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Global Research Community: collaboration and developments

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Title: Global Research Community: Collaboration and Developments

Organised by Mondragon University and initiated by the Aalborg Centre for PBL in Engineering Science and Sustainability under auspices of UNESCO, in collaboration with 13th Active Learning in Engineering Education Workshop (ALE) and International Symposium on Project Approaches in Engineering Education (PAEE)

Global Research Community: Collaboration and Developments

Erik de Graaff, Aida Guerra, Anette Kolmos, Nestor A. Arexolaleiba

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Global Research Community: Collaboration and Developments

Changing from a traditional teacher-centred educational approach to active and student-centred approach has proven to be an effective strategy for higher education to address the challenges posed by society and professional practice in our time. Students need to develop competencies such as lifelong learning, teamwork, communication, creativity and critical thinking in order to deal with challenges like technological innovation, sustainable development, and globalization. Problem based, project organised learning (PBL) is a methodology focusing on students who learn take an active role in directing their own learning and allows them to develop the before mentioned competencies.

With a history of almost 50 years PBL has grown far beyond the founder universities at McMaster, Maastricht, Roskilde or Aalborg, and spread all over the world, involving different professional fields and types of education. PBL evolved beyond educational practice, developing a community of practice where the members share concerns, knowledge, experiences and partnerships.

The International Research Symposium on PBL (IRSPBL) is one of the meeting places, which gathers researchers, practitioners and industrial partners from all over the world contributing to the PBL landscape. It has been a great pleasure to arrange the 5th International Research Symposium on Problem Based Learning Proceedings.

The past editions of IRSPBL focused on different aspects of PBL landscape. The first of symposium at Aalborg University in June 2008 aimed to initiate a worldwide community of researchers on PBL. For the continuation of the symposia UCPBL initiated collaboration with host organizations in different countries around the world. In 2009, the second research symposium was hosted by Victoria University (Melbourne, Australia) which was going through a process of organisation change towards PBL. At the time Victoria University was going through a process of organisational change introducing PBL in their curricula. The third IRSPBL focused on collecting best practices across the disciplines. Coventry University was also in the middle of a change process towards more PBL in her curricula. The fourth IRSPBL was hosted by UTM (Malaysia), and focused on collecting best practices across cultures. At UTM, several courses apply various PBL-practices.

In this fifth edition, IRSPBL joins forces with Active Learning in Engineering Education (ALE) and the International Symposium on Project Approaches in Engineering Education (PAEE) to organise the first International Joint Conference on the Learner in Engineering Education (IJCLEE 2015) hosted by Mondragon University, in San Sebastian, Spain. This is a quite unique event as it is three global organisations which all focus on student centred learning in various ways within engineering education. ALE focus on active learning, PAEE focus on projects, and the UNESCO Aalborg Centre focus on problem based and project based learning.

As such the three organisations represent a pathway to establishing real student centred curricula. Active learning can be integrated into existing course structures, whereas problem and project based learning will require much coordination at the curriculum level for efficient implementation. From a process perspective the student can easily be identified as a learner. However from organisational change perspective, where institutions adopt different strategies to implement PBL, the concept of learner must be expanded to include aspects like academic staff, management, and the institution itself.

Such concepts provide a holistic view of the different actors, structures and roles in the process of change towards PBL or other active, student-centred learning approaches.

Collectively, the three IJCLEE organisations collected more than 178 contributions coming from 37 different countries. A total of 46 contributions, from 27 different countries, were accepted for the proceedings of IRSPBL. The IRSPBL contributions cover a number of relevant PBL topics such as assessment, learning outcomes, students' engagement, management of change, curriculum and course design, PBL models, PBL application, ICT, professional development. This book represents some of the newest results from research on PBL in these different areas.

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

Erik de Graaff, Aida Guerra, Anette Kolmos and Nestor A. Arexolaleiba

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The International Research Symposium on Problem Based Learning (IRSPBL) organising committee expresses its gratitude to collaborators and partners, in special the reviewers who provided valued comments and suggestions to all paper contributions.

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Modelling the Assessment of Transversal Competences in Project Based Learning

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Abstract

The engineering practice requires the application of both technical and transversal competences, which raises the need to create learning opportunities that allows the development of those competences. These learning opportunities are based on student-centred active learning models, i.e. active learning methodologies that engage students in activities that promote a deeper learning and in the development of competences (e.g. problem and project-based learning and design-based learning). These learning models foster the development of transversal competences required by the professional practice. Project-based learning (PBL) methodologies consider a central project that integrates several contents in an interdisciplinary learning approach, acting simultaneously as a mean of interdisciplinary application of knowledge of different contents, and as a mean to create deeper learning of different contents. In PBL approaches, one of the common issues pointed out by students and teachers is the assessment process, which try to assess not only technical knowledge, but also technical and transversal competences. Considering that assessment is one of the curriculum processes with a higher impact on student's behaviour and results, there is the need to analyse and create assessment methods that improve the alignment between the demanded competences, the corresponding learning outcomes, and finally the assessment methods and criteria. This work aims to develop an innovative model of assessment of transversal competences for PBL, which intends to align methods of assessment with required project competences. Further, there will be a construction of specific methods and criteria of assessment interrelated with the matrix, developed for a specific PBL process that includes interactions with industrial companies.

Keywords: Project-Based Learning, Assessment, Transversal Competences

1 Introduction

The professional practice of engineering fields requires the competence to solve complex open and ill-defined problems, which implies articulating in an interdisciplinary way knowledge, methods and tools from different areas. Furthermore, it is common that the engineers have to deal with this complexity, integrating or leading multicultural teams in projects with multiple profiles. Thus, there is a need to contribