculum form written exams to project documentation and oral presentations.

This gave a respectable kick of motivation to students and teachers and much better results/marks for the students. It was much easier now for the students to detect the relevance of the provided content. But with the growing success the idea of changing the lectures to a problem based approach within single courses became virulent in some way and led into a severe conflict of time and resources for the students. After a more or less relaxed start of the semester the students had to face a growing number of presentations during the last week of lectures. The possibilities to expand the period for the presentation was not a real alternative because it cut off the project time for the early given presentations and students had to interrupt the project work for the topics to be presented at the end of the semester instead of having more capacity to work it out. Students focussed more and more on their favourite projects and forgot to prepare for conventional exams.

Bottom Up Approach to Start the Institutional Change

A better coordination of separate projects within a semester was not a sufficient solution to resolve these conflicts. So the software engineering course at Heilbronn University started to develop a more general approach to come to a more successful level of problem and project oriented learning (Benz & Jaeger, 2008). The Trial and Error phase was influenced by the concept of Problem based Learning (Duch *et al.,* 2001; Barrows & Tamblyn, 1980), as implemented in Aalborg, Denmark (Kolmos *et al.*, 2004) and the 4C/ID Model as implemented in Groningen, Netherlands (van Merriënboer, 1997). However, the concept had to be adapted to the rigid German University system and its limitations in resources.
The first step was to implement some interesting virus to infect more colleagues with the ideas of PBL. To prove that even first semester students are able to solve some interesting industry related problems an open project was launched. The students had to develop some project management software in a special programming environment. This environment based on wikis (Benz, 2006) allows students who have not yet sufficient knowledge about programming to implement a satisfying and industry applicable solution (Benz & Jaeger, 2008). To close the gap of software development knowledge students of the second year were invited to do the database development for this project. So an industry based project could be implemented simultaneously in two courses of first and second year.

The next step is to connect three courses of the first semester within one project. The courses are:

- Basics of business process management (to provide the industry based project)
- Basics of software engineering (to provide the methodical approach) and
- Learning How to Learn

So the first semester students get a deeper understanding of how application fields like business application, methodological basics like software engineering and basics of how to work on problems and how to learn fit together to a common mind set.

After the first semester the didactical concept and the results will be evaluated by colleagues teaching in first and/or second semester but who are not yet involved in a 'cross-course' project. The goal is to integrate other courses in the first semester project and to build the nucleus for a common project in the second semester.

Every semester the course integrating projects can be implemented to the next course level. In the already implemented levels the project handling will become more and more settled and stable.

Extensive discussions and common decisions of how to proceed will lead to a common concept of how to implement PBL the 'Heilbronn way' for the inner circle, the PBL group at the University. Another important task will be to document and publish discussions and results that led to this concept. To provide technical support for the exchange of experiences, discussions and lessons learned a set of Wikis and learning platforms is implemented as general vehicles. At the same time working together in a common project helps to identify overlapping content in different courses and point out gaps of provided information or knowledge in a certain level. So it should automatically lead to adapting content of different courses. But this is the hardest part to convince colleagues to change 'their' content to reach a better whole unit. Changing the curriculum to project oriented semester units and facilitating a degree programme with rooms and other resources needs the help of the executive board of the University.

Preparing the Top Down Approach

When starting the initiative of implementing PBL at the software engineering programme the vice chancellor's office is preparing first steps of a roll out to other faculties in offering a programme for teaching the teachers.

A programme is set up for some leading key persons at the different technical faculties of Heilbronn University. They will start with some introductive workshops provided by staff members of the UICEE Centre for Problem-Based Learning at Aalborg University. These key users are offered to continue step by step with the different modules of the PBL masters programme at Aalborg University (http://www.mpbl.aau.dk/). The modules will help to finally leave the trial and error status and set up PBL in a more professional way.

The programme is composed of four major modules (Aalborg University, 2006):

- First step will be to develop the teaching competencies. The module includes the theories of learning and forms the foundation of PBL within the field of engineering education, as well as the various PBL models. Focus in the project work is on reflection, individually and in groups, on the previous teaching experiences and competencies of the participants.
- The second module has its focus on planning a PBL-based teaching experiment within the participant's own institution or work place.
- Project work and implementation of the PBL-based teaching experiment within the participant's own institution or work place is worked out in module 3.
- The master programme will close with an independent critical analysis and evaluation, based on theories and methods in the field, of the implemented teaching experiments and the final thesis.

The programme will help to provide highly professional PBL courses at the University. To implement the institutional change in the structure of the University and the different curricular and to integrate almost all teaching staff members will be hard work for the University board and the vice-chancellor's office.

Case 3: PBL at Victoria University, Australia

PBL as a pedagogical teaching and learning method in Engineering at Victoria University has been actively applied for four years. The initial transition from the lecture-based methodology was a short one, resulting in two different PBL models practiced across the two engineering schools. The School of Architectural, Civil, and Mechanical Engineering practiced PBL at a subject level, and the School of Electrical Engineering practiced PBL at a slightly higher level, at curriculum level. In the last year the Faculty of Health, Engineering and Science at Victoria University has undergone a review in which two critical recommendations very much related to PBL were raised. One was to develop a common first year in Engineering, and the other, significantly important, to develop a common PBL model for Engineering at VU. Prior to the development of a common first year in engineering, it was important that we defined what PBL means to Victoria University engineering. This definition which includes a semester model to practice PBL, would guide us to the development of not only a common first year, however the development of the entire engineering degree.

The VU Engineering PBL Model

The PBL Curriculum Advisory Group to the Curriculum Development Project (PJ-HES-08009) worked towards the development of common and unique PBL model for Engineering at Victoria University.

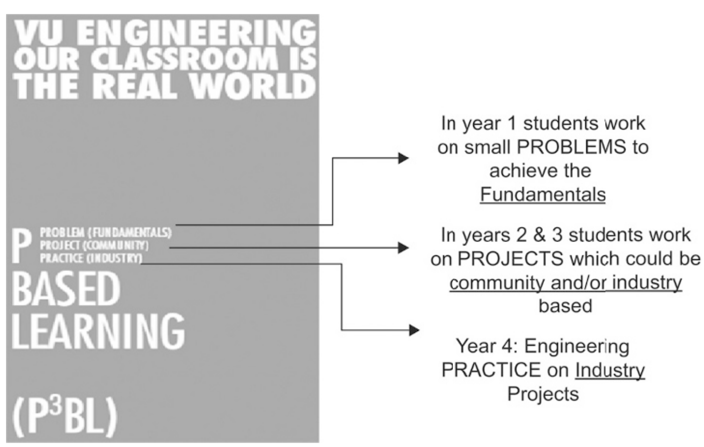

Figure 9. The VU Engineering PBL model.

On the basis of long discussion periods, consultation periods, national and international research into PBL and pedagogy, it was agreed that it is very important and critical to identify a model that is unique to Engineering at Victoria University. The VU Engineering PBL Model is illustrated in the figure 2 below.
It was indicated that fundamental knowledge is critical for all engineers in the first year of their education, and that this would be guided by smaller 'problems' in year 1, rather than larger projects.

Table 3. The three 'P's in PBL at VU Engineering

Problem-based P-unit	*Project-based P-unit*	*Practice-based P-unit*
Unit is built around a series of problems	Unit is built around a single project (12-24 weeks)	Unit is built around work experience in industry
Problems are generated by teachers	Projects are generated by community/industry client	Work is actively determined by employer
Problems are ill-structured, open-ended and derived from engineering practice	Problems are ill-structured, open-ended and mimic engineering practice	Work activity is professional practice
Students are based on campus	Students are based on campus but also meet at least twice with client(s) on site	Students are based in industry
Students work on problems for most of unit time	Students work on problems for most of unit time	Students work as directed, reflect in own time
Students work in teams	Students work in teams (or individually in Year 4)	Students work in teams or individually as directed
Students determine learning issues and find learning resources	Students determine learning issues, project approach and project outcome	Students work as directed
Teachers provide guidance by modelling, scaffolding, coaching and fading	Teachers provide guidance by modelling, scaffolding, coaching and fading	Teachers provide coaching and mentoring
Learning outcomes are generic and technical	Learning outcomes are generic and technical (deep in project area)	Learning outcomes are generic and technical (situation specific)
Assessment by individual portfolio demonstrating achievement of learning outcomes, including assessment by self(reflection) and team members	Assessment by group plus individual portfolio demonstrating achievement of learning outcomes, including assessment by self(reflection) and team members and client(s)	Assessment by individual portfolio demonstrating achievement of learning outcomes, including assessment by employer
Problem-based learning may be supported by other teaching-learning activities (e.g. workshops, learning packages, lectures)	Project-based learning may be supported by other teaching-learning activities (e.g. workshops, learning packages, lectures)	Pratice-based learning may be supported by other teaching-learning activities (e.g. workshops, e-mail, phone, online resources)
Does not meet VU Learning in the Workplace & Community Engagement (LiWC) requirements	Meets VU Learning in the Workplace & Community Engagement (LiWC) requirements	Meets VU Learning in the Workplace & Community Engagement (LiWC) requirements

In line with the university policy of 25% Learning in the Workplace and Community Engagement (LiWC), it was agreed that students are introduced to community and/or industry projects in the 2nd and 3rd year of the program, and that practice on industry projects takes place in industry and/or university in the final year.

The model is also guided by the principles approved by the PBL Program Steering Committee, notably that at least 25% of assessed work will be Learning in the Work Place and Community (LiWC). As it can be seen from figure 2, the ‘P’ in PBL in Engineering at Victoria University means more than ‘problem’ based learning. Rather, it is defined as Problem/Project/Practice based learning (P_3BL). Table 1 below illustrates the proposed characteristics of the three ‘P’s in PBL at VU Engineering.

With a clear and common definition of what PBL means to VU Engineering, it was important that we next sketch out and define a semester model that is commonly used in all Engineering degrees across all year levels.

VU Engineering PBL Semester Model

The Curriculum Development Advisory Group considered three (3) semester models on the understanding that one will be the master semester model for the programme with variation both in P:S activity ratio in % (25:75, 50:50, 100:0). The type of P (Problem, Project, Practice) as discussed will be Problems in year 1, Project(s) in year 2 and 3, and Practice on industry projects in year 4. In this document, ‘P-unit’ refers to a unit of study based on Problem/Project/Practice work. ‘S-unit’ refers to a support unit of study.

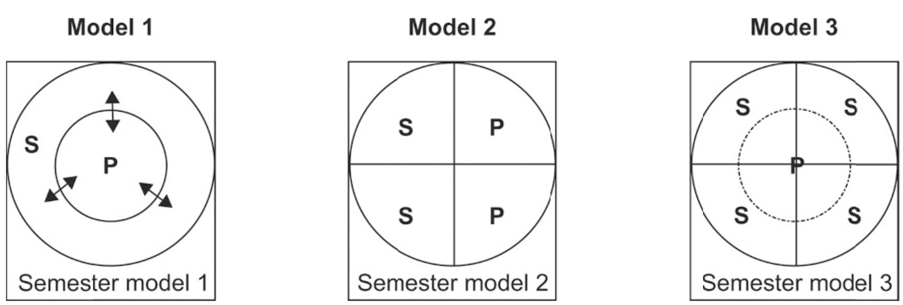

Figure 10. The VU Engineering PBL semester model.

From the above illustrated semester models, Model 1 was selected as the semester model to be used for the design, development, and implementation of all Engineering degrees (year 1 to year 4).

The model is guided by the principles approved by the PBL Program Steering Committee, notably that at least 50% of the academic programs will be delivered in the PBL mode (following the PBL process) and the other 50% or less will act as supporting unit(s) to the PBL unit. Other factors in selecting Model 1 were due to the agreed principles discussed with the PBL advisory group, notably that:

- A PBL programme does not need to use PBL approaches in every unit of study but every unit of study must contribute in some way to PBL.
- P(s) are the centre of each semester as a separate P-unit.
- Throughout the course, P will change from Problem (several per unit) to Project (one per unit – student primarily campus-based) to Practice (project in industry – student primarily industry based).

In addition, this semester model offers a full vertical as well as horizontal integration in the development of skills and knowledge of engineering students.

DISCUSSION AND SUMMARY

The global requirements for innovation give rise to challenges and new tasks to engineering universities. Engineers today are expected to master a combination of disparate capabilities, not only technical competencies concerning problem solving, technological production and innovation, but also interdisciplinary skills of cooperation, communication, management and lifelong learning abilities. A learning and teaching methodology to achieve not only the technical competencies, but also the innovative, creative, and increasingly important cultural competencies, is PBL.

We have discussed in this paper a theoretical understanding of innovation in engineering education. Innovative examples and cases of PBL practice from diverse contexts, which include PBL at Aalborg University Denmark, Heilbronn University Germany, and Victoria University Australia, were illustrated for reflection of sustainable innovation in engineering education. This was performed from a PBL approach. From the case studies, it can be seen that the 'P' in PBL could stand for more than just Problem Based Learning. This is an important characteristic to consider when designing and developing an innovative PBL learning and teaching methodology.

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AFFILIATIONS

Alex Stojcevski
Professor of Electrical and Electronics Engineering
School of Engineering
Deakin University Australia

Xiangyun Du
Director of Confucius Institute for Innovation & Learning
Aalborg University, Denmark

Tomas Benz
Professor in Software Engineering, Vice Dean of the Faculty of Computer Science
Heilbronn University, Germany

SONIA M. GÓMEZ PUENTE, CORINNE JONGENEELEN AND
JACOB PERRENET

6. DESIGN-BASED LEARNING IN MECHANICAL ENGINEERING EDUCATION

The innovation process and the challenges of the roles of the tutor

INTRODUCTION

Since 1997 Design-based Learning (DBL) has become the educational concept at Eindhoven University of Technology (TU/e). There was a need at that time to develop a common view for innovation in the educational system. DBL has been modelled to serve the purposes of scientific technical education with an underlying emphasis in 'design' (Wijnen, 2000). The rationale behind this approach was to provide the programs with a more competence-based orientation and to educate students to meet the requirements of technical systems. The profile of DBL was thus described in terms of features (i.e. Professionalization, Activation, Co-operation, Creativity, Integration, Multidisciplinary). DBL was not implemented following a uniform curriculum model, rather it was implemented according to the needs and ideas in every specific department. For Mechanical Engineering, the DBL working methodology to solve problems is based on Problem-based Learning (PBL), whereas the method to design a product departs from on project process orientation.

In the following sections we will first describe and compare the two educational concepts of Problem-based Learning and Project-based Learning. Next we will describe the innovation process at TU/e with a focus on Mechanical Engineering. To explain the role of the tutor in DBL at the Mechanical Engineering department, we will need to sketch the program as a whole as well as the assessment process within DBL. We will conclude with discussions about some dilemmas of the role of the tutor in DBL and relate those to his role in PBL and in Project-based Learning in general.

PROBLEM-BASED LEARNING (PBL) AND PROJECT-BASED LEARNING: DIFFERENCES AND SIMILARITIES

Problem-based Learning (PBL) was introduced in 1969 at McMaster University in Canada for the study of medicine (Barrows, 1984). PBL is a student-centred instructional strategy in which students solve context specific cases and open-ended challenging problems. Students work collaboratively as self-directed and

L.C. de Campos, E.A.T. Dirani, A.L. Manrique and N. van Hattum-Janssen (Eds.), Project Approaches to Learning in Engineering Education: The Practice of Teamwork, 89–108.

active investigators while developing problem-solving skills and learning to transfer knowledge to new situations. PBL also helps to increase motivation. This model has been successfully integrated in many educational programs i.e. Medicine, Law, Economics, Psychology, Sciences, and Liberal Arts with, to certain extend, adaptations in each program such as the incorporation of the element of project work in the domain of sciences. The necessity of adaptation in the science domain is explained in Perrenet, Bouhuijs & Smits (2000). The main reasons given are that many topics in the engineering domain are characterized by a hierarchical knowledge structure and by complex problem solving.

Aalborg University in Denmark is the first institution which has introduced project-based learning as a key educational concept, in 1974. This concept is framed in project management and process orientation and is rooted in the learning principles of problem-oriented, project-organized education, and learning-focused. (Dym, Agogino, Eris, Frey, Leifer, 2005). The idea behind project-organized education is that projects have a multidisciplinary character in which groups of students work while developing lifelong learning skills.

For already longer than four and three decades respectively PBL and project-based learning have been the educational model at Maastricht University in the Netherlands and Aalborg University in Denmark (Kolmos, 2006; Moust, van Berkel & Schmidt, 2005). Common elements to be easily recognizable in PBL and project work are that they both have a strong accent in self-direction, collaboration and in multi-disciplinary problem orientation. For both approaches the basic principle is to create authentic scenarios which mirror the real life and market situations (http://pblmm.k12.ca.us/PBLGuide/PBL&PBL.htm). Some of the similarities between PBL and the Aalborg project-based learning concept can be also found in that both have similar characteristics, i.e. an open curriculum and a focus on experience-based learning (Kolmos, 1996).

Although there has been substantial literature written on the similarities and differences between problem-based learning and project-based learning it becomes sometimes difficult to draw the line to distinguish among one and another. The models are at times used in a combination and/or they can play complementary roles.

At the level of learning principles there are substantial reasons to unify these two models. According to Graaff and Kolmos (2003; 2007, in Kolmos, De Graaff, Du, 2009), the PBL learning principles are categorized in three approaches: learning, contents and social, and are used to better explain the educational concept of PBL. These learning principles and the organizing categories have obviously influenced the set-up of PBL learning situations. Based on Figure 1, content becomes an interdisciplinary element in which theory is applied in practical settings and in which analytical and research methodologies are used to reach the learning outcomes of the curriculum. The framework to carry out PBL is therefore embedded in problems that have to be solved in a systematic and project-based manner (Kolmos, De Graaff, & Du, 2009).

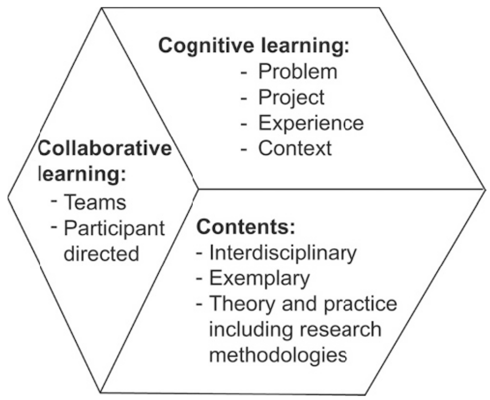

Figure 1. PBL Learning Principles (Kolmos, de Graaff, Du, 2009).

Differences between PBL and project-based learning can only be found in subtle distinctions between the focus of the curriculum. The emphasis in project-based learning lies in the learning process rather than in the teaching process. The level of self-direction within project work, therefore, is higher than within PBL since students have to manage their projects in terms of time and resources (Perrenet, Bouhuijs & Smits, 2000).

THE INNOVATION PROCESS AT TU/E AND THE TRANSFORMATION PROCESS AT THE MECHANICAL ENGINEERING DEPARTMENT

In its Institutional Plan for 1998-2001, the TU/e stated that it would develop a university-wide educational philosophy for the university-based training of engineers: *Design-based Learning.* However, already in 1994, the curriculum of Mechanical Engineering was restructured (Smits & Janssen, 1996) as a reaction to an increase of student dropout, a decrease of student intake and demands from government and industry. The former model offered lectures in the morning and problem solving instruction for mathematics and physics in addition to lab work in the afternoon during the first three years. Inspired by the example of Maastricht, adapting it to the characteristics of the domain, a 'partial' PBL-strategy was chosen. While in the pure PBL approach of Maastricht, PBL is the rule and lectures are the exception, in the new program of Mechanical Engineering still 60% of curriculum still consists of lectures and related practice assignments. For the actual implementation of DBL, the University choose a strategy with a mix of top-down and bottom-up approaches. For each of the ten programmes the eight departments lined out one typical project to be carried out over two years.

This head start of 'innovation before the innovation' brought Mechanical Engineering in a special position. However, the ideal intention of taking the Mechanical Engineering curriculum as a model was only followed by the new program of Biomedical Engineering. The reasons behind are that the curriculum of Biomedical Engineering is closely related to Mechanical Engineering from Eindhoven as well as to Medical Science from Maastricht.

Another important event was the organisation of a study tour for a mixed student-and-staff group from all over the university to the universities of Aalborg and Roskilde. The Danish project work appeared to be an inspiring example. For most programs, the implementation eventually meant the incorporation of a series of projects into the curriculum (i.e. at Computer Sciences courses have been readjusted to give more room for projects) along with related skills training. Some programs only strengthened already existing elements (i.e. at Mechanical Engineering the tutor has got different roles). Other representations of project work, such as the new program of Industrial Design, was set up competency based, with the student as a junior employee and the teacher as a consultant working in realistic settings. The implementation of the DBL concept was done, therefore, with great diversity.

DBL served to bring together research and education (Wijnen, 2000). The focus centered on the application of acquired knowledge and the development of skills. As an activating educational form DBL was inserted in the curricula to have students work in groups collaboratively on multidisciplinary design assignments. The ultimate goal was to motivate students and enable them as creative professionals to integrate knowledge and skills in realistic design problems (Wijnen, 2000).

Despite the fact that one of the DBL objectives was to strengthen coherence and cohesion within the TU/e, the experience of more than ten years of implementation, however, is that DBL as an *educational concept* still remains broad (Werkgroep OGO & Kwaliteit, 2003). While for some educational programmes DBL has served as a foundation for curriculum renewal, for others, however, it has been interpreted as an *educational form* to integrate in courses.

The typical implementation project line out for Mechanical Engineering had as a main activity the creation of a tutor handbook. Working in small teams guided by a faculty member was already an important element in the programme ever since the 1994 innovation. Staff experience which had been gathered with this new model was highly varied. The tutors were supposed to practice new educational skills, such as group coaching and gain practice in the different roles of the tutor (Delhoofen, 1996). Following the pure PBL Maastricht model, suggestions from educational experts in this field were made for transferring responsibility from staff to students, i.e. levels of freedom in project management. However, these practices were not part of the traditional standard repertoire at Mechanical Engineering. The PBL model was then contextualized to serve the demands of the design character of mechanical engineers and design-based learning became the appropriate vehicle to lead the transformation process. For a more detailed description of the innovation process at the TU/e as a whole, see Perrenet (2001) and Perrenet & Mulders (2002).

PROBLEM-BASED LEARNING AND PROJECT-BASED LEARNING COMPARED TO DBL AT MECHANICAL ENGINEERING

A difference between PBL groups and project work groups is that the PBL groups (average ten students) are larger than the project groups (average eight students) (Perrenet, Bouhuijs & Smits, 2000). In all cases, the role of the tutor as a supervisor of the group activities is at the centre of this approach and the tasks are modified to respond to the processes and complexity in content expertise of problems and projects. In PBL, the teacher has a more process-oriented supervision role. In project-based work the role of the teacher focuses on monitoring the product (Kolmos, 1996). Variations in the role of the tutor within DBL are visible in the learning outcomes of each Bachelor year program. For instance, the role of the tutor in the first year of the Bachelor's program has a monitoring and orientation character. (S)he mainly watches process and progress. During the second year of the Bachelor's program the tutor's role has a more defined content expert character (see also the section: The role of the tutor in DBL at the Mechanical Engineering Department).

Essentially, the characteristics of PBL methodology, namely, the 'Seven Jump', (Moust, Bouhuijs & Schmidt, 1998, in Moust 2000), i.e. analyzing unclear terms and concepts; defining, consequently, the problem; brainstorming and carrying out a systematic analysis; formulating and executing, accordingly, own self-study assignments; and finally, reporting (see also next section), form the backbone of the PBL structure. In the Aalborg model, the working methodology is based on project management and process orientation. The 'Seven Jump' methodology has been adapted within DBL as a working methodology to develop analytical skills in problem solving situations. However, while with PBL the learning activity begins with a problem and follows an inquiry model, the students within DBL follow a product orientation which has the product as the starting point. Students have to design the end product for which they also create a plan to manage the development of the project. Students in DBL work in teams to create products, materials, processes, and systems. See Table 1 for further details on three models.

Moreover, the PBL objectives i.e. acquisition of knowledge and skills to be retrieved in the working place and the acquisition of problem-solving skills to be used in a professional setting (Perrenet, Bouhuijs & Smits, 2000) are to be found among the DBL objectives as well.

In the PBL curriculum at Maastricht University[1], multidisciplinary courses take six to eight weeks in which both subject-matter and skills are integrated around a central theme (Moust, van Berkel & Schmidt, 2005). In the Aalborg model, projects can run along a semester, while DBL projects last four to eight weeks.

Table 1. General comparison of PBL, project-based learning and Design-based Learning in different universities (adapted from Du, X.Y., 2009)

	Problem	***Process***	***Team***	***Assessment***	***Role of teaching***
Aalborg	One semester Problems (5 months) - open and narrow	Project Management and process skills	4-7 students Self-selected Discussing, writing and together,	Individual judgement in a team-based exam	Facilitation based – Consultancy (low level Of instruction)
Maastricht	One week - Case based	Seven jump	5-10 students Discussing together	Individual exam progress Testing	Facilitation based – tutoring (low level of instruction)
Eindhoven University of Technology (Mechanical Engineering)	Four to eight weeks	Twice a week 2-hour meeting (in Bachelor Year 1) Twice a week 1-hour meeting (in Bachelor Year 2) Problem solving methodology in group work	6-8 students	Group report Tutor assessment (individual assessment) Peer Assessment	Teacher is project coordinator Tutor supervises process (Year 1) Tutor is content expert (Year 2)

DESIGN-BASED LEARNING IN THE MECHANICAL ENGINEERING CURRICULUM

The Background

Before describing the role of the tutor in DBL within Mechanical Engineering it is essential to gain a general overview of the Bachelor's curriculum. The overarching umbrella for the engineer competence profile at TU/e is framed in the competence criteria designed for Bachelor's and Master Curricula (Meijers, van Overveld & Perrenet, 2005). The university graduate profile is defined by seven areas of competence, namely: 1. Competent in one or more scientific disciplines; 2. Competent in doing research; 3. Competent in designing; 4. A scientific approach; 5. Basic intellectual skills; 6 Competent in co-operating and communicating; and finally, 7. Takes account of the temporal and social context. Secondly, the profile is defined with levels at four dimensions: 1. Analysis;

2. Synthesis; 3. Abstraction; and 4. Concretization. Every program is to be evaluated against the criteria of this framework.

This is done by interviewing all lecturers about their courses. For DBL the project coordinators have been interviewed. The main questions in each interview are, firstly, how much time students should spend on each of the seven competence areas, and, secondly, how much time at each level of academic thinking and acting along the four dimensions. Profile and level are determined by means of aggregation of the interview data. A specific investigation has been done into the differences between DBL courses and the other Bachelor courses in the first two years. The most prominent differences turned out to be that non-DBL courses had much more study load in area 1 (disciplinary competence), while DBL-courses had much more study load in area 6 (co-operate and communicate). Also in areas 2 (doing research) and 3 (designing), the DBL courses had more study load than the non-DBL courses. An investigation concerning the competences within the competence areas showed that together DBL and non-DBL courses covered all competences. The DBL courses uniquely covered several competences of area 6, such as verbal communication, communication in a second language and team roles.

Also clear differences showed up along three of the four dimensions, i.e. synthetic, abstract, and concrete. The dimensions synthetic and concrete were more often applicable for DBL courses than for non-DBL courses. The dimension abstract was more often applicable to non-DBL courses than to DBL courses. In the dimension synthetic the DBL courses generally emphasize higher levels of complexity than non-DBL courses, such as the levels of designing components and optimizing the system. In the dimension concrete almost all attention to the higher complexity levels of creating a manufacturing plan, manufacturing the system, and putting the system into operation is given within DBL courses. For analytic, synthetic and, especially, concrete, DBL-courses generally attend to more levels within a course than non-DBL courses do. (For abstract, non-DBL courses generally attend to more levels within a course).

Within the curriculum of Mechanical Engineering, DBL plays an important role in developing student’s competences in areas 3 and 6 and in parts of the other areas as well. These are for example: the ability to integrate existing knowledge into a design; the ability to produce and execute a design plan; to have creative and synthetic skills with respect to a design problem; the ability to communicate in writing and verbally about the results of learning; the ability to work within an interdisciplinary team. The design of the projects, therefore, is framed in the six underlying educational DBL features (i.e. professionalization; activation; co-operation; creativity; integration and multidisciplinary.

Design-based Learning has been specifically adjusted to meet the needs of the Mechanical Engineering curriculum where DBL is aligned with the curriculum. DBL has a strong emphasis on developing technical and scientific knowledge; on acquiring abilities to conceive models to solve multidisciplinary problems; and to work in teams as well (Perrenet, Bouhuijs & Smits, 2000). Analyzing, modelling, testing and application of project-related skills are the underpinning competencies for the mechanical engineering profile that students acquire in DBL projects.

The Curriculum

To develop a solid theoretical basis in the curriculum of the Bachelor's program of the Mechanical Engineering Department students work on courses for 60 percent of the time. Parallel to the courses they work on the DBL-projects in groups of eight students for the other 40 percent of the time.

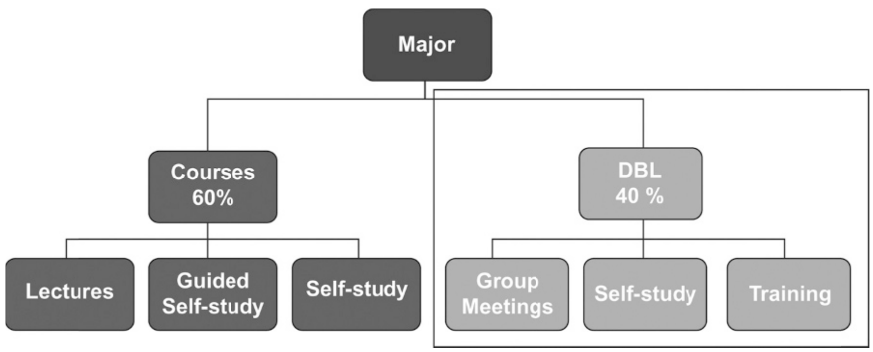

Figure 2. DBL embedment in Mechanical Engineering curriculum.

Both the first and the second year consist of a total of 12 courses and eight DBL-projects, the structure of one semester is represented in Table 2. Some of the DBL-projects are programmed together with or directly after a related course, so that students learn how to apply the knowledge they gained in the course in the practice of designing. But there are also projects which do not have a direct relation with courses. In this regard, students have to gain new knowledge to solve a design-problem.

Table 2. DBL in the Mechanical Engineering curriculum

Semester			
Block		Block	
Course 1 (3ECTS) Course 2 (3ECTS) Course 3 (3ECTS)		Course 1 (3ECTS) Course 2 (3ECTS) Course 3 (3ECTS)	
DBL (3ECTS)	DBL (3ECTS)	DBL (3ECTS)	DBL (3ECTS)

The DBL Meetings and Group Dynamics

The DBL group meetings take place twice a week. The duration of the meetings varies from two hours in the first year, which is when the students learn how to hold a meeting, to one hour in the second year. The role of the students in the DBL meetings rotates. Each student holds a different role, i.e. chairman, who prepares the agenda; the secretary, who makes the minutes; and, the summariser, who makes summaries of group assignments on the board (Handout Peer Review, 2003). Within DBL students learn to recognize and work within different group dynamics. The students learn how to work together as a group, and how to reflect on the group dynamics i.e. Belbin team roles (Belbin, 1993). The group composition during the first year of DBL remains the same for a whole semester.
In the second year, students know what kind of group member they are and how they can balance their natural role with the rest of the group members. For example, a student who is a 'natural leader' will feel more comfortable in a group with hard workers who only listen to him, rather than in a group in which where there are more students with the same type of character. The group composition changes for every project.

Training for Students and Tutors

A DBL project typically consists of a case study that takes from four to eight weeks and that is often supported by different skills-training. In the first semester, for instance, students follow training on how to work in groups (Moust, Bouhuijs & Schmidt, 1997), how to make a presentation and how to write a technical/academic report. Besides these process-skills they also receive training in different kinds of technical skills such as the basics of how to work with different computer programs (Matlab, CAD, CAM, FEM) and other tools that they can use to solve problems.

Likewise, the tutor follows a one-day training with the overall objective of getting acquainted with the role of the tutor in different situations (i.e. teacher, coach and facilitator of the learning process, (Delhoofen, 1996), and in the tutor's supervision skills. The training topics for the first year tutor consist of the degree of freedom in projects, supervision styles, motivation of students, giving feedback to students and assessment. The training methodology is based on role plays and the use of video clips in which critical situations are discussed. The training for second year tutors is a combination of the tutor's role and project content, the planning, and the assessment procedures as well.

THE ROLE OF THE TUTOR IN DBL AT THE MECHANICAL ENGINEERING DEPARTMENT

The student and project guidance in DBL involves different actors. The project co-ordinator, who is the project owner, watches over the learning outcomes of the group. For every year, there is a year co-ordinator. The mission of the year co-ordinator is to assure that there is alignment among projects.

The tutor has two primary tasks in DBL. Firstly, the responsibility of the tutor is to assure that the learning outcomes of the specific project as subset of the overall learning outcomes are achieved. They also have to guarantee the coordination among project co-ordinators, to arrange tutor meetings and to solve problems with individual students and groups. Secondly, the tutor has a specific task as an assessor. The tutor holds the 'assessor hat' for the individual assessment grades. This role is shared with the project co-ordinator who, eventually, grades the final product.

In addition to this, the tutor holds different roles during the three years of the Bachelor's program. The following tutor's roles can be defined:

- The facilitator role: the tutor is responsible for facilitating the learning process and assuring that it flows as expected. As a mentor, (s)he also coaches students in the new academic environment. The tutor supports the group to reach a goal, to learn to work in teams and to help solve all problems encountered in the process so that the project outcomes can successfully be achieved. Encouraging communication during the process and creating a learning and reflective culture are some of the tasks of the facilitator.
- The expert role: the tutor provides content input where needed by asking motivating and challenging questions and by showing the students where they might find relevant literature.
- The project-manager role: the tutor guides individual students and provides subject-matter input upon request of the students.

In the first year, the role of the tutor takes a more process-oriented character since the complexity and the level of difficulties of projects in the first years demands less content input (Figure 3). To learn how to design, students work on parts of the design cycle, namely, analyzing, modeling or testing and they apply different basic skills in the skill trainings. The tutor, as a facilitator, supports students in the reflection of the application of knowledge into practical schemes. The tutors for the first year are the experienced (senior) tutors or Ph.D. students who themselves have studied following the DBL methodology. They are, therefore, acquainted with the DBL method, with the "ins-and-outs" of group problems, processes and assessment procedures.

It is also important to clarify that the tutor's role as a mentor must be seen as completely separated from the tutor's role in DBL since the mentor tasks are related to the supervision and guidance in the study progress of the student. These tasks, therefore, must be regarded as belonging outside the boundaries of Design-based Learning.

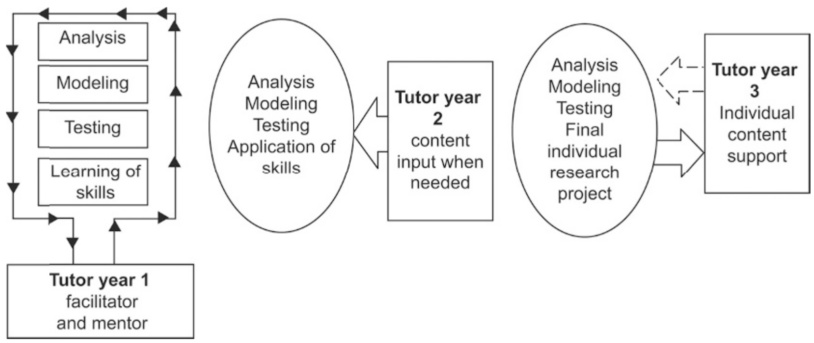

Figure 3. The tutor's role changes from facilitator and mentor to content expert and to project manager.

In the second year, however, due to the high demand in subject matter expertise, the tutor holds 'an expert hat' (Figure 3). In the project period students have to combine the competencies that they have learned during the first year together with the expected learning outcomes determined for the second year. It requires a high level of application of both knowledge and skills. The different design steps are combined in one project and the skills learned during the first year can be applied. The tutor motivates students to contribute critically by asking questions. Furthermore, the tutor provides formative and summative input on the competences of the students related to the subject (i.e. analytical and critical skills; inventiveness; theoretical knowledge and practical skills) as well as to the process competences (i.e. role of group members) according to agreed upon criteria. During the second year, the character of the DBL project requires domain expertise from the tutors. Therefore, the tutors are those working in the same research group as the project coordinator. The tutors are normally Ph.D. students, post-docs, research assistants, and Master students who are specialized in the topic of the given DBL project.

However, during the third year of the Bachelor's program, the tutor and the project co-ordinator are the same person and essentially perform the role of a project manager. DBL takes the form of a self-directed research project; the student has to apply to 'real-life' cases the analysis, modelling and testing phases in the design of a product. The student approaches the tutor whenever guidance is necessary. The tutor still holds the content expert role when requested but (s)he is not any longer the facilitator of the learning process because by now, the student has already become a self- directed learner. (Figure 3).

THE ASSESSMENT PROCESS IN DESIGN-BASED LEARNING: INDIVIDUAL ASSESSMENT, GROUP ASSESSMENT AND PEER ASSESSMENT

The assessment process in DBL and within the context of Mechanical Engineering is carried out by three different types of actors (i.e. the project co-ordinator, the tutor and the students), with the use of three different assessment instruments (i.e. group reports, individual assessment done by the tutor, and peer assessment). Fifty percent of the overall grade consists of the deliverables (the same grade for all of the group members); 25% consists of the tutor assessment individually on students, and 25% of the score is based on peer assessment. The group grades are given by the project co-ordinator and an individual grade is given by the tutor.

However, it was identified in the context of Mechanical Engineering that it is almost unfeasible for a tutor to assess a student just by what (s)he shows during the DBL meetings. To solve this assessment problem, a digital learning environment was created in which students have to post their self-study outcomes. With this e-tool the tutor is able to gain an overview of the students' contributions and judge the input and results of the individual students. One of the tasks of the tutor is to evaluate the group during the meetings. The tutor provides feedback at the end of the meetings. The feedback centers around both the group process (first Bachelor's year) as well as the subject matter (second Bachelor's year) while working on the cases, and the individual contribution that every student provides.

The tutor assessment focuses on *subject-related skills* such as analytical ability; inventiveness; critical ability; theoretical knowledge; practical skills (Handout Peer Review, 2003). But there is also a focus on *group-related aspects*, namely, the role as the discussion leader; the role as minute's secretary; the role as summarizer; the role as representative; and, the role as member of the group (Figure 4).

Blok F	**Meeting**										**Assessment on a scale of 1 to 5; only rounded up marks**
Meeting	1	2	3	4	5	6	7	8	9	10	
Date											
Name											
Contribution (Con)	(Self-study presentation and posted work on studyweb)										**Observations**
Group member (GM)	(Analytical, Inventive, Critical, Theoretical, Practical, X = absent with notice; XX = absent without notice)										
0											
0											
Group function (GF)	(Se = Secretary, C = Chairman, Su = Summarizer)										**Role order**
0											
0											
	1	2	3	4	5	6	7	8	9	10	
	Meeting										

Figure 4. Assessment form used at the Mechanical Engineering Department.

In 2001, peer review was introduced within the DBL assessment set-up by which a part of the individual grade is given by the students to each other. This was introduced as a respond to students' complaints about 'free-riders' within the group work (Visschers-Pleijers, Mulders & van der Wouw, 2001).

In the first year the students get a peer review training by the International Relations Office (STU) where they learn how to agree on assessment criteria, how to give constructive feedback and how to come up with an accurate grade. This student assessment is done by peer review and it accounts for 25 percent of the individual grade in the first year. In the second year, peer review accounts for 50 percent of the individual assessment. The three parts of the final grade are assessed by different parties, namely, the project co-ordinator, the tutor and the peer assessment system. In order to pass the DBL-project, the grading of all three parties must be passed successfully. It is the task of the tutor to guide the peer review process, to create an open discussion about the collaboration in the group and to give constructive feedback to each of the group members not only after every meeting but also during the assessment procedure.

The peer assessment procedure is as follows: during the first meeting students agree the criteria on which they will be assessing each other (see Figure 5). Before the last meeting takes place, students are requested at home to assign --,-, +, ++ (Handout Peer Review, 2003) to themselves and to each other. By doing so, they are able to think carefully about the assessment criteria they would like to use.

Afterwards, all the review forms of the students are combined and are followed by discussions. Students are thus requested to not only give feedback but also to justify their judgments with well-supported arguments. Finally, the students come to a final grade. It is the tutor's task to guide this process and to make sure that every student is heard and that the feedback round is done properly.

The key element of providing feedback becomes of extreme importance. The rationale behind providing constructive and formative feedback is to create reinforcement and positive influence in the student behaviour. By using assessment to inform students on progress, input is provided for the improvement of both products and processes. It is crucial, as well, that the students are aware and fully informed about the content and form of the assessment procedures.

THE IMPLICIT META-COGNITIVE ROLE OF THE TUTOR

The DBL methodology applied by the Mechanical Engineering department accompanied by the different roles of the tutor in different moments has a clear objective to stimulate student learning. In this sense, the role of the tutor has another dimension when it comes to supporting students in learning to learn.

One of the primary tasks of the tutor is to guide and facilitate the process of learning by students by supporting them to integrate and apply the findings and information (Moust & Schmidt, 1994). Encouraging communication during the process and creating a learning and reflective culture are some of the tasks of the facilitator. The type of active learning strategies to support meta-cognitive processes are ample ranging from team working, self-study discussions, oral presentations, group-based concept map building, among others, which promote communication among peers and reflection on one's own experiences (Pascual & Uribe, 2006). The commonly use of guiding the students in this inquiry process and giving them the opportunity to re-orient themselves is by asking probing questions with the overall goal of challenging the students. Reflection techniques are mainly based on questions or 'nondirective comments' (Barrows, 1985; in Moust, 2000), such as *"What do you think yourself about it? Why do you think that it is fine like this?*; Or, "*does anybody have another opinion about it?"* using suitable examples, or by confronting students with situations by playing the role of a devil's advocate (Moust & Schmidt, 1994).

The underlying process factor engaged to the tutor's role in the first year at the Mechanical Engineering department is that the tutor acts as catalyst of activating the learning environment in which the students need to produce knowledge. In this sense, their ability to use facilitation skills is a major feature in the quality of problem-based learning (Barrows, 1988, in Moust & Schmidt, 1994). In doing so, the tutor in the first year uses, as a facilitator, the Experiential Learning Cycle by David Kolb (Reese & Walkers, 2006) in an implicit manner. The experiential learning cycle is based on a four-step spiral (Figure 6) to help learners gaining insights into the learning process by reflecting on the four steps: experiencing, reflecting, generalizing and applying. The formula used by the tutor centers around asking questions to help student walking the learning cycle to motivate their arguments instead of providing themselves the answers. The tutor might not follow the cycle in its original structure, since (s)he uses it in an adapted manner that supports students to learn. One of the ways to use it is that the tutor might go in several small loops and a number of times during group meetings. Students are supported to acquire self-directed skills since students learn how to analyze learning processes against learning outcomes; identify missing points and understand better concepts and topics; and, reflect on the processes in solving problems. By asking questions, the tutor helps students to walk around the four phases. Likewise, the tutor facilitates the process of thinking about the problem statement, how the students can demonstrate that they have achieved the learning outcomes, but also how they have learned and what they have learned during this process.

The tutor in the second year safeguards that the knowledge of the topic is properly applied throughout the different phases of the project. Using the learning cycle, the tutor adapts this model to inquire and assess how progress is being achieved. The reached results become the priority of the tutor. Within the experiential learning cycle, students operate more independently in the 'experiencing' and 'applying' parts whereas the expert tutor provides content support in the 'reflecting' and 'conceptualizing' parts of the cycle. In the third year, however, the student has already become a self-independent learner, and (s)he is able to use the experiential learning cycle implicitly.

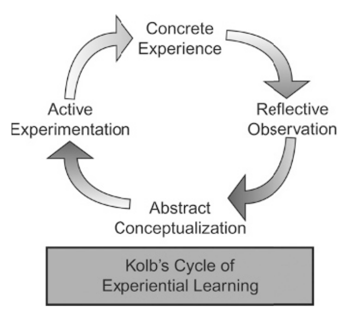

Figure 5. Experiential Learning Cycle (David Kolb) http://serc.carleton.edu/introgeo/enviroprojects/what.html.

The Experiential Learning Cycle provides a suitable platform to support learners to go through the experiences while undertaking the different steps of the design-based process in group work. This model, accompanied by the character of the seven step approach, helps the students to go implicitly around the process of setting goals, selecting the appropriate strategy among a variety of possible choices; carrying out the planned scheme, and analyzing afterwards how the results of the implemented scheme turned out.

This also brings consequences for the need to design tailor-made training for the tutors depending to the different levels of involvement either as a facilitator of the learning process, as a content expert and/or as an assessor. It is also important that students are aware of the changes within the tutors' role.

THE DILEMMAS OF THE ROLES OF THE TUTOR IN DBL

Although the role of the tutor is essential in DBL and it has been adapted to the Mechanical Engineering department there are a number of dilemmas that come up from the current implementation. A number of shortcomings can be identified: the recruitment of suitable tutors; the motivation of tutors together with the time they have to spend in each group; the financial constraints; as well as the low quality in students' report writing (achievement of learning outcomes) are some of the drawbacks encountered. These deficiencies can undermine the role the tutor has within the groups. The role of the tutor is at stake and, therefore, deserves serious considerations.

Experience shows that it becomes difficult to find suitable tutors for the first and second year of the Bachelors' program. The supervision of the DBL groups is regarded sometimes as a burden rather than a motivating issue. Therefore, the option of selecting Master students to hold the tutor's role has been introduced with the overall idea of surmounting the motivation problem.

First of all, experiences with Master students for the first year have been positive according to students' surveys from the Mechanical Engineering department. However, introducing Master students brings about a two-fold type of consequences: firstly, there are financial implications of making such a decision (the students' salaries have to be paid). The same holds for some of the Ph.D. students who are not faculty staff members but researchers employed by an external research institution. They are volunteers and don't have educational obligations as tutors. The management of the Mechanical Engineering department has to decide whether they are able to get this financial burden on its shoulders while for the faculty staff members the tutor tasks are part of their routine job.

Secondly, the introduction of 'less experienced tutors' can damage the image and credibility of the tutorship. To try to engage Master students as tutors may have a dangerous boomerang effect. The need to introduce a more academic seniority into the tutorship becomes an issue which demands careful attention. Considerations on selecting tutors who act as well as subject-matter specialist in the first year in combination with their process expertise can give an added value to the tutorship and, consequently, can be regarded as an input to the students' learning process. This will help to elude wrong interpretations on whether DBL could be considered a less important subject than a regular course.

There are other types of considerations, however, supporting the idea of having students as tutors in DBL group work. According to Schmidt, van der Arend, Kokx & Boon (1995), the tutors' contribution depends to a great extend on the type of obstacles that students find while working in groups in problem-solving processes. Teachers avoid performing another role rather than the traditional one of teaching. The traditional teaching in the form of lecturing, however, does not match with the problem-based approach since the latter emphasizes having students actively involved in seeking information to solve problems. In this sense, the alternative to academic staff fulfilling the role of the tutor is to use students who themselves have experienced problem-based learning. They are, likewise, more sensitive to the groups' needs in terms of guidance, information and support.

There is substantial literature on the impact on students' results in problem-based learning by having involved staff tutors or student tutors. Results on student's achievement in problem-based learning show benefits of using staff tutors (Schmidt et al, 1993b, in Moust & Schmidt, 1994). However, though the literature shows that problem-based learning is a staff-intensive approach (Moust & Schmidt, 1994) there are also arguments to support that group work guided by student tutors can be as valuable as the staff members, (i.e. student tutors compensate for the lack of content knowledge by giving more attention to learning difficulties of small-group tutorials, group motivation, and group dynamics). First of all, the learning environment and prior knowledge play a crucial role in the students' learning process. Lack of prior knowledge does not provide the necessary structure to the students, and, as a consequence, they tend to go back to the tutor looking for clear guidance. In this case, the students who are guided by subject-matter experts may benefit to a greater extent than those students who have a student tutor (Moust & Schmidt, 1994).

Although all factors mentioned above do not specifically represent the situation at the Mechanical Engineering department, there are, however, similar aspects such as the constraints identified in reporting requirements. This deficiency has been mainly identified in the students' reports of first and second year students. By reinforcing the role of the tutor and more specifically by providing him with responsibilities to supervise the project reports beforehand some of the challenges of the tutor's role will be surmounted.

CONCLUSIONS AND DISCUSSION

The innovation of Design Based Learning at the TU/e has been, and still is, a complex process. DBL, related to Problem-based Learning as well as to Project-based Learning, has been implemented in various ways, adapted to the needs and context of the various programmes. Part of this diversification is obviously due to the differences in the phase of development of the various programs. A new program (or even a new university, as was the case of PBL in Maastricht) gives much more opportunities for an innovative program than a programme with a long tradition. Part of it is due to the differences in the need to change as felt by staff and management.

Within the innovation process in which DBL is embarked, nowadays, a more demanding engineering profile is being fostered at the Mechanical Engineering department. This profile is contributing to model the future engineers from whom it is not only expected to have knowledge but also other type of process competencies such as among others problem solving, innovation, cooperation and communication (Du & Kolmos, 2006, and Meijers, van Overveld & Perrenet, 2005). Within this framework, the DBL as an educational concept is supporting this profile. The tutor plays a crucial role in this scenario, as a facilitator of the learning process, as a content expert, and/or as an assessor.

However, there are still some drawbacks in the current tutorship system at the Mechanical Engineering department. Some of the challenges are summed up as follows: 'motivation' is one of the fundamental problems that tutors are confronted with; as well as, the low quality in the achievement of some learning outcomes (i.e. students' quality in report writing).

Reasons to come across with unmotivated tutors, especially in the first year (and less in the second one), are:

1. First year tutors are less involved in the subject that is given in the projects.
2. There is a lower level of collaboration between the tutors and the project co-ordinator. A consequence is that the learning outcomes of the specific project are not always as clear as expected.

The problem of unmotivated tutors has a direct link with the relation between the tutors and the project co-ordinators. It deserves major attention. The tutors' role in the first year will need to get reinforced. Reinforcement in this sense includes that the tutors get more responsibility in the supervision of the learning outcomes. Both the tutor and the project co-ordinator need to define more clearly define the tasks giving structure to the tutor's profile and criteria.

The immediate effect of having such a problem is that it becomes difficult to find suitable tutors. The positive and the negative aspects of the temporary solution of selecting Master students to hold the tutor's role have already been discussed in this paper. The risk of implementing such a solution is that the DBL projects can be regarded as less important parts of the curriculum than other courses. Furthermore, due to the general character of the projects in the first year, there are no research groups specialized in the first-year topics. The tutor's responsibilities are linked to the nature of the project which in this case is to be framed more in the process than in the content.

Moreover, to underline this process-orientation task and give an extra value to the relation with the project co-ordinator it would be essential to increase the collaboration between the co-ordinator and the tutor so that the tutor holds a more relevant and well-defined specific function. In this sense, both the tutor and the project co-ordinator become a team. The latest also holds for the improvement of the relation of these two actors in the second year. However, in the second year the projects are linked to a research group and, therefore, the tutors are automatically more involved in the assessment process.

With regard to the second constraint, there are a variety of aspects which play a major role when it comes to meeting the standard requirement criteria for the students' reports. One of the main issues is that project co-ordinators find it difficult to give low grades. Reasons are to be found in that the assessment of projects focuses on content and less on presentation. Besides, and due to the fact that the final grade is a group's grade, the belief is that the good students efforts count for the whole group when it comes to the group mark. Furthermore, experience learns that the requirements for a 'good report' are not always clear to the students.

At this moment, there are, however, some possibilities to make a step forward in the improvement of these shortcomings. The underlying effect is to emphasize collaboration among project co-ordinators to set clear criteria and norms for the definition of the expected quality in the reports as well as to identify the crucial phases in report presentation in the curriculum. There are, likewise, other types of implications. Tutors need to become stricter when it comes to the assessment of the reports just as the project co-ordinators have to do. To do so, the tutors will have to widen their role and gain more responsibilities within their tasks so that they will be able to provide feedback and advice on the structure on report pitfalls to the students. By doing so, the students gain a chance to improve the assessment.

Despite the fact that there are still some challenges to surmount with regards to the improvement of the role of the tutor in DBL, it is also worth mentioning that thanks to the tutor, students get a better grip of the application of knowledge through design-based learning projects. DBL has enhanced quality of education and has brought cohesion between education and research. Design-based learning as a model has enriched the educational programs at TU/e, although during the coming period attention will be paid to create a balance in the role of the tutor within this educational model.

NOTE

[1] The exception is the curriculum of Knowledge Engineering. Because of its science characteristics, the project-based approach was preferred

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AFFILIATIONS

Sonia M. Gómez Puente
Teacher Trainer and Educational Advisor, Education and Training Department
TU/e Eindhoven University of Technology, The Netherlands

Corinne J. M. Jongeneelen
Education Co-ordinator, Mechanical Engineering Department,
TU/e Eindhoven University of Technology, The Netherlands

Jacob C. Perrenet
Educational Researcher
Eindhoven School of Education, The Netherlands

JORDI SEGALÀS

7. THE EPS EXPERIENCE AT UPC-BARCELONA TECH

THE EUROPEAN PROJECT SEMESTER

The EPS was not an original idea. It was first developed in Denmark at the Copenhagen University of Engineering in the Industrial Design field. The main reason why we choose to implement the programme at UPC is that it was a new international programme adapted to the European Higher Education Area which was just being implemented in Spain at that time. Moreover it was suitable for last-year engineering students, who were the main target of our international mobility programmes.

Nowadays EPS is working at a European level and 10 universities are running an EPS programme (see Table 6). These universities cooperate with the aim of further improving and expanding the EPS experience. This collaboration has also contributed to building up the EPSEVG's international relations.

Table 6. EPS providers in 2010

University	*Country*
Artesis University College Antwerp	Belgium
Copenhagen University of Engineering	Denmark
Ecole Nationale d'Ingénieurs Tarbes	France
Kiel University of Applied Sciences	Germany
Novia University of Applied Science	Finland
Oslo University College of Engineering	Norway
Polytechnic University of Valencia	Spain
School of Engineering of Vilanova i la Geltrú	Spain
Technical University of Lodz	Poland
University of Applied Sciences of Avans Hogeschool	the Netherlands

The main characteristics of the EPS programme perfectly fitted the initial motivation of implementing the programme at UPC. It is an international programme that uses English as the working language. It enables students from different countries and nationalities to work together in a common project, thus promoting multicultural values. Additionally it is multidisciplinary since it enables students from different engineering backgrounds to work together in a common project. This feature perfectly matched the background of the EPSEVG which offers studies in different engineering disciplines. Finally it is an intensive one-

L.C. de Campos, E.A.T. Dirani, A.L. Manrique and N. van Hattum-Janssen (Eds.), Project Approaches to Learning in Engineering Education: The Practice of Teamwork, 109–124.

semester programme worth 30 ECTS, which is a perfect scheme for mobility purposes. Only one of the characteristics of the EPS, to address the real needs of companies, did not fit the initial motivation of implementing the programme at the EPSEVG. Although fulfilling this characteristic would indeed require an additional effort, we did not perceive it as obstacle to our purposes.

The scheme of the EPS programme comprises two complementary parts and the distribution of the 30 ECTS among these two parts varies between the different EPS providers:

A project: during the semester and under the guidance of an academic tutor, an international team of four to six students works on a real-life multidisciplinary project for a Spanish or an international company. The work teams are made up of students with different academic backgrounds from all over Europe. Individual and group tutorials will be offered during the semester.

Intensive seminars: a short intensive programme with practical workshops about topics related to project management will also be offered to enhance the work related to the project. These complementary workshops will also help students develop their communication and cooperation skills.

UPC-Barcelona Tech and the School of Engineering of Vilanova i la Geltrú

UPC-Barcelona Tech (UPC) is a Spanish public institution dedicated to higher education and research that is specialised in the fields of architecture, science and engineering. The School of Engineering of Vilanova i la Geltrú (EPSEVG) is one of UPC's 17th schools of engineering and it is located 40 km to the south of Barcelona. The EPSEVG is a medium size school with 1100 students, 250 faculty members and 17 departments.

The EPSEVG traditionally offered a multidisciplinary range of degrees that provided the perfect setting for a real multidisciplinary EPS program. The school offered a set of six Bachelor degrees (Mechanical engineering, Industrial Design and Product Management Engineering, Electric Engineering, Electronic Engineering, Telecommunications Engineering, and Computer Science Engineering) and one Master degree (Master Degree on Electronics and Industrial Automatics).

In order to be able to offer this wide range of disciplines in engineering, the EPSEVG hosted a quite big number of departments: 17. However interdepartmental cooperation was not usual and had not been promoted until that moment. Therefore the EPS meant an opportunity of taking advantage of the number of departments hosted by the school to encourage the multidisciplinary approach. But at the same time it was also a challenge to promote multidisciplinarity as a result of the collaboration between departments.

Besides the interdepartamental collaboration, another issue had to be addressed in order to guarantee the success of EPS. The Project Based Learning (PBL) curriculum structure had not been used at the EPSEVG until EPS was implemented at the school.

The EPSEVG had already experience with student international mobility and had participated in European mobility programmes since they were first started. The new Board of Directors appointed in 2008 made a real commitment for the internationalisation of the EPSEVG and was determined to engage in increasing mobility participation, both by faculty members and students, and also to improve the integration of the mobility scheme in the study programmes offered by the school.. The engagement of the EPSEVG Board of Directors and the support of UPC central Board of Governors was a crucial factor for the EPS success at UPC.

THE EPS AT THE SCHOOL OF ENGINEERING OF VILANOVA I LA GELTRÚ, THE SUSTAINABILITY FOCUS

Although the EPS was not an original idea, we decided to give the EPS in Vilanova i la Geltrú a distinctive focus which would differentiate it from the rest of programmes running around Europe. This is why from the beginning, the EPSEVG's EPS programme was enriched with a sustainability focus which fulfilled another of the commitments of the recently appointed Board of Directors.

Sustainability complies with the needs of the society of the XXI century:

> Society needs scientists, engineers, managers and politicians who can shape the systems of our society in a way that sustains rather than degrades the natural environment and enhances human health and well-being (Mulder *et al.* 2008).

There are many documents referring to the competences on sustainability that students should have when graduating in higher education institutions. On the field of engineering, the Barcelona Declaration (2004) approved during the celebration of the EESD Conference in 2004 is a reference document and it declares that today's engineers must be able to:

- Understand how their work interacts with society and the environment, locally and globally, in order to identify potential challenges, risks and impacts.
- Understand the contribution of their work in different cultural, social and political contexts and take those differences into account.
- Work in multidisciplinary teams, in order to adapt current technology to the demands imposed by sustainable lifestyles, resource efficiency, pollution prevention and waste management.
- Apply a holistic and systemic approach to solving problems and the ability to move beyond the tradition of breaking reality down into disconnected parts.
- Participate actively in the discussion and definition of economic, social and technological policies, to help redirect society towards more sustainable development.
- Apply professional knowledge according to deontological principles and universal values and ethics.
- Listen closely to the demands of citizens and other stakeholders and let them have a say in the development of new technologies and infrastructures.

In order to help EPS students to acquire these extra competences related to Sustainability, two seminars have been added in the short intensive seminar programme: Sustainable Technology and Sustainable Businesses. It is also ensured that the sustainability focus is introduced at all the EPS projects.

Despite this slight adjustment of the EPS programme to ensure the sustainability competences of students, the EPS philosophy and structure at UPC is maintained the same as the original.

THE EPS STRUCTURE AT UPC

Besides applying Project Based Learning (PBL) and the multidisciplinary approach, EPS added two new components to the curriculum structure of the EPSEVG: teaching technological courses in English and the intercultural factor.

At the EPSEVG, the 30 ECTS of the EPS programme are distributed in the following way: the intensive seminars have a load of 10 ECTS and the project work has a load of 20 ECTS. The intensive seminars are listed in Table 7.

Table 7. Intensive seminars offered at the EPSEVG

Competences	***ECTS***	***Seminar***	***ECTS***
Communication	4	English Communication Skills	2
		Spanish Language	2
European Law and Market	1	International Marketing	1
Project Management	2.5	Project Management	1
		Teambuilding	1
		Systemic Innovation	0,5
Sustainability	2.5	Human Technology	0.5
		Sustainability and Business	1
		Sustainable Technology	1

The projects developed within the EPS programme are real projects proposed by companies of the region. The project proposals from the companies have to accomplish the next criteria:

- Multidisciplinarity: a project in which a variety of fields of engineering and also business knowledge abilities and skills need to be applied. Complexity: a project feasible to be done by last year Bachelor students.
- Difficulty: a project which can be done in 12 weeks.
- Supervisor: the Company has to provide a supervisor and facilitate all the information needed to perform the project in English.

At the EPSEVG, the EPS schedule is divided in three parts (figure 1). During the first four weeks, the intensive seminars are taught in the mornings. Afternoons are kept free in order to allow students to work the contents of the seminars further, to get familiar with the projects which are to be developed and also to begin applying the competences they are acquiring to the projects they will work on more intensively afterwards. During this initial period, students also have the opportunity of knowing each other and to acquaint with the EPS companions.

The second part is the main part in which the project is developed. It lasts 12 weeks. During this period, the English and Spanish communication seminars keep going on and the supervisors follow closely the development of the projects and of the teams of students. In the middle of this period (week 10 of the whole programme), students have an interim presentation of the work they have done so far and they need to deliver a report of the project development and the planning for the next 6 weeks.

Finally, the last week of the semester is devoted to the assessment of the project. During this week students deliver the final results of the project with the final report. They also deliver a scientific paper, a poster and a PowerPoint presentation of the project and they have to defend the project in front of the evaluation committee.

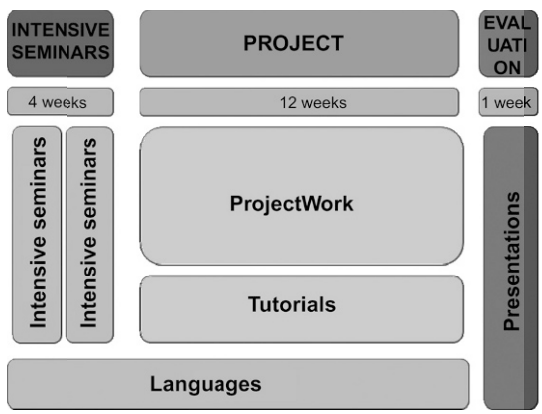

Figure 16. Structure of the EPS programme.

As already mentioned, offering the EPS at the EPSEVG entailed many challenges. The most important were to apply project based learning, to break the highly-instituted monodisciplinary culture and to run seminars in English.

First of all we needed to know in-depth what was EPS and how we should overcome the organising challenges that we were going to face. To do so we visited two of the providers who already offered the EPS programme who shared with us the process of introducing the EPS into their universities.

Once we knew exactly what EPS implied from the organising point of view, the next step was to convince the whole EPSEVG community of the importance of running such a program: international visibility, upgrading the learning of our students, increasing the international exchange possibilities, introducing project based learning etc. To do so, we started a participatory process with all the stakeholders involved in the program, asking them how they would valued the EPS in the EPSEVG and which was the best way to organise it within our organisation.

These participatory meetings were very important, because they allowed that most of the community feels like being part of the programme and was not a top-down approach which sometimes creates resistance among some faculty. To give visibility to the programme and increase the community participation we organised the EPS annual providers meeting at Vilanova the year before we started the program, inviting also the regional business association of Vilanova so they knew the programme and facilitate the process of looking for projects in companies. The providers meeting takes place every year to a new provider university of the EPS program.

Once EPS was accepted by everybody as an excellent educational program, some more practical aspects had to be solved. The first one was to introduce the PBL culture in the school. To facilitate this process we organised some training courses for faculty in PBL in international settings: "Project Based Learning: Management of groups" and "Teambuilding for supervisors". We also organised a course about how to teach technological courses in English "English for university lecturers: teaching content through English". These training courses were highly appreciated by faculty and had a high participation rate.

Finally, in order to introduce the multidisciplinary culture essential to embed the EPS among faculty, two supervisors from different departments were assigned to each group of students. This way faculty from different departments were forced to collaborate in the same project.

A crucial aspect of the EPS is teambuilding. In order to ensure the success of our EPS program, teambuilding strategies were applied to all the actors involved in the program. There are many teambuilding strategies, but we cannot say that some are better than others. The effectiveness depends on the final goal of the strategy for example: motivating a team, teaching the team self-regulation strategies, helping participants to learn more about themselves (strengths and weaknesses), identifying and utilising the strengths of team members, improving team productivity, etc. All of these require different teambuilding strategies.

In consequence, we developed three different tailored teambuilding strategies for each group of actors.

The Group of Students

- Goal: their goal is clear: to perform a real project for a company.
- Problems: they don't know each other; they have different academic backgrounds, and different nationalities therefore they also have different cultural backgrounds.
- Teambuilding goals: To train students to work in groups, to solve communication problems, to build trust among the members of the team and to identify their individual natural behavioural tendencies in a team context.
- Strategy: Students took a teambuilding course where they analyzed models of team behaviour, developed team communication skills and applied group bonding sessions. Additionally, several social activities were organised.

Faculty and Company Supervisors

- Goal: their goal is to guide the students in the learning process during the performance of the project and to assure a successful working atmosphere.
- Problems: The faculty may lack experience in supervising students in multidisciplinary frameworks. EPS is process-oriented however the faculty is more experienced in assessing products.
- Teambuilding goals: to motivate faculty; to build up an effective collaboration between them, with the coordinator of the programme and the students. Moreover they need training in teambuilding strategies to supervise the students more effectively.
- Strategy: Training courses in teambuilding strategies in international frameworks and in assessing the project process.

Administrative Staff

- Goal: their goal is not so specific: to facilitate to students and teachers the necessary administrative infrastructure for a successful EPS program.
- Problems: Lack of a cooperation culture between different administrative departments such as the international office, the career centre, the academic administration unit, etc. Lack of motivation as the new programme was perceived as extra work.
- Team building goal: To motivate the staff and to build up an effective collaboration between them.
- Strategy: To highlight the importance of their role in the programme and the importance of the programme for the organisation; to organise social activities and to involve them in all the extra-academic activities organised within the program.

EPS ASSESSMENT

The programme encompasses three differentiated assessments depending on the target: Students learning, teachers and supervisors and, the overall. Next sections highlight the assessment processes applied and the results of the two years that EPS have been run.

STUDENTS LEARNING ASSESSMENT

The European Credit Transfer System

The European Credit Transfer System (ECTS) is a student-centred system based on the student workload required to achieve the objectives of a programme. Objectives are preferably specified in terms of the learning outcomes and the competences to be acquired.

The ECTS was introduced in 1989 within the framework of Erasmus, which is now part of the Socrates programme. The system facilitated the recognition of periods of study abroad and thus enhanced the quality and volume of student mobility in Europe.

The ECTS makes it easy for all students, both local and foreign, to understand and compare study programmes. The ECTS facilitates mobility and academic recognition.

The ECTS is based on the principle that the workload of a full-time student during one academic year is equal to 60 credits. The workload of a full-time study programme in Europe amounts, in most cases, to around 1500-1800 hours per year. Therefore, one credit represents around 25 to 30 working hours.

ECTS credits can only be obtained on successful completion of the required work and after appropriate assessment of the learning outcomes achieved. Learning outcomes are sets of competences, expressing what the student will know, understand or be able to do after completion of a process of learning, whether it is long or short.

Student workload in the ECTS consists of the time required to complete all planned learning activities such as attending lectures, seminars, independent and private study, preparation of projects, examinations, and so forth.

The ECTS grading scale ranks the students on a statistical basis. Therefore, statistical data on student performance is a prerequisite for applying the ECTS grading system. Grades are assigned among students with a pass grade as follows:

- A best 10%
- B next 25%
- C next 30%
- D next 25%
- E next 10%

A distinction is made between the grades FX and F that are used for unsuccessful students. FX means: “fail—some more work required to pass” and F means: “fail—considerable further work required”. The inclusion of failure rates in the Transcript of Records is optional.

Seminars Assessment

Assessment for the supporting seminars is undertaken by each course lecturer. Assessment is based on attendance, active contribution and the results of assignments, reports and presentations.

Interim Project Assessment

In week 10, students assess themselves and the members of their team and the groups deliver an interim report and present work undertaken up to this point. Every member of the group is responsible for the complete report and the presentation. The report should show the progress of the team and will be the basis for the final report. During the presentation, every member of the group presents part of the results of the group work.

The university supervisor discusses the progress of the project based on:
The interim report

- The report
- The presentation
- The progress reports
- The peer assessments

Project Assessment

Assessment marks are derived from the following sources:

- Supervisors and external examiners who observe team/student conduct and progress and examine the documentation submitted.
- Student oral presentations.
- Student teams who are asked to create an individual weighting factor (WF) to reflect the workload of each member of the team during the project. The 100 point distribution is decided on unanimously.
- An evaluation of student participation in the courses. This is based on deliberation and discussion with the course lecturer, on attendance and on course exercises.

The final overall mark is agreed by a moderating panel made up of all people involved in the project. The focus is on the people involved (the students), the product produced (the documentation submitted for the report etc.) and the project process (the teamwork). Table 8 shows an overview of the aspects that are assessed and the people involved in the assessment process.

Table 8. Aspects Assessed and People Involved

Focus	*Aspect*	*Total mark*	*Supervisor*	*External examiner*	*Student*
Individual	Oral presentation	15 %	✔	✔	
Product	Professional content	35 %	✔	✔	
	Communication value	15 %	✔	✔	
Process	Teamwork	35 %	✔		✔

The marks for the individual oral presentation are awarded using similar criteria to those discussed above. In particular, consideration is given to style, structure and content together with an assessment of the degree of achievement in relation to the degree of difficulty of the project.

The group project report submitted takes into consideration the aspects summarised in Table 9:

Table 9. Aspects assessed of the project report

Heading	*Brief description*
Style	Overall quality of the presentation in terms of illustrations, format and general tidiness
Structure	Layout of the report: logical, concise and easy to follow
Content	Presence of all relevant information and lack of "padding"
Background	A clear introduction giving the reader a general grounding in the subject
Statement of objectives, discussion of results and achievements	A clear and precise statement of objectives, and a critical analysis of the achievements in comparison with the stated objectives
Conclusion and recommendations	A brief restatement of the conclusions, with recommendations for ways in which the project could progress or the results be implemented

It is difficult, but important, to follow up and assess the group process. During the course, teamwork is followed closely, to ensure that the students take advantage of working in a group. The difficulty lies in apportioning credit for work submitted by the team to individual team members. In an ideal situation, equal credit would be given to each member of the team. In practice, however, each member's contribution will vary both in quality and quantity. Therefore, a system of self and peer assessment and a system of distributing points among team members is used to apportion credit and to achieve a fair spread of marks. Compulsory weekly meetings are held between project groups and their supervisors. These meetings give the supervisors the opportunity to work closely with the teams. Minutes are made of all meetings, and a copy is kept in the group Log Book. Every month of the semester, the supervisors meet to discuss issues related to the project groups. The supervisor gives an overall teamwork grade/mark (TWL), using the headings and keywords, as shown in Table 10.

Table 10. Aspects assessed of the team work report

Heading	*Brief description*
Willingness to build upon ideas of others	Listening skills, loyalty, willingness to take on ideas, contribute ideas, interact with others, approach to the project
Understanding of the team process	Presence or absence of personal input and suggestions, contributions, participation in meetings, chairing a meeting, preparing a meeting, interdisciplinary coherence, conflict awareness, dealing with conflicts, action
Leadership at appropriate times	Problem awareness, implementation, initiative, attentiveness, ability to focus, recognising responsibility, evaluation of alternative strategies, selection of optimal actions
Positive attitude	Motivation, flexibility, operative, cooperative, collaborative, industrious, good attendance, acquisition of new knowledge
Initiative shown	Creativity, possibility, awareness, barriers, presence or absence of personal input and suggestions, activity

Moreover students peer and assess themselves through answering the seven questions 1–7 listed below, which are formally asked twice during the course, once at mid-term and again just before the final examination, and circling the numbers from 1 (lowest) to 5 (highest) that most accurately reflect their opinion of themselves and their peers.

1. Technical contribution to a main field (quality)
2. Technical contribution to a main field (quantity)
3. Willingness to build upon the ideas of others
4. Understanding of the team process
5. Leadership at appropriate times
6. Positive attitude
7. Initiative shown

In addition, each team member must be prepared to answer the following four questions in writing, both at mid-term and in the final group project report:

1. What was your specialist contribution to the completed product (the group report)?
2. What is your opinion of the work process you have been through and how did you contribute to it?
3. How did you contribute socially to the performance of the process?
4. What is your opinion of the completed work?

Final Project Examination Procedure

The final examination is held as a seminar with the following content:

1. Oral presentation of the written report
2. Discussion of professional specialist content of the report
3. Discussion of the precise communication value of the written report
4. Evaluation of teamwork (the project process)

The marks for various parts of the assessment are entered into a final examination sheet consisting of three tables (see next page). Comments regarding any particular heading could be noted, for example, on the back of the aforementioned examination sheet.

FACULTY ASSESSMENT

Faculty plays an important role in terms of students learning to work in projects and apply the required knowledge that each project requires. In order to assess and improve faculty teaching EPS-Vilanova uses the Students' Evaluation of Education Quality (SEEQ) questioner which was developed by Dr. Herbert Marsh (1993). The core features of SEEQ are the evaluation of eight characteristics of effective teaching using a five-point scale (strongly agree – agree – neutral - disagree - strongly disagree): Learning; Individual Rapport; Enthusiasm; Examinations; Organisation; Breadth; Group Interaction; Assignments

Each of these categories contains three or four questions. For example, the Learning category looks like this, with students responding on a five-point scale:

1. I found this course intellectually challenging and stimulating.
2. I learned something that I consider valuable.
3. My interest in the subject increased as a consequence of this course.
4. I learned and understood the subject materials of this course.

Two open-ended or narrative-response questions end the questionnaire:

1. Which characteristics of this instructor or course have been most valuable to your learning experience?
2. Which characteristics of this instructor or course are most important for him/her to improve (particularly aspects not covered in this form)?

SEEQ provides valid information on strengths, and it also helps faculty focus on opportunities for improvement so that they can set priorities and discover means to become more effective teachers.

PROGRAMME ASSESSMENT

The EPS programme as a whole learning activity is also assessed by the students. Students are asked about their opinion of the programme and to answer to a set of questions related to the programme in general, the seminars and the project (see Table 11).

A HISTORY OF SUCCESS

In February 2008 UPC started its first EPS. Nine students from six different nationalities (Austria, Finland, Germany, Romania, Spain and Turkey) and five different engineering specialities participated in the first edition of the programme. The students worked in three projects: "*Autonomous Meteorological Buoy*", "*Design and Layout of the Renewable Energy Equipment for the New Roof of EPSEVG*" and "*Autonomous Acoustic Buoy*" proposed by the university departments.

Student Name: Date:
Team No.:

	Oral presentation	Report	Report	Teamwork
Name	0. Individual	1. Prof. content	2. Com. value	Process perform
Supv.:	%	%	%	TW_L:
Exam.:	%	%	%	
Mark	%	%	%	TW:%

Table a.

TW_L in Table a. is a group teamwork mark, allotted to the team by the team supervisor. To apportion credit to each individual team member for their contribution, students are asked to distribute 100 points among themselves to produce a weighting factor (WF), as seen in Table 2. The individual teamwork mark TW, shown in Table a, is then calculated by equation 1 and transferred to table c below.

(1) $TW = TW_l \times WF$

Student name	Student's point distribution	Weighting factor: $WF_i = p_i/c$	Remarks
A	p_i		
B			
C			
D			
E			
F			
Average	$c = \frac{\Sigma_i^n p_i}{n}$		

Table b. Calculation of individual weighting factor (WF)

	Assessment	% from Table a	Final mark
0	Oral presentation, individual	x 0.15	%
1	Professional specialist content	x 0.35	%
2	Communication value	x 0.15	%
TW	Process performance	x 0.35	%
			Sum:%
			ECTS mark:

Table c.

Figure 17. Final Project examination sheet.

Table 11. Assessment of the EPS overall programme

General	
Structure of 4 weeks of seminars and 12 weeks of project	0 1 2 3 4 5
Guest lectures (such as the Teambuilding Course)	0 1 2 3 4 5
Coordination of the program	0 1 2 3 4 5
The information you received before your arrival	0 1 2 3 4 5
Support from the International Office regarding EPS	0 1 2 3 4 5
Intensive seminars	
Offered courses were helpful for the project	0 1 2 3 4 5
Quality of the provided material for the courses	0 1 2 3 4 5
Teaching staff was qualified enough	0 1 2 3 4 5
You have learned something valuable	0 1 2 3 4 5
Assessments of the courses	0 1 2 3 4 5
Project	0 1 2 3 4 5
The projects proposed by the company	0 1 2 3 4 5
Cooperation with the company	0 1 2 3 4 5
Support from the supervisors during the project	0 1 2 3 4 5
Accessibility of supervisors	0 1 2 3 4 5
End result of the project	

Since then the numbers of students, nationalities, students' background and projects has increased, as shown in the Figure 18

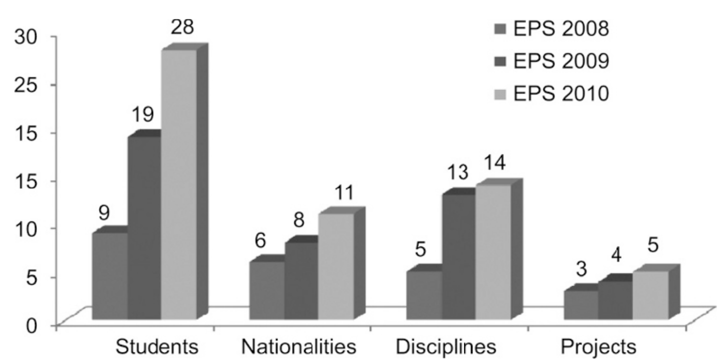

Figure 18. Evolution of EPS indicators.

The assessment of the programme shows that the learning achieved by students was excellent, as all the students who have participated in the EPS at the EPSEVG have successfully passed the EPS program. The faculty results from the SEEQ questionnaire are also very high in all the evaluated aspects (see Figure 19). More than 40 teachers have participated in the EPS either as teachers or supervisors during the first three editions of the programme.

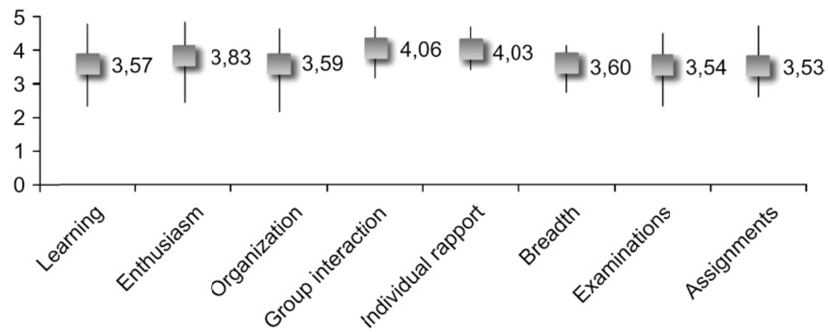

Figure 19. Assessment of teachers of the seminaries (0 Low – 5 High).

Most importantly the overall programme has always been very highly rated, and the comments from students have always been very positive. For example, these are the comments of three students that took the EPS in 2008:

> *Developing devices in an international team with different mother languages was really challenging. To communicate with team members or supervisors the specific terms had to be used and thus the range of special vocabulary increased significantly. Also, the varying kinds of mentality in the group or the Spanish way of working have been sources for in future helpful experiences. Things do not always have to be exactly on time or work perfectly. For students it is even more useful if they can learn because of the mistakes which were made. Summed up, the EPS for me was a great programme and will for sure help me in my future life. Student from Oulu University of Applied Sciences (Finland)*

> *From my point of view, I can only recommend everybody, who wants to taste a bit of the real working life, to take part in the EPS project, because it will be an unforgettable experience. Student from Fachhochschule Kiel of Applied Sciences (Germany)*

> *My overall impression of this semester is clearly positive. Teachers were always cooperative and communication in English was easy with everybody. Student from Fachhochschule Kiel (Germany)*

The Spanish Ministry for Higher Education started in 2009 to adapt the university degrees to the European Higher Education Area (EHEA), and we had to redesign all our programs. An example of the success of EPS is that it has been included in all the new bachelor programs that we are now offering in our school under the EHEA framework.

CONCLUSIONS

When we first designed EPS we were sure that this programme would be very valuable for our students in terms of learning to work in real projects, self-learning, to work in interdisciplinary frameworks, to work in intercultural teams, communication skills in English, etc., nevertheless organising such a programme in our school was really challenging taking into account the lack of previous experiences in this kind of Project Based Learning programs in English. However the results from the two years that EPS has been running and the high demand from international students in the current year reveal that EPS is very successful.

When organising such new programs it is crucial to involve all the actors (students, faculty, administrative staff, the university board and the business sector) from the very beginning of the designing process. This involvement helps everybody to understand the relevance of the program. It also adds high-quality inputs to the organisation of the programme and it facilitates its implementation.

Based on the experience from the EPS, the EPSEVG is currently planning to organise a new Design Project Semester that will start in fall semester of 2012.

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AFFILIATIONS

Jordi Segalàs
Associate Professor at the Research Institute for Sustainability Science and Technology
Universitat Politècnica de Catalunya UPC-Barcelona Tech Spain

JÚLIO BARREIROS MARTINS

8. PORTUGUESE VERSIONS OF PBL FOR ENGINEERING EDUCATION AT UNIVERSITY LEVEL

INTRODUCTION AND HISTORIC MARKS

Teaching and Learning is a Complex Process.

Teaching and learning in Engineering Education in Portuguese universities in the 1950-1959 was divided in two cycles. The first cycle included science subjects mainly: Mathematics, General Physics, General Chemistry, Chemical Analysis, Electricity and Electricity, Newtonian Mechanics, Mineralogy and Geology. Each subject had an annual duration and all the subjects were taught at the Sciences Faculty of the three universities of the Country under the name of 'Preparation for Engineering Courses'. Nearly all the contents were common to all branches of Engineering (Civil, Mechanical, Electrical, Chemical, etc). The teaching methods varied somewhat from subject to subject according to the teacher. Each subject had a head-teacher, a PhD senior professor, according to Law free to teach what he would understand to be the main part of the Science Branch involved. In his work the senior professor was supported by several junior PhD students. These, apart from supporting the Professor in the, Room Problems, lab and field works, etc., had to do research under supervision of the Professor. It was an Education of 'Magisterial' ('Napoleonic') type, teacher-centred. The teacher chooses, based on his own insights, the programmes of his subjects and the text books for the students. The main 'book' was a collection of notes made by some of the best students and copied by their colleagues. The professor gave his lectures in amphitheatres, writing on the blackboard, sometimes not looking at the students. Some other professors would give their lectures with open room doors. The students (or others) would enter the room at any time and could go out when they desired. However, the students had to attend the classes to solve problems, lab and field works. When the number of absences was greater than one third of the number foreseen and stated in the beginning of the scholar year for that type of students work, the student was excluded of the subject, and the student had to repeat the subject next year.

L.C. de Campos, E.A.T. Dirani, A.L. Manrique and N. van Hattum-Janssen (Eds.), Project Approaches to Learning in Engineering Education: The Practice of Teamwork, 125–146.

Assessment

After each lab or field work, done individually, each student had to write a report with justification of the results obtained. If the results were wrong and/or the report was not satisfactory for the teacher, the student failed and had to repeat the subject. The acceptance of the reports was a condition to be admitted to written examinations (only, students with a mark of 40%, or over, in the written examination could go to an oral examination in order to pass) at the end of each term (winter, spring and June). Having an average mark of about 70% (in the subject, in most cases) the student was not subject to a written and oral final examination. The lab and field works were graded and the concerning mark entered in the final mark. The final examinations were held in July and could be repeated in September/October for those who have failed in July. These criteria could vary from subject to subject, depending of the professor. E.g. university professors had pedagogical and scientific independence in the teaching of 'their' subjects.

The titles and summaries of the lab (and field) works to be done by the students were stamped in the beginning of the term, with indication of the basic books containing the theory and practice concerning the work. The books were, generally in Spanish, but also in French, English and German.

The students had no role in the departments, but in some subjects there were admitted as 'students workers', which could be absent in the rooms of practical work. However, they had to do the lab (and field) works and present the concerning reports. In this cycle of studies the subjects were related to 'Science' only, not to 'Engineering' and might, in some cases, have nothing with an engineering branch (Civil, Mechanical, etc.). So the subjects were common to science students (courses in Mathematics, Physics, Chemistry, etc.). Only, after passing these three years of Science Studies, the student could enter the Faculty of Engineering of the University (Oporto or Lisbon).

The First Cycle

In the first cycle of studies, there was no in some cases coordination between subjects. For example, the student might have to learn 'Electricity and Magnetism' in the Department of Physics, before having enough Mathematics in the Department of Mathematics. However, the student could not attend Mathematics II, without having passed Mathematics I, and that is understandable.

In the student's Lab works the role of the teacher in the lab was, in some cases. that of an 'inspector' only, not helping the student. Nevertheless, the teacher in the lab solved problems of lack of materials and failures of equipments. Therefore, the lab works were examinations, whose preparation each student had to do by himself (self learning). There was no group laboratory works.

The so called 'practical classes' in class rooms, were the solution of problems related to the theory taught at the 'magisterial' lectures by the professor. The role of the teacher in the class room was that of solving doubts of the students, during the solution of the proposed problems. The written examinations were directed towards ‘intelligence’ and not ‘memory’, except in subjects such has Mineralogy and Geology. In some cases, the students received beforehand the proposed problems to be solved in the next practical classes and so, they could try to solve the problems at home. Also, the teacher in class room called a good student to solve the problem in the black board, and usually,, in that case, there was questions and discussions between students and teacher. Out of the class rooms, some junior teachers accepted to receive students for correction of mistakes the students have in the solution of the proposed or other problems. Some professors did that also.

Looking for the whole method of teaching and learning in the first cycle of studies it can be said that was a mixed method not only centred at the teacher, but also in the student, since he must also learn by himself matters not taught by the teachers, reading text books in the Library, etc. .

In general, in the first cycle of studies teachers were Ph. D senior professors of Pure Science, knowing nothing of Engineering. For that reason, the curriculum plan of those three years was elaborated without taking account the Engineering Profession. So, later, when the students entered the Faculty of Engineering, some teachers of this Faculty, Professional Engineers, used to say that the Electricity the students had learned in the Faculty of Science ‘did not flow in the wires’…

The second cycle of studies, of thee years also, was performed in the Faculty of Engineering (Oporto or Lisbon, Coimbra had no Faculty of Engineering, by the time).

In the Faculty of Engineering there were 5 branches of Engineering: Civil, Mechanics, Electrical, Chemical and Mining. The main subjects in each course were specific of the corresponding Branch, but there were some ‘transverse’ subjects and some ‘humanities’, (Economics, Laws, etc.).

The Second Cycle

The teaching and learning method of the second cycle of studies was also of the mixed type centred at the teacher and at the student, but in a different way of that in the first cycle, since there were design and field works together with lab works. But there were ‘magisterial’ lectures for theory. The students had to search in the library books and papers with the fundaments of the equipment they have to use in the lab and in the field, or in the ‘design room’. Many times the students worked in groups in order to perform the lot of lab and field. The works were supervised by junior teachers who helped the students to solve difficulties, gave explanations on the functioning of the equipment and discuss results indicating error causes. During Easter Holidays, there were programmed study visits to works running near the town or further in the country. Sometimes the study visits were outside the country. A teacher always was in the team. The study visits were beforehand agreed with the entities concerned (Contractor, Public Department, or Private Enterprise, etc). At the time of the visit there was always a Contractor’s Engineer explaining the Design and showing features of execution. Students and the teacher asked questions about the design and execution and that was most useful for the learning act. The students were divided in groups and each group has to produce a report on the visit, with drawings, photos, and explanations. Sometimes some reports were further discussed in the classrooms

In each subject, there were also problems to solve, related to application of the theory

Traineeships

In the summer holidays in August and September, each student had to do a traineeship in a private enterprise, contractor, and public department. The traineeship was aimed at a specific subject, like Surveying, Roads, Bridges, Applied Hydraulics, etc.. At the beginning of the year, the student, with suggestions and help of the teachers, searched for entities able and accepting to give opportunity for a traineeship to an engineering student. The entity had to provide an engineer as a supervisor of the student during the traineeship. The object and work to be done by the student should be of interest for the entity giving the traineeship. The entity had to provide, equipments and materials for the execution of the work. In field work it had to provide unskilled manpower, when necessary. At the end of the work the student had to produce a report (or small design) to be handled to the Supervising Engineer and to the Faculty Teacher. The traineeship was classified by agreement of both, engineer and teacher. The mark of each traineeship entered with a good weight in the final mark of the student in its course.

At that time (1950-1970), there were no Master's courses in Portugal, since the beginner course was already of 6 years. This was in disagreement with what happened in other countries where the beginner courses in engineering were a 2 or 3 years Bachelors' Course. In Portugal, there were also Bachelors' courses, but they were given at Industrial and Commercial Institutes, not at Universities.

Imperial College

From 1960 to 1962 the author attended an MSc (Eng.) at Imperial College, University of London specialising in Soil Mechanics. It was a two years course with about 20 students, all, except one, foreigners. There were five teachers, one for each sub-subject. All of them were Full Professors and some Doctors in Science. There were no junior teachers. All the Professors, other than teaching and doing research, were Professionals, Consultants of Private and Public Entities. Some also directed editorial boards of specialised international journals.

In the first year there were five subjects, one taught by a Professor. The teaching and learning method was teacher as well as student-centred. There were 'magisterial' lectures for theory. The students had to search in library books and papers with the fundaments of the equipment they have to use in the laboratory. There was no field work, except during holidays. The students in groups of five had to search in libraries for the fundamentals of the lab work and details of equipment and execution, similarly to what happened in the Faculty of Engineering in Portugal some years before. However, there was a difference: At Imperial

College there was no teacher in the lab, during the execution of each soil test. The students had to find all pieces of equipment and tools in the cabinets and assemble all in order to perform each test. At the end of each test, the group has to produce a report with the fundamentals of the test, explanation, results and their discussion. The students could read papers and borrow books in Science Museum Library at any time, including weekends. They also could have photocopies of papers at a reasonable price. Further than lab works there the students had to solve a large number of problems of application of the matters lectured by each professor. Out of the lecturing time; the teachers were available in their offices for discussions with a student at prefixed hours. At the beginning of the MSc course the teachers advised the students to attend complementary lectures other than those of Soil Mechanics, like Structures, Applied Mathematics., etc. At Imperial College any registered student could attend any theoretical lecture given at any time in the College by any teacher. In the lunch breaks (12h-14h) professors from other Colleges, Cambridge and Oxford included, members of the Parliament, etc. came to the Imperial College giving Lectures on Sociology, Political Science, Humanities, in general. At the same time, there were also Art performances (Poetry, Music, etc.)

In the second year, each student had to do research only, finally writing a MSc thesis with the results of the research performed, usually in the lab. The students with 50% or more in the first year had to choose a Professor as supervisor and agree with him the subject of the research and the Plan of Research. This plan, with a title for the MSc thesis, had to be approved later by the Professor Head of the MSc course. There were weekly discussions between the student and his supervisor and at least at the end of each term the student had to write a progress report summarising the work done and the results attained. Around April (or before), a balance was done of the results accomplished and if they were consistent, the supervisor would allow the student to start writing his thesis. The writing started with a draft, done by the student, of a Plan of Thesis to be discussed and approved by the supervisor.

Later on, a draft of the thesis was handled to the supervisor, who, reading the draft, would make corrections and suggestions. Finally, the thesis was printed and handled and registered. A Council of Professors indicated the names of speciality professors of other Colleges (University of Cambridge, etc.), to be invited have potential External Examiners. They were contacted, one by one, and when one accepted the job, a date could be fixed for the discussion of the thesis. The final classification was ‘approved’ or ‘not approved’. However, a distinction was ‘approved’ with the mention ‘may be published as a London University MSc Thesis.’

In each year the best M. Sc. were invited to register for studies for a Ph.D. degree. For this purpose the PhD candidate needed not to attend new lecture courses. The student had to find a Supervisor, usually that of the MSc thesis and repeat the steps he has done for the MSc degree during three years more. The equipment and lab tests were much more sophisticated and in some cases it has to be invented by the PhD student himself, since the research work had to contribute for international advances in Science and Engineering in the domain (Civil Engineering, Mechanical Engineering, etc).

University of Mozambique

In 1963 the author started to lecture in the University of Mozambique, as one of the founders of this University (now called Eduardo Mondlane University). By that time the first degree Engineering Courses in Portugal changed from six two five years. Concerning Teaching and Learning Methodologies in Engineering Education, the author attempt to avoid the mistakes he found in the Portugal in the fifties. Nevertheless the best of the Learning in those years in the Faculty of Engineering of Portugal and in the Imperial College of London has been implemented in Mozambique. It should be noted that the author when have initiated his university teaching had already some professional experience as Engineer in the Engineering Laboratory of Mozambique. This Laboratory, at the time, was also 'Consultant' of the Public Works Department helping the Design and execution of all the infrastructures of Mozambique (roads, bridges, ports, airports, dams, etc.). Furthermore the author was member of the Public Works Council of Mozambique, where all the important Public Works Projects were discussed and approved before execution. In this way he knew well what is essential in the preparation a Civil Engineering professional.

For that, the author tried to involve in the five years Plans of Studies for all the Branches of Engineering in Mozambique, senior professors and senior engineering professional from Portugal.

The first aim was to obtain Plans of Study with a coherent chain of subjects from the 1st to the 5th year. In those Plans of Study were included some subjects of Humanities, given mainly by teachers of Economy, Law, Sociology. Pressure was put in the students to complete all the subjects in each year: A subject II might not be attended at the same time as subject I. e. precedence's have been enforced for a number of subjects. The teacher of a subject had to handle to the students at the first lecturing day the complete and detailed programme of the subject, The fundamental text books to be used (in number not over 3), which had to be existent in the Library of the University.

The teacher had to tell the students how to buy the main text books within a few days. Also the teacher had to state the rules to obtain 'attendance' of the subject and details of the examinations. The texts of written papers of examinations in preceding years were posted. A list of solved problems and problems to be solved and solutions was published. Details of the lab and field works to be done by the students were posted. All this information, together with the summaries of the lectures already was given to the secretary of each department in a folder specific of each subject. Any registered student might see at any day a copy of that folder. As in Portugal the students had to attend and report programmed 'Study Visits' to Works near the town or in the country, sometimes in South-Africa. The professors from Portugal, who had assisted in defining the Plans of Study, had continued to supervise the courses and pressing some of their best final year students to go to the new University. Also, the author invited directly those best people. Several of the professors of Portugal themselves had go to Mozambique. Meanwhile, the author presented a PhD thesis to the Faculty of Engineering of the Oporto University and obtained the PhD in Civil Engineering. Similarly other PhDs from Portugal initiated other engineering courses in Mozambique. The author tested several teaching methodologies. The most promising was, instead of magisterial lectures, to give the students a summary of the matters the students had to look at beforehand, and the text book or lecture notes where the content was explained together with examples of application. The next lecture in the class room was a discussion over the understanding of the contents at stake. In this way it was possible the deep understanding of the content, even by the lower ranking students.

Of course, using this method, the teacher has a larger workload preparing his lecturing work and the method fails when the classes have more than, say, 20 students. In our case about 80% of students were successful with this method.

THE PORTUGUESE REVOLUTION OF APRIL 1974

Effects on the Education in Portugal, in Engineering Education, in particular.

The Portuguese Revolution of April 1974 abruptly changed teaching and learning methods in Portugal. It seemed to be a latter Cultural Chinese Revolution together with some anarchism. The hierarchy in the Portuguese universities went upside down. With the ideas of a Government from the People for the People, teaching passed from directed and taught by professors to learning-centred and directed by the students. This happened even in the Basic and Secondary Education. The students took over the universities and the majority of the professors have been put out of their universities. The only professors staying were leftwing political professors and teachers.

As an example, the Faculty of Science and Technology of the older University of Coimbra was directed by a student and Faculty of Engineering of the Oporto University was directed by a junior Assistant Teacher. The bloody events in Mozambique (and Angola) brought the author back to the North of Portugal. And so the author was able to continue his ‘mission’ as university teacher at the starting University of Minho. However, before entering the University of Minho, the author, for family reasons, tried Coimbra and Oporto and was well accepted by the ruling students with the condition of a radical change of the educational methods. All teachers wood act only as a ‘consultants’ for the students. I. e. learning was centred and directed by the students. So the role of the teacher was to ‘suggest’ matters to be learned in each subject, text books to be read, lab tests to be done, etc. The students had to do all the work by themselves and, when in difficulty, might voluntarily consult the teacher. Concerning examinations, the students classified themselves. But in this point there was a fatal error. There was nobody to sign the grade lists, deposited at the secretaries. At Universities, the madness was short in time, but in the Basic and Secondary Education it continues. Nevertheless, until about one year ago the Chancellor of a Portuguese university might be elected with the favourable votes of the students associated to the votes of the secretary and technical staff, against the votes of all teachers, professors included. A recent Law put things in reasonable terms: The students' votes can no more overrule those of the teachers. But the Universities continue to have no role in the admission of university students. Also, students of lower quality can transfer themselves from lower ranking 'Polytechnics', private universities and foreigner universities to departments of Portuguese universities that cannot test the level of their knowledge and the students get automatically equivalence in the subjects they have pass in the original schools they attended.

On the other hand, the public universities in Portugal are blamed by the Press and some high rank officials, from time to time; for the large number of university students retained without passing and finishing their Courses.

As said, the Basic and Secondary Education was and is the most affected by the April Revolution in Portugal. The following are some of the reasons for that:

First: The Basic and Secondary Education is stronghold in Lisbon at the Ministry of Education. Ministry Officials issue detailed instructions on everything concerning Education. Basic and Secondary Schools have null power in the teaching and management. Furthermore, the Syndicate of the Professors (Leftwing) controls the Ministry from the April Revolution e continues doing it. Many ministers of Education pass and the Syndicate Leaders are the same with strong positions inside the Ministry.

Second: High rank officials of the Ministry of Education give detailed directives to the Basic and Secondary Schools about the teaching and learning stating that learning must be not work done by the student but a ludic activity from the 1st to the 12th year of study. Also, text books and 'manuals' with figures and photos make appeal in the same direction.

Third: In practice, teachers are not allowed to fail or 'retain' students. Recently a Minister of Education told the Press that retaining a pupil, although with no quality to pass, would be very expensive and had psychological effects in the pupil leading him to abandon the school.

Forth: There are no external examinations of the students except the 12th (final) year. There are intermediate examinations done by sampling to evaluate the Schools performance, only. With no responsibility for the students submitted to examination.

Fifth: Matters such as Mathematics and Physics are badly programmed. There are gaps and over positions and the content is not well enchained. Instead, the elementary fundamentals the programmes contain first informal information. So the students do not take the teaching as a serious and valuable thing. Neither are they invited to think deeply on the subjects they must learn.

Therefore, the average quality of the students that enter the Engineering university Courses is lower and is much difficult for the university teachers to prepare good professionals in Design and Execution in Engineering.

Another difficulty in Engineering Education in Portugal comes from the fact that the good or bad teaching has no role in the Academic promotion of a university teacher. In the Professorship proves much importance is given to the papers the candidate has published in first rank journals of the specialty, less importance to the Engineering Designs of important works (Long Span Bridges, High Buildings, Dams, etc.) he has performed and, practically nothing, to the pedagogical work of the candidate .

BOLOGNA DECLARATIONS OR PROCESS

In the 19th June, 1999 the Ministers of Education or their representatives of several European Countries signed a Declaration[1], originating what is now called the Bologna Process with the signatures of 29 countries representatives of Ministers of Education. The Bologna Declaration is not a treaty. Nevertheless, the governments of the European countries concerned have the compromise of reorganizing the university system of Education according to the following principles:

> The main aim of the Declaration is to increase the international competiveness of the European university system of Education. To ensure that the European university system of Education attain a world degree of attraction similar to their extraordinary cultural and scientific traditions, the undersigned state the targets to be attained in the first decade of the third millennium:

- To promote amongst the European citizens the employability[2] and international competiveness for the European university system of Education.
- To adopt a system based in three cycles[3] of studies:
- 1st cycle with the duration of three years;
- 2nd cycle with the duration of one and half to two years (exceptionally one year);
- 3rd cycle.
- Implement the Diploma Supplement
- Establish a transferable credits system (ECTS[4]) common to the European Countries, and promote a larger mobility[5] of students. The credits may be obtained in a context of Non University Education, including the lifelong learning[6], since they are recognised by the university that admit them of the candidate.
- To promote the mobility of the students (in the opportunities of study and graduation) and of teachers, researchers and staff, without lost of acquired rights.
- To promote the European cooperation concerning quality evaluation, in order to develop criteria and comparable methodologies.
- To promote the European Dimensions of the university Education, namely:
    - Curriculum development.
    - Inter-institutional cooperation.
    - Integrated programs of study and research.

The Declaration pretends mark a change in relation to the up-to-date Politics of University Education in the European Countries and state a compromise for reformation of their University systems of Education.

The later meetings were in Prague[7], Berlin[8], Bergen[9], London[10], Louvain[11], Budapest and Vienna[12] the next one will take place in Bucharest in 2012.

It is important to note that, although there were 29 initial signatory countries and more 17 countries in the final[13], the signatures are of ministry representatives and not of Chancellors of universities. Since, in countries as Germany, the universities are autonomous relating to Teaching and Research, a large number of German universities, maintain the rules of admission to the Engineering Courses. So students from Polytechnics in no way can transfer to some of the universities, and in other universities the candidates are submitted to examinations, since universities understand the level of Education in the Polytechnics is lower than in universities. Currently, in Germany Polytechnics are not allowed by the Ministry of Education to handle Ph. D. degrees. Similar cases happen in France in 'Grands Écoles' (École Central des Ponts et Chaussées, etc.) and the Netherlands.

DIFFICULTIES OF IMPLEMENTATION OF THE BOLOGNA DECLARATIONS IN PORTUGAL

The first difficulty is the impossibility in engineering of, in three years, to give enough preparation to the new graduates for 'employability', the main target of the Bologna Declarations. With three years time of learning the new graduate cannot perform Design and Execution of works of an Engineering branch (Civil, Mechanical, etc). Due to this the Institutions of Medicine, Laws and Architecture have rejected the Government attempts to implement the Bologna Declarations in Faculties. An they succeeded. In what concerns the Engineers Institution the question is not yet settled. Meanwhile, the Government issued laws implementing the Bologna Declarations in Engineering and Faculties have to issue a 1st degree Diploma after 3 years of study. The Faculties call that Diploma in Engineering Sciences, which, of course, does not allow the new graduate to be admitted in the Portuguese Engineers Institution as 'Engineer'. To solve this problem the public universities ask the Government and some were allowed to have Integrated Master Courses of 3+2 years, which is equivalent to the 5 years Course before Bologna. All this as created some disorder in relation to employment, since in many public entities the new 3 years Diploma is taken equal to the old 3 years Diploma in Engineering. To augment the confusion the Government stated by Law, the automatic transfer, at requirement of the student, of students from Polytechnics to Universities and, in what refers the Profession of Engineer, the equivalence between Diplomas taken in Polytechnics and in Universities, with frontal opposition of the Portuguese Engineers Institution.

A second difficulty in the implementation of the Bologna Declarations refers to the promotion of the mobility of the students, teachers and staff, another important aim of the Process. On one hand most of the European universities demand to the foreigner candidates proves of national Language understanding, and also of scientific knowledge, for the new student to be able to attend engineering Courses, as before Bologna. It must be noted that now as before Bologna, there are the Socrates and Erasmus programs for interchange of students between European universities. In this interchange Bologna might help with ‘regulations’, since there are a number of distortions in this process. In a first example one engineering student obtain a grant and has gone from one Portuguese university to a well known Belgian university to finish the last semester of her Course. The student was going without a programme of study well defined and accepted by supervisor in the University of origin. At arrival, the student is handled to a junior Assistant Teacher of the specialty. This Assistant was preparing his Ph.D. thesis and a saw in the context an opportunity to obtain skilled manpower at zero cost. In this way gave to the foreigner student a routine lab work needed for his thesis, but with no interest for the future Engineer. In the end gave the student a final mark equal to the average she had at the University of Origin. In another example, a student from a well known Italian university arrived at the University of Minho in Portugal. The student presented himself without any programme of study well defined. His CV showed he was in the 3rd year of a Civil Engineering Course with some subjects still to complete. Also, the curriculum plans of the Italian University were not similar to those in the University of Minho. To make things worse, the student did not know the Portuguese language. Under these conditions, the student was unable to attend lectures and continue his studies at the University of Minho. Nevertheless there are many cases of success, but there is a need to ‘regulate’ the mobility of the students and it was thought the Bologna Declarations would help in this point, but there is no notice of that. The mobility is aimed not only for students but for teachers and professionals, also. However, that means nothing without ‘freedom of using a Profession’ in al UE. So far, as an example, a Portuguese Physician cannot open an Office in Paris, as he can in Lisbon. The same happens with an Engineer, etc.

Regarding ‘Credit Units’ (ECTs) the open facilities are apparently good, but there is the difficulties down stated. In fact, the concept of ‘Credit Unit’ is not the same in Portugal and elsewhere. In Portugal the Education authorities’ state: ‘*one credit corresponds to about 30 hours of work. The load of work in a programme of integral study in Europe attain in the majority of cases 1500-1800 hours in a an academic year and in those cases one credit is equivalent to 25- 30 hours of work*. The following comments can be done in relation to this definition’- The formulae above for the annual quantity of work required to a university student seem to be based on the annual quantity of work required from any worker which works 50 weeks per year (excluded already holidays) and 5 days per week, which gives a total of 1750 hours of work

However, the pertinent question is: Is the quantity of student’s work, may be manual, appropriated to measure the preparation of a professional in Medicine or Engineering? Traditionally, instead of the quantity of student’s work, the measure for the preparation of the candidate to a Diploma was the quantity and diversity of ‘contents’ of the Branch concerned that the student had to know deeply and be in conditions to apply. This was roughly measure by the number of lectures handles by the senior teacher in each subject and also by the number Problems solved and of lab and field works the student had to perform and report. It may be argued that this way of evaluate student's preparation is out of date, but the alternative seems not be much better.

Bologna claims that traditional lectures have disappeared and that and teaching and learning is student-centred, speaking of developments in student capacities such 'learn to think', 'learn to learn', 'learn to analyse situations and to solve problems', 'leadership', 'innovation', 'group work', communication, etc., but does not speak of 'understanding deeply' the matters of the subjects and the prove of that understanding, nor it speaks of the actual ways of achieving the formulated aims, other than the 'Credit Units' (ECTs) the student must obtain.

In order to develop or create the above capacities, Bologna suggests including as 'Credit Units' in relation to student activities that were not compulsive before, being called 'circum-scholars'

All this seems to be in conflict with the main aim of after 3 years of study the people, holding a degree in Engineering, to be 'employable' as Engineer.

Actually, it seems Bologna wishes to overcome the old difficulty of distinction between a 'University Engineer' prepared for Conceiving, Designing and Executing Large and Complex works, and the 'Site or Field Engineer', present in the workshops.

In Portugal, unfortunately, this is a question of 'Social Status' and the April Revolution brought much more confusion on the discussion that still continues. Of course, a student from a Polytechnic must be allowed to finish his Course in an University, but there is need to know, at entrance, the level of his knowledge.

After all, a good progress of the Bologna Process is the institution of the Diploma Supplement (DS) to be attached to the main Diploma, in the National Language and in English, where must be described the contents of the Plan of Studies the holder fulfilled and the path he followed. This Document is based in the model developed by the European Commission, European Council and UNESCO in order to produce international transparency in diplomas, degrees, certificates, etc.

Bologna as the Portuguese Governments have much concern about the amount of students that fails in universities (drop-out rate). However, no actual action is referred for the Education before entrance in the universities. The number of years in the Basic and Secondary Education is 12 in Portugal and 13 in some other European Countries. However, that means little. The main points are those referred above about the actual anarchy in Basic and Secondary Education in Portugal.

IMPLEMENTATION OF THE BOLOGNA DECLARATIONS OR PROCESS IN PORTUGAL

Preceding the Implementation, by Law, of the Bologna Declaration or Process in Portugal, there were dozens of meetings in 2000 to 2007 about the subject. The discussions had two main points:

-i) The automatic equivalence or not of the academic degrees taken in Polytechnics to those taken in Public Universities. The automatic equivalence or not of the academic degrees taken in Private Universities to those taken in Public

Universities, also. After the April Revolution a large number of Polytechnics and of Private Universities has been installed in Portugal and larger number of Engineering Courses. An example: before April 1975 there were 2 Civil Engineering Courses in Portugal. Today, there are more than 27, most in public universities and polytechnics.

-ii) Relating to teaching and learning, it was understood that Bologna cuts radically with teacher-centred magisterial teaching. Teaching and learning must be student-centred. PBL (Problem-Based Learning or Project-Based Learning) methods should be implemented. In fact, the Bologna Declarations does not refer explicitly to a methodology for education, but there are signs in the direction of student-centred teaching and learning methods. However, many people pointed out that methods such as PBL would require much more means in the universities, both in terms of material means (spaces, labs, rooms, etc) as well as the preparation of teachers. Meanwhile the government budget for universities has been cut. Nevertheless, the Bologna process was implemented in Portugal by law (D.L. n.º 42 of the 22nd February, 2005, D.L n.º 107 of the 25th June 2008). These laws were accompanied by detailed instructions concerning the teaching and learning methods of the PBL type. Furthermore the Higher Education authorities stress that PBL Learning, reducing contacts between students and teachers, would lead to smaller expenditures. A demonstration that this is not true in relation to Engineering Education can be seen in the next section. In 2007 a report of the European Association of Universities said that Portuguese Universities were not implementing the Bologna Credits System and student-centred teaching and learning correctly and that the Portuguese teachers had not understood the opportunities of the change. Another report of a European Mission that came to the University of Évora, in the south of Portugal, said that progress had been made there in order to implement student-centred learning. Both reports stressed the need for reinforcement of the budgets of the universities. Otherwise the implementation would fail. To conclude this section the following is what can be seen in what refers Mathematics and Physics for Engineering at most of the Portuguese Universities

1. The total number of hours per week of students and teachers in rooms and labs was reduced to 22. Powerpoint lectures are given at high speed. That fixes the amount of content students must know. The aim is to give in 3 years the same amount of content that was given before Bologna in 5 years. The idea is to make the holder of a 1rst degree in Engineering 'employable'.
2. On the internet site of each subject the teacher publishes the slides of the PowerPoint and the text books the student has to read. He also publishes a number of problems to be solved by the students.
3. For the tutorial hours in class rooms of 30 students, the student must have prepared the proposed problems at home. A junior teacher is in the classroom for purpose of the students asking questions, but not all the students can be attended.[14]

In the lab works the students do the jobs in groups and each group writes a joint report. There are no oral discussions to evaluate individual knowledge. The mark for lab work usually has a weight of 10% in relation to the maximum total mark. In this way it is understandable that the weaker students are very sorry with the Bologna Process. This is, perhaps, the reason for some students' manifests in Spain against the Bologna Process.

In any case, at all, the effects of implementation of the Bologna rules must be evaluated and this should be done by systematic inquiring before-Bologna and after-Bologna Professional Engineers.

The Portuguese Government has created a Ranking Agency for Evaluation and Accreditation for Guaranty of the Quality of University Education (DL. n.º 369 of the 5th November, 2007 and Council Board for that Agency (Resolution nº 19 published in DR 2nd Series of the 18th , June, 2008)

In what refers 'Employability' it should be noted that the explosion of the number of Engineering Courses in Portugal, some of them without correspondence in the needs of Industry, has also reduced the 'Employability' for many of them.

THE FUNDAMENTAL BASES FOR THE ENGINEERING EDUCATION AND THE CONCEPT OF UNIVERSITY ENGINEER AND. A POINT OF VIEW

What distinguishes the University Engineer from other Professional is mainly the capacity to solve Engineering Problems. For that the Engineer has to use Sciences (Mathematics, Physics and Chemistry, etc.) as tools. Therefore, the Engineer must have knowledge on those areas in the direction of solving problems. Furthermore, the Engineer must learn to use his imagination, local experience and the experimental world results accumulated with the purpose of solving any complex problem he comes across. I. e. Engineer must have 'Engenhance', Art of Artisan, Art of Artist and be able to use well Applied Science. He does not need to be good Scientist.

In reviewing the fundamentals for engineering education, it is important to take into account the main targets of any teaching and learning method: the acquisition by the student of a large integrated body of knowledge, which can be quickly remembered and applied in the solution of engineering problems. I. e. the aim is to develop in the student the following capacities:

- Ability to solve problems with an engineering reasoning, which implies 'common sense' in the solution and not a much elaborated thinking.
- Ability to do concept and design.
- Ability to learn in an autonomous way (autodidactic)
- Ability to work within a team.

METHODS AND STRATEGIES FOR TEACHING AND LEARNING. PBL IN ENGINEERING EDUCATION.

Nowadays, there are a number of methods and strategies for teaching and learning (Collaborative Learning, Cooperative Learning, Discovery Based Learning, Problem Based Learning and Project Research Based Learning (PBL). However, the attempts to understand the act of learning are very old. Considering the western world only, Jean-Jacques Rousseau (1742), John Dewey (1897, 1888, 1938) and Jean Piaget (1951, 2001) can be referredWith regard to PBL, the first experiences were realised in the domain of Medicine, at the Medical School of the MacMaster University, Canada (Barrows & Mitchell, 1975; Barrows, 1998). Afterwards, these ecxpriences have been extended to several European Schools of Engineering (Gibson *et al*., 2002; Jones, 2004; Heitmann, 2004;. Seiler, 2004; Milgrom, 2004; de Graaff, 2004; Mohr, 2004; Ostlund, S., 2004, Kaiser, 2004,). And to the U.S.A: (Sheppard, S , 2004) and to Australia (Rojiter, J, 2006; Stojcevski & Veljanovski, 2006; Bronson, *et al*., 2007; Krishan *et al*. , 2007; Venkatesan *et al*. , 2007). Perhaps due to the Bologna Process some European universities start to use PBL.

LEARNING STUDENT CENTRED AS REFERRED BY SOME AUTHORS

Students are responsible for their own learning

It is assumed that the students are able to identify what they must learn and the resources they will need to attain their targets. In this way the students could do the design of their individual needs to conclude a given engineering course, starting from their actual knowledge and experience which are variable from student to student. The University would serve to supply the means. The students would be autodidacts, a capacity supposed essential in any profession, also in engineering where new types of problems arrive and the means of communication increase exponentially with time. The following truism is assumed: 'Half of what an engineering student learns at university will be wrong or out of date, by the time the he enters in the actual Practice of Engineering'. For worse, it is not known which half of the knowledge the student learned is wrong.

This means that a Teacher, being present in a group of students who try to learn some subject, should be advisor of the group, only, when the students understood to consult him. This would be a radical method of student-centred and student directed. Little after the April (1974) Revolution in Portugal he students took over the universities and tried to implement this learning Method. Other role of the Teacher might be to provide the students with Engineering problems to be solved by the students and challenging situations that implied appropriated 'simulations', etc. The main capacity a Teacher might have would be that of discovering how a student might become an autodidact, and all the teachers had to be trained for this function. Furthermore, a Teacher would be a tutor of a group of students of his specialty.

The simulation of engineering problems might have be not well done, for the students to be obliged to ask questions. In the learning based in actual problems, the problems to be proposed to the students solve should have multiple hypothesis, multiple answers and multiple solutions, to oblige the students to do critical reasoning. The problems to put to the learning students must be engineering problems of the actual world (engineering ways of facing floods, failure of dams, crashing of vehicles, etc. etc.)

Learning should integrate a large range of Subjects related to the understanding and solution of the basic engineering problems In adopting PBL the problems put to the students should not refer to a Subject only. The problems put should involve, for example, Surveying, Strength of Materials, Structures, Hydraulics, Highways, etc. During learning the students should learn how to integrate knowledge from several subjects which contribute to a given phenomena, say catastrophic floods and the ways to avoid them or to minimise its effects. In this way the students would be obliged to remember, to organise and to apply knowledge from Basic Subjects, such as Mathematics, Propedeutical Subjects, such as Strength of Materials and Applied Subjects, such as Reinforced Concrete. This is what the Engineer does in actual Professional Practice.

To be able to cooperate is essential The collaboration amongst students occurs in group discussions with the tutor. However, the students must be incentivised to collaborate during studding time. Group work is the most important part in Learning. Helping each other and discussion within a Group work the students understand better the details of the content and feel compensated for that. It is in group work that the students develop leadership and responsibility qualities. So, collaboration is a important capacity the students must acquire, since in Practice they will be always members of a work Team.

A careful analysis of what has been learned with the work already done, and a discussion on the concepts and principles applied is essential Before accomplishing their work in a problem, the students must reflect on what has been learned and verify if there is lack of something for the global understanding of the problem and of the mechanisms of solution. Additionally the students must reflect on the way the previous knowledge from several subjects contributed to the solution of the problem at stake, and on the kind of future problems that can be solve in the same way. Reflecting the students evaluate the importance of the concepts and principles they learned and convey to the solution of the problem and memorise better the content they have to remember.

The Plans of Study Must Contain a Sequence of Activities Reflecting Rigorously what Happens in Engineering Practice

In every Learning Process the students, during learning, must follow the same type of activities with the same sequence of the Engineering Practice activities. Furthermore the selected problems for learning must be relevant for the Professional Engineer.

The examinations must well measure the progress that a student has done in relation to the capacity to solve Engineering Problems. Although one part of the student's classification may come from an oral discussion after a problem have been solved, a written general examination must be done to test the lot of knowledge the student acquired and his capacity to solve Engineering Problems.

Train of the students by use of the capacities they have acquired during their Course The external Stages at the end of the Course, at least those, are and always were, a fundamental part in the formation of a engineering student. The universities must search connections with public and private entities and deal with them Stages allowing the final year students to train what they learned during their studies. In the performance of Stages there is the need for a number cares in order to the actual aim of the traineeship will not corrupted. First of all, a programme of work for the student must be done. The work must be useful for the involved external entity. Secondly, that entity must formally nominate one of its engineers to supervise the students work. Also, the student must have a teacher from the university who beforehand has drowned the programme of work in contact with the engineer and future supervisor. The programme of work must have steps of execution and timings. All of this implies that the entity that gives a traineeship must supply the material means (space in drawing room, etc.) and, may be, unskilled manpower for the student to perform the work. For example, the traineeship must not be a way for the entity to obtain skilled manpower at zero cost, putting the student doing routine calculation for budgets.

Modifications to be done in the Plan of Studies if PBL is adopted If the PBL Methodology is adopted there is need to do modifications in the Plan of Studies. Also the faculty material and human means must be reinforced as shown above. Otherwise, the failure is inevitable and there will be lack of student's motivation due to failure in their expectations.

Some more elements on the interpretations being done in Portugal and elsewhere to the PBL Methodologies As told above, the Portuguese governmental authorities for Education in universities say that student-centred methodologies lead to smaller expenses. However, published experiences for Engineering in Australian universities prove that, in PBL Learning, the classes must not have more than 20 students divided in 4 or 5 groups. This implies a large increase in teaching staff. It also implies a radical change in the curriculum plan and in the training of all the support staff.

SOME MORE NOTES ON THE ROLE OF THE TEACHER IN ENGINEERING EDUCATION

Even in student-centred PBL, the student has to be taught to search, for example, efficient bibliography in the internet for the solution of a problem he has in hand. Without the help of a teacher it would take to the student much time in finding the appropriate articles he needs. It should be noted that only about 5% of the huge amount of internet technical literature concerning some subject is useful to Engineering Practice. Therefore, the student needs direction from the Engineering teacher that must be a professional Engineer, also. Otherwise, the student feels lost. Concerning the subjects of engineering application the teacher responsible for a subject must include in the study the international Norms for Design and Execution, since these Norms are a repository of the world experience accumulated along many years on the matter at stake. Another source of knowledge the student must be taught to manage is the analysis in the internet and technical literature of 'Works Cases' (failures of infrastructure or equipments, etc.). Failures are full scale tests and so they are the best experiences to be learned. The student must discover what was wrong in the Design and/or in the Execution for the occurrence of failure.

In relation to the evaluation of the knowledge of each student the role of the teacher is essential, also. Written examinations usually are the only ones done. However, that is not good for many students. Furthermore, the students may learn during examinations, also. But for that the contact between teacher and student is fundamental. The used a so called written-oral examinations. This consists in testing at the same time thee groups of about 5 students each solving a question on a table of a room. A written question is put before each student, different from student to student. One teacher in the room looks after each group of student going from table to table. So the teacher may speck with a student without interference of anybody, allowing the teacher to evaluate well if the student can or not solve the question and how he does the job. In a few minutes o new question can be handed to the student and altogether in a morning or afternoon about 45 students can be well delaminated. Another type of evaluation of the capacities acquired by a student was put forward. It consisted in inviting the student, during the semester, to do a 'public' presentation on a content related to a subject, chosen by the student. After the presentation the student had to answer the questions put by the audience of colleagues and teacher. To learn to speak and reason in public plays an important role in the formation of a university engineering student or other.

CONCLUSIONS

- Teaching and learning is an activity between teacher and students and therefore group work by its very nature.
- By decision of the Portuguese Government, in implementing the Bologna Process in Portugal, a 3rd cycle university students have to attend and pass a number of postgraduate Subjects, before starting the preparation of their PhD thesis.

- In Portugal Master's and PhD programmes are tutorial, so teaching and learning needs more lecturing staff.
- To implement Bologna in the first degrees in engineering also, the teaching must be tutorial, what Implies more lecturing staff, in opposition to what the Government says and does, reducing the budgets for the public universities. These have to use PhD students for tutorials of the first degrees, as is done in many US universities.
- The university must prepare a graduate in Engineering for Conception, Design and Execution of Large Works and Engineering Equipments, in the same way as in the preparation of a doctor, practitioner of medicine. There is a strong correlation between the practice of engineering and the practice of medicine. As in the medical schools, in the final years the medicine student has to practice in hospitals amongst professionals of medicine and nurses, the student of engineering must do practical work in works, factories and design offices, out of the university amongst professionals of engineering and technicians.
- A well understood and financed implementation of PBL seems to be the best for engineering education.
- To implement PBL, engineering faculties must have more lecturing staff and other, more class rooms, labs, etc.. It is not enough to try to apply 'e-learning'.
- To implement PBL, students of each class in each subject must be divided in groups of 4 or 5. For this and other reasons, the Plans of Study must be deeply changed.
- Further than a set of subjects with contents well linked, the curriculum plan must include site study visits to works, factories, etc., public or private. i must also include traineeships at the end of the course, which might be done outside the country. In any case there is need of a good programming for traineeships and study visits.
- A well conceived curriculum plan must include some Humanities also (Economy, Finances and Credit, Industrial Laws, Political Science, etc.).
- For the evaluation of the knowledge of each student it is recommended what has been said above. Researchers in cognitive science state that examinations help to fix fundamental content for long in memory.
- The capacities to be a very good Engineering Researcher are not the same than those needed to be a very good Professional in Engineering Design, neither those to be a very good Constructor. However, every good Engineering Teacher should be a reasonable Researcher, Designer and Constructor. This must be so, because nobody can Teach what he does not uses in Practice.

OPEN QUESTIONS

- How to use, in Practice and in the best way, the internet as an instrument for Teaching and Learning University Engineering?
- How to create and increase motivation in a student for pursuing University Engineering Studies?

- What is the best way to develop in the University Engineering student knowledge of Humanities (Economy, Finances and Credit, Industrial Laws, Political Science, etc.).
- What is the most efficient Method of Teaching and Learning: the Deductive or the Inductive Methods? Does the best method depend of the type of content to learn?
- What capacities and skills are to be developed in the Engineering Student? How to develop them?
- Does the inventive capacity born with an individual? Or is the inventive capacity developable? What is the way to develop inventive capacity?
- Is it possible to foresee the inventive capacity of a candidate to an Engineering Course by psychological tests?
- Is instinctive knowledge born with an individual? Or is the inventive capacity developable? What is the way to develop inventive capacity?
- Assuming that part of the Senior University Engineering Teachers must be Professionals in Industry and the other part Researchers only, what would be the major part?

NOTES

[1] http://www.bologna-bergen2005.no/Docs/00-Main_doc/990719BOLOGNA_DECLARATION.PDF
[2] http://www.ond.vlaanderen.be/hogeronderwijs/bologna/actionlines/employability.htm
[3] http://www.ond.vlaanderen.be/hogeronderwijs/bologna/actionlines/QF_three_cycle_system.htm
[4] http://www.uc.pt/ge3s/guia/docs/ects_manual.pdf; http://www.uc.pt/ge3s/guia/docs/ects-usersguide.pdf
[5] http://www.ond.vlaanderen.be/hogeronderwijs/bologna/actionlines/mobility.htm
[6] http://www.ond.vlaanderen.be/hogeronderwijs/bologna/actionlines/LLL.htm
[7] http://www.bologna-bergen2005.no/Docs/00-Main_doc/010519PRAGUE_COMMUNIQUE.PDF
[8] http://www.bologna-bergen2005.no/Docs/00-Main_doc/030919Berlin_Communique.PDF
[9] http://www.bologna-bergen2005.no/Docs/00-Main_doc/050520_Bergen_Communique.pdf
[10] http://www.ond.vlaanderen.be/hogeronderwijs/bologna/documents/MDC/London_Communique18May2007.pdf
[11] http://www.ond.vlaanderen.be/hogeronderwijs/bologna/conference/documents/leuven_louvain-la-neuve_communiqu%C3%A9_april_2009.pdf
[12] http://www.ond.vlaanderen.be/hogeronderwijs/bologna/2010_conference/
[13] http://www.ond.vlaanderen.be/hogeronderwijs/bologna/pcao/
[14] Some teachers publish before the final written examinations the solutions of the problems they proposed, but not all teachers do that. In the final examinations no student can get out of the examination room with the written questions he had to answer. Not even with its draft. Some teachers publish before the final written examinations the texts of the final examinations of the year before, but not all teachers do that.

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AFFILIATIONS

Júlio Barreiros Martins
Department of Civil Engineering
University of Minho, Portugal

SANDRA FERNANDES, MARIA ASSUNÇÃO FLORES AND
RUI M. LIMA

9. STUDENT ASSESSMENT IN PROJECT BASED LEARNING

INTRODUCTION

In recent years, student assessment in higher education settings has changed. There has been a shift from the traditional testing culture to an assessment culture (Birenbaum, 1996) which favours the integration of assessment, teaching and learning, through active student involvement and authentic assessment tasks (Sambell et al., 1997).

Both summative and formative assessment highly influence student learning (Boud, 2000). This author concluded that, unfortunately, the influence of formative assessment is subtler than summative assessment and that the latter seems to drive out learning at the same time it seeks to measure it. This occurs because assessment is not viewed as an act of the learner but performed on him, in which the responsibility for judgements is placed in the hands of others rather than the student himself. The question is "how to replace this misleading image with one that locates assessment in the hands of learners, while acknowledging the legitimate role of certification by others?" (Boud, 2000:155).

Fernandes (2005) presents a different notion of formative assessment, an interactive type, centred on students' cognitive processes and on processes of feedback, regulation, self-regulation and self-assessment of learning. He calls it an *Alternative Formative Assessment* (AFA), as it favours the improvement of learning rather than its classification solely, its integration in the teaching and learning process, giving students a leading role in the learning process. It is different from any other kind of assessment which gives more emphasis to the processes of classification and to the summative results of the students. Its main purpose is to monitor and to improve students' learning, focusing its attention on the processes, but without ignoring the products, based on transparency, participation and clear integration of assessment in the teaching and learning process (Fernandes, 2005). Cognitive and meta-cognitive processes also gain relevance in this approach, helping students develop internal processes, such as self-control, self-assessment and self-regulation of learning. In this context, students acquire a more central role, as active student involvement in formative assessment is increasingly encouraged.

Sambell et al. (1997) studied the effects of alternative ways of assessing student learning through a number of case studies of assessment in practice. This research

L.C. de Campos, E.A.T. Dirani, A.L. Manrique and N. van Hattum-Janssen (Eds.), Project Approaches to Learning in Engineering Education: The Practice of Teamwork, 147–160.

revealed that assessment had a positive effect on student learning and was considered fair when it was related to authentic tasks, encouraged knowledge application in realistic contexts, provided adequate feedback about students' progression and measured complex skills and qualities, amongst other features (Sambell et al., 1997).

This paper draws upon research from a broader study aimed at assessing the impact of Project-Led Education (PLE) on students' learning processes and outcomes. It describes a case study which took place at a Portuguese University, in the first year of an Engineering programme, giving special attention to the assessment method adopted in this approach. A brief presentation of the organization and functioning of this project approach is described in the first part of this chapter, followed by a discussion of the main assessment procedures undertaken to assess student learning and the project's outcomes. The chapter concludes with the presentation of a set of findings based on students and teachers perceptions, drawing attention to the main strengths and weaknesses of project-led education. The implications of assessment procedures are also discussed.

PROJECT-LED EDUCATION: A CASE STUDY

The case study reported in this chapter takes place at a Portuguese university, located in northern Portugal. It reports data from PLE experiences carried out at an Engineering program, from the academic year 2005/2006 to 2007/2008 (Fernandes et al., 2007a, 2008; Lima et al., 2007). In Project-Led Education, students work together in teams to solve large-scale open-ended projects. The key features aim at fostering student-centeredness, teamwork, interdisciplinarity, linking theory to practice, development of critical thinking and competencies related to interpersonal communication and project management (Powell & Weenk, 2003).

PLE is coordinated by a team made up of the course coordinator, lecturers, tutors and researchers. The kind of project selected for each semester includes a challenging theme, which requires the development of students' learning outcomes of the four Project Supporting Courses (PSC) - *Introduction to Industrial Management and Engineering, Computer Programming, Calculation C* and *General Chemistry*.

The teams are composed of six to eight students and they have a tutor that supports them and monitors the development of the project. The tutor's role is to facilitate student progress and monitor the learning process (Alves, Moreira & Sousa, 2007; Veiga Simão, *et al*., 2008).

STUDENT ASSESSMENT IN PLE

The assessment system in PLE is based on continuous assessment of the project supporting courses (PSC) and assessment of the projects' processes and results. The percentage of each of these two components on students' final grade started off with an equal weight (50%). Later on, continuous assessment of the PSC had a slighter increase to 60% and 40% attributed to the assessment of the projects' processes and results (Fernandes, Flores & Lima, 2012; Fernandes, Flores & Lima, 2010). Student assessment is based on an individual and group result, as shown on Table 1.

Table 1. Components and Weights of Project Assessment (Fernandes, Flores & Lima, 2009a:264)

	Project Assessment	2004/2005 1º Sem.	2005/2006 2º Sem.	2006/2007 1º Sem.	ºSem.	2007/2008 1º Sem.	2008/2009 1º Sem.
Group Assessment (Final Product)	*Final Report*	20%	20%	25%	25%	25%	25%
	Revised Final Report	30%	30%	30%	35%	35%	35%
	Oral Presentations	10%	10%	15%	20%	20%	20%
	Developed Prototypes	20%	20%	20%	10%	20%	20%
	Final Discussion	20%	20%	-	-	-	-
	Delivery of Equipment	-	-	10%	-	-	-
	Audits on Process Assessment	-	-	-	10%	-	-
Individual Assessment	*Correction Factor 1* (due to teacher and tutor assessment)	50%	50%	-	-	-	-
	Correction Factor 2 (due to peer assessment processes – the average within the group is equal to 1.0)	50%	50%	80%	80%	80%	80%
	Written Test on the Project	-	-	20%	20%	20%	20%

When organizing an interdisciplinary project, the monitoring and assessment of students' learning process should occur in a systematic and continuous form, providing useful and contextualized information on groups' performance. The use of multiple methods of data collection, at different phases of the project, is of crucial importance in order to support the monitoring and assessment of the students' learning process, guaranteeing a permanent follow up. Therefore, student assessment in PLE focuses not only on the product, but also on the learning process. During the project, students develop a set of competencies related to teamwork and project management, which are one of the most significant and observable learning outcomes promoted by these project approaches. Throughout the development of the project, students meet regularly with their tutor and also with the staff coordination team, who have the opportunity to monitor and assess the generic competencies developed by students and also provide adequate feedback for improving student learning.

Product assessment, in turn, includes the assessment of student's technical competencies, which are demonstrated on their written reports, oral presentations, prototypes and written test. All these milestones are assessed in a summative way and result in a group classification. Besides this, each PSC defines its own way of assessing students, which may be based on small group tasks or work assignments and written tests, throughout the projects' development. From 2006/2007 onwards, the group grade had an individual correction factor that depended on a written test at the end of the project and on peer assessment processes, held four times throughout the semester (Fernandes, *et al*., 2009).

In PLE, several intervenients, such as teachers, tutors and students, participate in the assessment process. Teachers are involved mostly in the assessment of the learning outcomes and technical competencies required for the project. Besides the assessment of the project´s milestones, teachers also carry out other assessment activities and tasks within his/her course unit. The tutors have an importante role in the assessment of student's learnig process, and not so much on the learning outcomes (Alves, Moreira & Sousa, 2007; Veiga Simão *et al*., 2008). His role is to support and monitor the group dynamics and assure that the groups are working on the project. Finally, students also participate in the assesment process, in a very active way. They participate both in the assessment of the project (product) and also in the asssessment of the team members (process). The assessment of the project includes peer assessment of the oral presentations and the mid-term project reports, providing formative feedback and suggestions for improving the work done by their teammates. This activity intends to provide students with the opportunity to reflect on their work and compare it with their teammates and, altogether, share knowledge and learn from each other. In regard to the process assessment, peer assessment of teamwork is carried out by students four times throughout the semester, where each team member assesses the individual performance of his/her teammates, using a linkert scale based on six criteria (Fernandes *et al*., 2009).

In the PLE experiences carried out, the monitoring and assessment of the learning process have been guaranteed by the articulation and integration of two types of strategies in the learning process: on the one hand, a set of Milestones aimed at viewing the state of progress of the students' projects at specific moments, and on the other hand, a set of instruments centred in processes of co-assessment of group dynamics, self-assessment and peer assessment. The following table (Table 2) shows the moments and tools that contribute to the monitoring and assessment of the learning process in PLE. The first column indicates the projects' Milestones and the second column details the tools recently included in order to support the assessment of the learning process. A brief description of these tools, including their main purpose and some examples of the questions included in the questionnaires, are also presented in this table.

Table 2. Monitoring and Assessing the Learning Process in PLE

Milestones	Tools that Support the Assessment of the Learning Process		
Mini-Project (Week 1) Group Meeting with the Tutor (Every week) Formal Presentation (Week 5) Tutorial Meeting (Week 7) Formal presentation Intermediate Report (Week 10) Tutorial Meeting (Week 13) Preliminary Final report (Week 15) Final report (Week 18) Written test Prototype Final Presentation and Discussion (Week 20)	Assessment of the Students Initial Expectations (Week 1)	It assesses students' expectations and motivation about PLE, at the beginning of the experience.	- What motivated me the most about PLE? - Which aspects do I consider more/less positive about the experience? - What do I think of the assessment method? - What difficulties will I find? How will I overcome them? - Comments and suggestions.
	Self-Assessment of Performance (Week 5, 10, 15, 20)	It assesses students´ individual performance throughout the development of the project.	- How well am I doing? - What are my major strengths and weaknesses? - What have I learned with the group? - What has the group learned with me?
	Co-Assessment of Group Dynamics (Week 5, 10, 15, 20)	It assesses group functioning during the project, through a collective reflection.	- What is going well in the group? - What is not going well in the group? - How can the group improve?
	Peer Assessment (Week 5, 10, 15, 20)	It assesses the performance of each member of the group, on the basis of a set of criteria previously defined.	Criteria of Peer Assessment: (1-10 scale) - Presence in group meetings - Level of effort in the work - Suggestion of solutions - Original contributions - Interpersonal relationship - Fulfillment of stated deadlines
	Final Assessment of the Students (Week 20)	It assesses students' perceptions about the PLE experience, at the end of the semester.	- Impact on learning - what I learned. - Global assessment of the experience – more/less positive aspects. - Major difficulties and its overcoming. - Adequacy of the projects' theme. - What I would do different if initiated the project today. - Suggestions for improvement.

The project Milestones intend to supply the coordination team with information on the state of the progress of each group's project, in order to support the groups that are facing problems and include the necessary adjustments (Carvalho & Lima, 2006). Since students are free to decide what they want to make out of the projects' theme, it is possible that a project may reach a point where it could be considered unsustainable. To prevent this situation from happening, due to students little experience in managing projects with this dimension, the coordination team decided to include a set of milestones, where the groups make presentations on the state of the project and where the teachers and members of the other groups give feedback and suggestions on the work. As assessment situations to a certain extent, the Milestones are also a unique opportunity for students to demonstrate the soft skills they are developing throughout the project, making it possible for these competencies to become explicit and many times even observable. The fulfillment of the Mini-Project, the oral presentations, the tutorial meetings, the production of a concrete artefact - prototype in Lego Mindstorms, are some of the key-moments where it is possible for students to show their skills in communication, organization, leadership, initiative, creativity, etc.

It is commonly known that the success of a project does not only depend on individual performance but also on the groups' capacity to work as a team, undertaking a true cooperative work. Taking this aspect in account, students' assessment in PLE includes two components: an individual component and a group component. It is frequent to verify that the groups, during the twenty weeks of the semester, experience situations that oscillate between phases of high motivation, productivity, enthusiasm and self-confidence, but also less positive situations, like the lack of motivation, interpersonal conflicts in the group, the saturation of the projects' theme, the accumulation of work, the failing of stated deadlines etc. Being aware of these problems and promoting the discussion around the reasons that lead to this state of things is essential to guarantee group functioning and to keep the communication channels between students and teachers open. However, we notice that it is extremely difficult to get students to develop these types of reflections in an autonomous form. Most of the groups still lack some psychological maturity in creating a favorable environment to constructive criticism and an open dialogue between group members. In this way, self-assessment processes and co-assessment of the group dynamics, using instruments such as questionnaires or observation grids, are necessary in order to monitor students' learning process and lead to the improvement of individual performance. It is also important that the students are aware of their own capacities, strengths and weaknesses, which is only possible through processes of self-assessment and self-reflection. According to Boterf (2005), a qualified student is not only the one who knows how to act with competence; he is also capable of describing why he acts in a certain way to obtain success. In this process, the intervention of the tutor is considered extremely opportune, in order to stimulate student reflection. According to Powell (2004), the tutors' role should not be to supply answers but instead to give clues for the group itself to find the most adequate solution to the problems it faces. However, besides giving technical support on the project, the tutor will also have to play a double function by guiding students in the process of self-reflection, providing inputs and ideas for the development of project skills. Peer Assessment processes, centred in criteria previously defined and negotiated with the students, are equally an instrument which shows the perception that each teammate has of their own performance and the performance of others. This allows a better crossing of data from the results obtained in a more quantitative assessment (peer assessment) with the information acquired in the processes of self-assessment and co-assessment of group functioning, eminently qualitative.

STUDENTS AND TEACHERS PERCEPTIONS OF ASSESSMENT

Students Perceptions

According to student's perceptions, assessment in PLE focuses on deep-level learning and critical thinking, as the development of the project provides a real life context for linking theory to practice. In this way, students relate their work to broader and professional situations outside the academic world. Students' were greatly satisfied with the level of interdisciplinarity fostered by the projects' goal and assignments. This was illustrated in the projects' written test and also during the focus groups.

> PLE is quite interesting as you are not only worried about studying for tests. You also have the opportunity to link theory to practice, by solving real problems.

> Because there were different courses of the semester involved in the project, it made us develop the technical skills needed for the project. At the same time, we were also more interested in the different subject areas since we could see the direct application of the concepts that we were learning in the project.

However, not all of the students were enthusiastic about PLE. Findings from a survey applied to students, six months after the project was concluded, revealed that many students still prefer traditional teaching and assessment methods, in which they play a more passive role in the learning process. Some students recognized that they felt more comfortable when assessment was only dependent on their performance and when study efforts were related only to course contents, lectures in which students didn´t have to worry about applying or linking the concepts to real life situations or with other courses during the semester. These perceptions from students reveal different approaches to learning which may be linked to what Marton and Säljö (1976) identify as deep and surface approaches to learning. Other research studies are in line with this finding, such as Entwistle and Tait (1990) who found out that students who reported themselves as adopting surface approaches to learning preferred teaching and assessment procedures which supported that approach, whereas students reporting deep approaches preferred courses which were intellectually challenging and in which assessment procedures allowed them to demonstrate their understanding (Entwistle & Tait, 1995).

One of the disadvantages pointed out by students in regard to the learning process in PLE approaches is the heavy workload which it required, arguing that this had strong implications on their study efforts. Studies have shown that a severe workload may have an effect on the depth at which students study

(Sambell et al., 1997). Our findings also demonstrated that students claimed that not having enough time to invest in the level of learning being demanded was frustrating for them and that it would sometimes result, inevitably, in a surface approach to learning. Similar conclusions were reported by PLE students throughout the focus group discussions.

> Sometimes we had to choose between studying for tests or keeping up with the projects' milestones. We had to manage work related to the assessment of PSC and also tasks related to the project's development. Most of the times, we chose to work on the project instead of studying for tests.
>
> PLE steals much of your personal life. We had to stay at the University to work all afternoons! And when we weren't working on the project, we had to study for the tests. And the subject contents that we applied on the project weren't even enough to study for tests. It was only one small part of the courses' program. Student assessment in PSC did not take in account the projects' work.

Apart from the heavy workload, students also identified teamwork as a positive outcome which emerged from this kind of approach to learning. Many students stressed the impact of teamwork on their motivation and commitment to effective learning.

> Motivation is the key for successful learning. I didn't always put 100% effort on my work, but I think that's quite normal. However, I think that when you are part of a team, it is easier to complete work because there is always someone who is motivated and that kind of influences others. Team members support each other when difficulties arise.
>
> With PLE I needed to study because I had to apply contents on the project and I couldn't just stay behind otherwise I wouldn't understand the concepts. If we didn't have the midterm reports and the other milestones, we would only study at the end of the semester and the outcomes surely wouldn't be as good as they were.
>
> To be honest, now I am a little more relaxed in regard to learning… It's not like I'm playing around but last year (PLE) I was definitely working harder and under pressure.

Students also stressed the importance of getting feedback from teachers and tutors during the project. Throughout the project, the tutorial sessions and oral presentations fostered several opportunities for formative assessment, where students could become aware that mistakes are part of the learning process and that constructive feedback from teachers and tutors enables them to improve and achieve the learning outcomes.

> In PLE, feedback was very important because we had the opportunity to do better the next time. After submitting the projects' preliminary report, we received corrections of our work by teachers and tutors and we were able to improve on the next report as we were able to understand our mistakes. I think we learn a lot with our mistakes.

> Our tutor played an important role by providing feedback in regard to the projects' milestones. She tried to make sure that we kept up with the deadlines, so we would first send her our report in order to get a first impression of its quality and only then we would submit it.

When questioned about preferences in terms of PLE and Non PLE assessment methods, almost all students' responses focused on the grades that they get. When justifying their choices, students stated reasons mostly related to the fairness of the method, dependent or not on a group component, and the effort required to achieve the intended learning outcomes. Whether or not concerned with effective learning, some students proved to be solely concentrated on the easiest way of obtaining high grades, and in this way, traditional lectures and assessment procedures were perceived to be more appropriate. As a student states, "all study efforts are now [non PLE approach] concentrated on the contents that will be tested on examination and all my efforts are to improve grades".

> This semester [Non PLE] I feel more engaged in the courses because all my study efforts are focused on studying the course contents. Thus, all my efforts in studying the courses' content will have a positive impact on my grades. Knowing this gives me more motivation as I know that all my study efforts are to improve grades.

> I prefer traditional teaching instead of PLE because it is easier for me to achieve higher grades, besides the fact that I think assessment is fairer.

In addition to this, many students consider that learning is perceived as unrewarded activity in PLE, as they go through a lot of hard work to attain the projects' goals and they get a relatively low return in terms of marks. The assessment process seems not to reflect the emphasis on collaborative learning and the focus on process which it calls upon. These findings lend support to previous empirical work. For instance, PBL experiences held in British universities (Saven-Baden, 2004) and other studies based on alternative ways of assessing student learning (Sambell et al., 1997) also confirm students' disappointment with grades achieved, as they felt disempowered by the assessment system which did not value or reward effective learning. In some cases, students obtained higher grades on modules that were marked by an end-of-term exam rather than in courses with continuous assessment. There seemed to be a mismatch between the type of learning that took place and the respective assessment procedures which certificated learning (Saven-Baden, 2004). Future work should focus on ways of improving the assessment system to enhance student satisfaction.

Teachers Perceptions

In regard to teachers´ perceptions about PLE as a teaching and learning strategy and its effects on students' learning processes and outcomes, faculty staff highlight student engagement and academic success, as well as a deeper understanding of the concepts taught in each course as some of the major benefits of this learning approach.

Teachers have also recognized, besides the improvement of technical skills, the effectiveness of PLE in order to develop a set of transversal skills such as teamwork, problem solving, time management, oral and written communication skills, etc. Teachers also mentioned teamwork as a key issue to increase student motivation and commitment to effective learning.

> It is quite easy to compare student success in PLE experiences with other traditional approaches to teaching and learning. Student success was almost 100% in the PLE case; otherwise it would only be around 60%. But there is a good reason for that: students are more involved in the courses, not only because of the continuous assessment but also because of the practical side of the project. Students learn how to apply the concepts in real life situations.

> Finally, students [Industrial Management and Engineering] found out what Chemistry is all about!

> I could never imagine that first year students were capable of doing such an amazing work! I'm seriously thinking about inviting a team of students to do a presentation for my colleagues at my Department. (…) When you're not involved in the process [PLE], it is very difficult to understand what we're talking about.

The last statement presented illustrates the stunning reaction of one of the teachers, who was surprised by the students' outcomes at the end of the project. At the start of the semester, it is usual to find an attitude of some skepticism amongst the teachers new to PLE approaches, who are quite concerned with the amount and depth of factual knowledge which students will acquire in this process and how the project´s assessment method will take this into account. This uncertainty, along with the new challenges regarding a student centered learning approach show some of teachers' frequent doubts and fears of getting involved in more active learning experiences. When involved in project based learning or other active learning strategies, a different role is expected from teachers (Murray & McDonald, 1997). From transmitters of knowledge, teachers shift to the role of facilitators, by developing a dynamic process with students, fostering reflection and critical thinking within their learning process (Johnston & Tinning, 2001). This active role played by teachers has also strong implications for their workload. Since the first edition of PLE, implemented in 2004/2005, several evaluations of the project have pointed out that teachers', although the positive results achieved by students, are aware that PLE takes a great deal of their time. Even though the coordination team works as a team project and tasks are distributed amongst teachers and tutors, the workload associated with this kind of student centered approach requires a much more demanding role from teachers. Some teachers only become aware of this fact when they actually get involved in PLE.

Teachers also stress the partnership developed within a multidisciplinary team which includes teachers and researchers from different fields, such as Science, Engineering and Education as an important input for collaboration, which might explain, to a certain extent, the successful implementation of this experience . The special contribution of researchers in the educational field has also been recognized as an asset for the successful implementation of these approaches, as seen in other contexts, such as in Medical Education in Portugal (Pinto, 2008). However, regardless of the effort which this coordination team has undertaken, the truth is that this learning methodology requires a high level of teachers' time and this has become a constraint for teachers.

> I have never thought that PLE would involve so much work! It is unfortunate that the people who usually criticize this approach to learning are not aware of the workload which it entails. People have no idea!

So, recently, several attempts have been made in order to reduce teachers' workload and make it more efficient. A recent study (Alves *et al*., 2009) carried out by a group of teachers involved in PLE, has tried to identify the major tasks which are responsible for taking up most of teachers time when involved in PLE and what alternatives are there in order to reduce teachers' workload and develop more efficient ways to enhance a better organization of future PLE editions. Findings suggest a set of project-related classes of activities which represent most of the teachers' workload. These include teachers' participation in coordination team meetings, tutorial sessions, observing students' oral presentations and finally tasks related to the review of student reports, providing feedback and grading. When combined, these four activities represent 72% of the total time spent by the coordination team members. So, a number of time-saving strategies were discussed in terms of advantages and risks concerning their implementation (Alves *et al*., 2009).

CONCLUSIONS

The assessment model of PLE and the procedures undertaken to evaluate students in this approach reveal a set of advantages and constraints in regard to students' learning process and outcomes. Findings based on students' perceptions suggest that assessment practices in PLE enhance deep-level learning, by linking theory to practice to solve real life problems. Feedback plays an important role in the assessment process of PLE, as students are provided with several opportunities to improve their work and are able to discuss results with teachers and tutors. Teachers, in turn, also considered PLE as a positive approach to enhance student learning and increase student motivation, as it allows students to identify their own learning needs and create opportunities to discuss and construct knowledge, applied to real life situations.

However, one of the main constraints of this innovative approach to learning is the heavy workload which it entails, for both teachers and students. For students, this aspect has a serious influence on their assessment and final grades. Some students feel that the assessment method in PLE is unrewarding, as they go through a lot of hard work to achieve the project's outcomes and, at the end, get a relatively low return in terms of grades. These findings lead to the conclusion that summative assessment is in the centre of students concerns and seems to be the most important result of their learning process, regardless of how meaningful and worthwhile learning is (Lindberg-Sand & Olsson, 2008). Besides this, it also suggests that students' beliefs and perceptions in regard to assessment are mostly based on the assumption that traditional forms of assessment represent unequivocally valid assessment mechanisms, as Sambell et al. (2007) pointed out. To overcome this stereotyped idea, alternative assessment procedures and criteria need to be explicit for all participants involved and ensure a rigorous process to guarantee the validity and reliability of assessment results.

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AFFILIATIONS

Sandra Fernandes
Faculty of Psychology and Education Sciences,
University of Coimbra, Portugal.

Maria A. Flores
Institute of Education,
University of Minho

Rui M. Lima
School of Engineering,
University of Minho

NATASCHA VAN HATTUM-JANSSEN

10. THE ROLE OF TEACHERS IN PROJECTS

INTRODUCTION

Today´s engineers are facing challenges that do not only require a solid engineering foundation, but also skills like team work and oral and written communication. Mills and Treagust (2003) explain clearly what is lacking in traditional engineering degree programmes that prepare students for the engineering practice.

1. Engineering curricula are too focussed on engineering science and technical courses without providing sufficient integration of these topics or relating them to industrial practice. Programs are content driven.
2. Current programs do not provide sufficient design experiences to students.
3. Graduates still lack communication skills and teamwork experience and programs need to incorporate more opportunities for students to develop these.
4. Programs need to develop more awareness amongst students of the social, environmental, economic and legal issues that are part of the reality of modern engineering practice.
5. Existing teachers lack practical experience, hence are not able to adequately relate theory to practice or provide design experiences. Present promotion systems reward research activities and not practical experience or teaching expertise.
6. The existing teaching and learning strategies or culture in engineering programs is outdated and needs to become more student-centred. (p. 3-4).

Many authors describe similar motives for dissatisfaction with current engineering curricula (Rouvrais et al., Walther & Radcliffe, 2007; Walkington, 2001; McCowan & Knapper, 2002; Vest, 2008) and have been looking for active learning methods that are based on constructivism (Daniels, 1996): learners construct meaning through interaction with others and with the world by interpreting that interaction and relating it to previous experiences. In traditional, lecture based courses, students do not have the opportunity to construct new knowledge through interaction with other as they are supposed to passively absorb as provided by their teacher. In project approaches to learning, students interact frequently and intensively with the teaching staff, their tutor and their team members. They have the opportunity to develop technical as well as transversal competencies in an interactive learning environment (Peschges et al., 1999; Powell & Weenk, 2003). Moesby (2005) defends the inclusion of transversal competencies

L.C. de Campos, E.A.T. Dirani, A.L. Manrique and N. van Hattum-Janssen (Eds.), Project Approaches to Learning in Engineering Education: The Practice of Teamwork, 161–176.

in engineering curricula, but also acknowledges the need for support of teachers and directors in the process of building transversal competencies into the curriculum.

Many of the students who participate in project approaches are enthusiastic about the way they learn. They find the projects demanding, but they acknowledge the added value of the project approach, engaging them much more than traditional education (see e.g. Lima et al, 2007). The students´ role changes from rather passive to actively engaged in learning. But, as also argued by Cheng et al. (2008):

> Student engagement is a joint responsibility which relies on the attitudes and behaviours of both students and faculty. (p. 351).

The role of teachers changes with the implementation of project approaches. Teachers serve not only as lecturers, but also as tutors or as a coordinator of a project semester. How these roles are different from the teacher as a lecturer and how teachers can prepare for their new roles are the central themes of this chapter. It starts with an overview on project approaches in engineering education and continues with an outline of the project approach as implemented at the Industrial Management and Engineering (IME) degree programme of the University of Minho, Portugal. It furthermore discusses the preparation of teachers for their new roles in projects.

PROJECTS IN ENGINEERING EDUCATION

The term `project-based learning´ designates a wide range of learning activities. It is impossible to give a specific and concise definition that accurately describes all kind of project-based learning activities. There are, however, two common elements in different definitions of project approaches. The first one is the active involvement of the student. In a project approach, the student is no longer a passive recipient of knowledge, but is actively constructing his or her own knowledge. Project approaches of learning are by definition student-centred. The second common element is the real-life nature of the problems that students are faced with, to enhance motivation and the understanding of the future professional practice. These common elements are complemented with other characteristics of engineering projects, pointed out by many authors. Although project approaches in engineering education may seem a rather recent answer to the demand more broadly educated engineers, as early as 1921, Stevenson defines in his book “The project method of teaching” on agricultural engineering, a project as follows:

> A project is a problematic act carried to completion in a natural setting. In this definition it is to be noted that: (a) there is implied an act carried to completion as over against the passive absorption of information; (b) there is insistence upon the problematic situation demanding reasoning rather than merely the memorizing of information; (c) by emphasizing the problematic aspect the priority of the problem over the statement of principles is clearly implied; and (d) the natural setting of problems as contrasted with an artificial setting is explicitly stated. (Stevenson, 1921, p. 43-44).

Later definitions of projects of other authors are fairly similar to the definition as given by Stevenson (1921). Schachterle and Vinther (1996) for example, distinguish a set of desirable characteristics of projects in engineering courses. According to them, projects should be integrative and synergetic, reveal a strong motivation of students, contextual and experiential, require team work, involve open-ended problem solving, appeal to the development of communication skills, are multi-disciplinary, show an intrinsic flexibility of the curriculum, produce a results that someone can use and prepare students for lifelong learning. Helle et al. (2006) also highlights the production of a concrete artefact, the team work and the solution of a problem. Moreover, they emphasise the changed role of the teaching staff from authoritarian to advisory and the considerable length of time that a project usually takes.

Helle et al. (2006) describe three types of project approaches that can be distinguished. The first one is what they call a project exercise and refers to the use of projects, usually within the context of a single course. The emphasis is on application of already acquired skills and knowledge. The project component is the second approach, including objectives like developing problem-solving abilities and autonomous working abilities. The project component approach is more interdisciplinary and is, in many cases, organised in parallel with other traditional courses. The third way of incorporating projects in a curriculum in what is called a project-orientation. This means an entire curriculum philosophy based on projects, using other courses only to supplement the projects. (Helle et al., 2006). This approach to projects is the most inclusive one, transforming a degree programme into a number of projects. It is a student-centred approach, not used just for application of existing knowledge, but first and foremost for the construction of new knowledge and the development of skills.

A similar distinction is made by Heitman (1996) who refers to project-oriented studies and a project organised curriculum. The first one involves small projects within individual courses, leading to a large project in the last year of the degree programme. In this approach, projects are usually combined with traditional teaching methods within the same course. Project-organised curricula on the other hand make use of projects as the structuring principle of the entire curriculum, meaning a large reduction of even elimination of subject-oriented courses. These projects are undertaken throughout the length of the course and vary in duration from a few weeks to one or two semesters.

Projects as implemented by the IME degree programme of the University of Minho are originally based on the ideas of Powell and Weenk (2003). According to them:

> PLE focuses on team-based activity relating to learning and to solving large-scale complex open-ended problems (Powell and Weenk 2003). Each project is usually supported by several theory-based lecture courses linked by a theme that labels the curriculum unit. A team of students tackles the project, provides a solution and delivers by an agreed time (a deadline) a team product such as a prototype and a team report. Students show what they have

> learned by discussing with staff the team product and reflecting on how they achieved it (p. 221).

They stress the importance of team work as a feature of project work. Students are to work in teams that have – as opposed to groups – a shared responsibility for learning and for the results of the projects. The team members have to work together effectively to be able to obtain a solution for the problem that is to be solved and are all held accountable for the final result, requiring the development of, among others, leadership and communication competencies, team skills and time management skills.

THE IME CASE

Since 2004, the Industrial Management and Engineering (IME) degree programme has implemented interdisciplinary projects in different semesters of the programme, which is, by now, a five year integrated Master´s degree in engineering. There were a number of reasons for the implementation of projects, both internal as well as external. The implementation of projects in the degree programme entailed fundamental changes of the existing teaching and learning paradigm.

Motives for Implementation

The external reason for the implementation of interdisciplinary project approaches can be summarised as the demands of the Bologna Declaration. Apart from the harmonisation process of courses that are made more comparable through the use of ECTS and clear descriptions of course objectives, the Bologna Declaration and its successors also focus on the knowledge society, more autonomy for students and lifelong learning. The pressures to change to methods that enable students to become more autonomous learners and to be prepared for lifelong learning were incentives to think seriously about more active methods of learning like problem-based learning and project-based learning. More attention for student-centred learning as opposed to teacher-centred instruction supported teaching staff in their search for more appropriate methods. During the Bologna related curricular reform processes taking place at all engineering degree programmes of the University of Minho, all programmes started to include some kind of a project approach. The project approaches though, were not similar approaches. A wide variety exists of projects approaches that have been implemented because of the demands of the Bologna Declaration. The project approach of the IME degree programme is close to project-orientation. Although not the entire degree programme is transformed into projects, a number of semesters have been transformed completely. This transformation process was strengthened by the Bologna process, but started before, based on the joint initiative of a group of teachers.

This group of teachers, who lectured at the IME degree programme, participated in a faculty development session by professor Peter Powell from the University of Twente, the Netherlands, on Project-Led Engineering Education

(Powell & Weenk, 2003) and started analyzing the added value of an interdisciplinary project that they could develop together. They found the following characteristics as beneficial for student learning:

Student learning is more active: students can no longer wait for till the exam period to start studying seriously. In the context of a project, they have to start in the very first week. The teachers do not prepare them for the project in lectures, but students have to discover by themselves what they need to know in order to be able to solve the project.

More interaction: there is more interaction between students and teachers and among students. Weekly meetings in small groups facilitate a closer contact between students and teachers.

Interdisciplinarity: through the different content areas that are needed in the project, students learn to integrate knowledge. Knowledge is less fragmented and more integrated.

Professional future: in an early stage, students get into contact with the professional reality of their (engineering) field, as projects are related to real engineering problems.

Transversal competencies: apart from technical competencies, students develop transversal competencies – e.g. leadership, group skills and presentation skills – through the intensive team work they are involved in.

These characteristics of learning through projects formed an important incentive for the first group of teachers that implemented a semester in which traditional courses were transformed into a project. A transformation of existing courses into a project that takes an entire semester is close to what Helle *et al.* (2006) call a project orientation. What in fact happened at the IME degree programme is that there was no restructuring of the curriculum. No new (project) courses were created and instead of creating new formal structures, the content of all the courses of a semester was transformed into one common project for all courses.

The first project that was implemented in the second semester of the first year 2004 was followed by many others, both in the first year, as well as the fourth and fifth year of the IME degree programme. The project approach is not completely according to the ideas of Powell and Weenk anymore. The teachers that initially started the project approach did not make a distinction between project-supporting courses and non-supporting courses. Mathematics, Physics, Chemistry and Informatics courses, that would not be part of interdisciplinary projects according to Powell and Weenk (2003) were included in each project to enhance the interdisciplinarity and to make students aware of the fact that competencies from these courses are part of the competencies that an engineer needs to solve problems.

Changes of the Teaching and Learning Paradigm

The transformation from separate courses to courses that share one common project theme implies many changes in the roles and the activities of teachers. A traditional teacher works rather autonomous and does not necessarily interact frequently with colleagues who teach in the same degree programme. Teachers, who are involved in a project, suddenly have to work closely together with their colleagues, in their role as teacher, or in their role of a tutor. The role of tutor is usually new to most teachers who start working with projects. It is different from that of a teacher, but the difference is not always clear to the tutors, who can also serve as teacher in a project at the same time. Many different activities can be carried out by a tutor and the question is whether these should all be part of the role of a tutor. In a study on tutor performance of the IME tutors involved in different projects, the following roles were found during interviews with tutors:

1) permanently monitoring the group while reaching project goals
2) monitoring the progress of the project
3) communicating problems to the coordinating team
4) functioning as a privileged communication channel towards the group
5) establishing a close relationship with the student team
6) identifying organizational problem within the team
7) identifying personal problem that reduce individual performance
8) participate in project assessment (reports and presentations)
9) participate in individual assessment of team members
10) contribute to the organisation and coordination of the project
11) guiding students to the relevant lecturer
12) supporting the development of presentations and reports (Alves *et al.)*.

Van Hattum-Janssen and Vasconcelos (2008) identify six areas that are considered important by students when evaluating tutor performance. The first one is the knowledge on project approaches in general and the knowledge on specific organizational aspects of a project. Tutors need to be able to explain what working in projects means to student teams and to be able to answer their questions on project work. The second area refers to attitudes on project work. A tutor needs to show that he or she believes in project work for engineering students. He needs to respect students and accept them as responsible for their own learning process. Furthermore, a tutor needs to monitor the progress of the project, according to students working in projects. He or she should discuss decisions that are made by the student teams, ask challenging questions, give feedback when necessary and stimulate students to be active team members. He also needs to stimulate the development of critical thinking and problem solving skills. Supporting team work and monitoring the individual learning process of team members are other relevant areas that a tutor should pay attention to (van Hattum-Janssen & Vasconcelos, 2008). As all of these responsibilities are different from the role of a teacher as a lecturer, the role of a teacher as a tutor is one of the most intrusive changes that teachers are confronted with.

Another change is the involvement of teachers in a specific form curriculum development. In a traditional organisation of courses, a teacher is responsible for his or her own course and defines learning outcomes, instructional methods and assessment method either alone or with other teachers from the same disciplinary area. In a project, they have to cross their disciplinary border and leap into other disciplines in order to be able to design a project for students. Teachers have to work together in a real team, characterised by a conscious membership, a shared goal and an ability to act in as a single team. The definition of a project theme that provides learning experiences for the development of all competencies involved, both technical as well as transversal, is the first step in the implementation of a project. As opposed to a traditional course organisation, a project starts from scratch by selecting a theme from a wide range of possible themes, instead of with a pre-defined set of competencies in a specific disciplinary area.

An interdisciplinary course, as argued by Davis (1995) is by its nature established to do something that a disciplinary course cannot do. Minnis and John-Steiner (1995) acknowledge that interdisciplinarity may be a challenge for those whose professional identity is based on recognition of expertise. Crossing borders of disciplines can pose an emotional risk. For academics, their discipline is a safe arena of assumptions, language conventions, conceptual frameworks and methods of inquiry. Experiencing another professional arena can feel threatening.

In order to design projects that are real interdisciplinary projects and not just a compilation of separate areas, teachers need to work together in a team that is prepared to step out of known routines and enter in a new form of cooperation.

Another change, related to the previous one, that teachers are facing when transforming traditional courses into a project approach, is the focus on transversal competencies. The development of transversal competencies was one of the motives to implement project approaches at the IME degree programme Teachers were convinced that students needed to work more actively on their transversal competencies and projects that are based on student team work create a learning environment that stimulates the development of these competencies. Although there is a consensus among teachers on the need to develop transversal competencies, the role of teachers in the developmental process is not clear. They are experts in their disciplinary area, but not necessarily on transversal competencies. Especially teachers who act as tutors are faced with questions that are new to them. Tutors monitor the process that students experience when working in teams and developing both technical as well as transversal competencies.

Tutors of student teams are supposed to monitor the progress of the project and help the students to keep on track during the semester. They are not supposed to be a content expert, but will help the teams to focus on the tasks that are relevant to fulfil the requirements of the project. Meanwhile, tutors discuss the development of transversal skills, like leadership, time management, project management and communication skills with the student team, based on peer and self- assessment by the members of the student team. Apart from the support of student teams related to progress and transversal competencies, tutors also have a role in conflict management. Students working in team are sometimes confronted with communication problems on a professional as well as a more personal level. The tutor is the most indicated person to meet when conflicts are impossible to solve within the student team. Tutors are not prepared for conflict management, but will need to be able to handle difficult situations.

THE PREPARATION OF TEACHERS FOR PROJECTS

At the University of Minho, engineering teachers have been prepared for their roles in project work in several ways. A project guide describing the goals of the project, the competencies included, the planning and deadlines for the student teams and the assessment methods is the first important document that assists teachers during the project. A tutor guide delineating the responsibilities of a tutor and his or her possible roles in conflict management is a second relevant document. Apart from these documents, training sessions are an important way of preparing teachers for a project approach. The following sections will describe the organisation of the training sessions in more detail, emphasising the learning experiences that teachers go through.

Previous Experiences with Group Work

Many of the teachers who make the transition from traditional approaches, focussed on one disciplinary area, in which they are experts and work relatively isolated, to project approaches, in which more than one subject is involved, have experiences with group work of students. They have given assignments to groups of students, who were supposed to work together and produce a report within a certain amount of time. They made students work in groups and experienced a number of drawbacks. One of the drawbacks is what is called “free riding” or “social loafing”, meaning that one or more members of the group do contribute little or nothing to the group work. The other members of the group are likely to become less motivated for the work that has to be done (Cheng & Warren, 2000). There is also the drawback of “hijacking” of group work by one member of the group, as explained by Kapp (2009). He describes a scenario of one student being completely in control of an assignment while preventing the other members of the group from participation in decision making. Teachers are also worried about the division of work between students and the subsequent learning experiences of each individual student. The comprehensiveness of learning may become biased when the focus of individual members is focused on specific aspects of the assignment only. Because of these drawbacks, teachers find it difficult to assess group work fairly. As Pitt (2000) concludes:

> Any method of selecting groups and allocating projects, whether random or systematic, will in general give some groups an advantage and some a disadvantage.

> Giving all students the same mark means that as a sensible group strategy the weaker students should contribute less.
>
> While the allocation of marks is a motivator, factors such as `teamwork' and `contribution to the group' are hard to define and essentially impossible to assess fairly.
>
> Rating students on some perceived performance has as much to do with perception as performance and may sometimes be unfair, e.g. the student who contributed least to the problem solving may give the most confident presentation at the end.
>
> Some assessment factors can actually promote dishonesty and competition. (p. 239-240).

The problems with group work in general and assessment of learning in particular makes teachers critical of group work and approaches that imply student team work. They have experienced that group of students develop systems of effective time management in which different assignments are distributed over several members of the same group, in the end having all names of the group members appear on the cover pages of the different reports. Teachers are aware of this phenomenon, but do not know how to handle it. They find it difficult to make students cooperate effectively in order to have group members learn from the assignment. Livingstone and Lynch (2002) argue that group work is often regarded as beneficial, but mention the lack of sound evidence for the effects of group work. In project approaches, students are supposed to work as a team, rather than a group. All students in the team are accountable for the final result. They share a common goal and have to work together effectively.

Teacher Training for Project Approaches

In order to prepare teachers and tutors for their new roles in projects, the University of Minho developed a training course for teachers in which they learn through a project how to be a tutor or a teacher in a project. Furthermore, the training session aims to produce a real project proposal for a project semester that will take place in the near future. The organisation of the training sessions is according to the principles of Weenk *et al.*(2004):

> In order to let lecturers experience how a certain teaching method works in practice, the workshops should be 'practise as you preach'. This means that the training methods we use should serve as an example for the teaching methods the lecturers can use and that we provide the lecturers with experiences from a student's point of view. . In order to make the time investment in attending the training programme worthwhile, the workshops should result in a 'product'. For example, this could be a design for planning one or more classroom sessions, a student project handbook, a scenario for the delivery of a course, etc. (p. 465).

In a training programme of five sessions, the participants experience team work in a way that has similarities with the student team work. The nature of the project is similar to that of the students in the sense that it is an open-ended problem. The team of participants will not know in advance what project proposal they will be presenting by the last session. There is no established outcome and a wide variety of project proposals is valid to develop the competencies as established by the team of participants. To the participants, it is a real-life project, as the proposal is to be used in a near future in a project semester. As the participants are from different disciplinary areas, they will experience the interdisciplinary nature of the project, the same way students will later on experience the interdisciplinarity.

The conditions of the project that the participants are carrying out during the training week are also similar to the conditions of the students. They deal with time pressure, as they have to present a complete project proposal in the last session. It is not always easy to align the different time table of participants and find time to work on the proposal, either together or individually, outside of the training sessions, so the participants experience a strong time pressure and strict intermediate deadlines, as do the students. Furthermore, they have to work in a team. Some of the participants may have worked together in a team in other context, mainly research related. Most are not used to working together in a team as teachers and sharing content related aspects of teaching.

In the first session, the participants receive the project they have to complete: by the end of the week: a sound proposal for a possible interdisciplinary project, including an assessment plan. In this session they also share ideas on different concepts of projects and what the impact of the different models on student learning is. By the end of the first session, they have their first meeting as a team to discuss possible ideas for project proposals.

In the second session, the participants analyse and experience team work. Both the formal aspects as well as the informal aspects of team work are discussed. The formal aspects include holding formal meetings, with a president, a secretary who make meeting minutes and a time keeper who makes sure that the meeting does not exceed a pre-established duration – usually one hour. Meetings with strict time limits are not common practice for most of the participants, so they have to find a way in which they can change their patterns towards a pattern that is more similar to what they will require from their students. Not having the opportunity to discuss different points of view for extensive periods of time and feeling pressure to take decisions within the time frame of a meeting is for some participants a rather large alteration of routines.

The informal part of team work refers to the role of a tutor in the team work process of students, especially the interpersonal communication of students. Through the conflict strategies of Johnson and Johnson (1991), tutors enhance their understanding of student behaviour in groups, enabling them to give students a better insight in possible sources of conflicts. Johnson and Johnson (1991) make a distinction between the importance that group members attribute to personal goals and personal relationships. The importance that a group member gives to either goals or relationships is perceived to affect how one handles in a conflict situation.

Five strategies can be used in conflict situation: withdrawing – giving up both personal goals and relationships, forcing – being highly goal oriented forcing others to accept solutions and as such giving up personal relations, smoothing – highly emphasising personal relations and prepared to give up personal goals for that sake, compromising – being moderately concerned with both personal relationships and goals, and confronting – valuing both aspects highly and looking for solutions that solve goals of both members. Students are supposed to become aware of their preferred strategy and learn how to change strategy if necessary.

The second sessions is closely related to the third one, in which the different roles of a tutor are discussed. In this session, the participants discuss what the differences between tutors and teachers are and learn that tutors are not by definition content experts. They are not supposed to serve as experts to students and do not participate in the assessment of teams. They have an obvious role in monitoring progress of groups, and, because of the confidential relationship they have with the tutor, assessment is not part of the role of the tutor.

Assessment is the theme of the penultimate session. Several dimensions of assessment are worked out during the session, leading to a comprehensive assessment scheme. The first dimension is on the balance between the project and the courses that are included in the project. Although the project is a common element of all courses, there is also room for course related activities that are not directly related to the project. Therefore, at the beginning of the semester, the coordination team has to decide on the weight of the project; the percentage of each course grade that will depend on the project. This percentage is usually around 50%, but can vary from 40 to 60%. The remaining percentage does not depend on the project and can be used for separate course assessment. The second dimension refers to technical and transversal competencies. As the main part of the project consists in technical competencies, these are highly ranked in the assessment scheme. Assessment tasks like prototypes, intermediate and final reports make up most of the final grade of each group. Transversal competencies though, are also included in e.g. the oral presentations. This leads to a third dimension: the assessment of individual versus the assessment of teams. This dimension is, in the IME model, closely related to the distinction between transversal and technical competencies. Part of the transversal competencies, like team work, leadership and interpersonal communication, are especially developed through team work. Assessment of these competencies is (van Hattum-Janssen, 2009) therefore, partly, reserved for the team members through peer and self assessment. Teachers and tutors are not able to follow the behaviour of the team members closely and cannot perform assessments that are based on processes taking place within the context of the teams. The assessment of peers and the students themselves are a valuable source for feedback on performance related to these competencies. The peer and self assessment results serve as a correction factor over the final team grade, so that each team member will receive in individualised grade, based on the final project results and on his or her performance within the team. In this session, the assessment scheme for the project proposals of the participants is discussed, including a time line of the different assessment activities, to enable a balanced workload for the student teams during the semester. The assessment activities that are not part of the project, but are course related only, are also to be included in the assessment scheme. A number of milestones are to be defined, with strict time limits for the student teams. Milestones include the mini-project at the end of the first week, intermediate report, the preliminary final report, the final report, the final presentation and the prototype.

The last session is dedicated to the presentation of the proposals that are elaborated by the participants. Teams of participants present a proposal for a project that could start the next semester. They present the most important features and discuss the proposal with the other groups. The proposals are the result of a weeklong intensive teamwork. The participants propose a project that is interdisciplinary and will require students´ team work and at the same time they also experience what it is like to work in a team on a project. Problems are analysed and discussed and the participants reflect extensively on the feasibility of the different project proposals. The teachers are supposed to work in teams in the same way the students are supposed to work in the next semester on the project they propose. They work in teams of about five members on an open-ended project, with a strict deadline. At regular moments, their progress is checked and discussed.

Participants usually start to understand that they can no longer position their course as the central one of the curriculum plan, and that there must be a willingness to work together and understand the concerns of colleagues. They become more aware that all of them contribute to the learning experiences of the students and that an interdisciplinary approach is more meaningful to a student and more congruent with the future professional engineering practice in which problems do not appear along strict disciplinary lines. Designing an interdisciplinary project that represents content of a number of different and sometimes seemingly unrelated areas, requires readiness to explore the boundaries of one's´ own area and a willingness to look for a project theme that is meaningful to all participating areas. The definition of a project theme that allows students to develop competencies in a number of different fields is not an easy process and entails skills that go beyond the technical ones of the engineering teaching staff. The participants face what it is like to be in a team process that will fail when one or more team members are inflexible, not willing to look for solutions that are acceptable to all, but perhaps not their first choice.

CONCLUSIONS

A shift from traditional approaches to project approaches implies a number of changes for the teaching staff. Roles changes, activities change and the relationships between colleagues and with students change. Supporting teachers in this changes process is an important factor that contributes to the successful implementation of project approaches. Or, as McKenna and Yalvac (2007) in their study on teaching approaches of engineering teachers put it,

> The success of the success of innovative education projects is highly dependent on the faculty who implement the innovations in their classrooms" (p. 406).

A sound preparation of teachers for the new reality they are going to be involved in, contributes to a successful implementation process. Teachers need to experience, in the training for project approaches, what students are experiencing when they have to work in a team on an interdisciplinary project.

During the training sessions, the participants experience on a small scale, what students undergo in their teams. They face some of the problems that students face while working in a team under strict time control and with a challenging problem to solve.

The participants consider the training sessions a useful way of preparing for a project. Apart from the preparation for the content part of the project, the training also helps to increase awareness of the teaching staff of the concept of a project orientation to learning. Student learning is no longer regarded as a compilation of different curricular units in which one teacher is only responsible for one particular unit and that might perhaps include projects. In this case, the traditional learning experiences are substituted by a project that included a number of (complementary) content areas, meaning that e.g. the Math teacher, the Physics teacher, the Informatics teacher and the Mechanical Engineering teacher prepare one project together, including knowledge and skills of all the respective content areas. The training session changes they way participants think about projects. They learn that a project approach does not imply a lecture-based theoretical introduction, before students can work on a project. Students construct new knowledge through the project, and will, most likely, learn more than with a traditional lecture-based course. In order to carry out the project successfully, students may need knowledge that is not part of the included subject areas. The ability to construct new knowledge is not only beneficial for the students, but also motivates teachers as they are receiving continuous feedback from students and

Teachers who participate in training sessions that make them experience part of what students experience during a project semester, do not just prepare a project for the near future, but also undergo what it is like to work in a project. They become aware of positive and negative aspects of intensive team work, the strict deadlines, the real-life problem and the interdisciplinary nature of projects through experiential learning, a process in which the teacher as a participant is actively involved in a learning experience, reflects on the experience, forms abstracts concepts and can actively experiment what he learned in practice (Kolb, 1984).

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AFFILIATIONS

Natascha van Hattum-Janssen
Research Centre in Education
University of Minho, Portugal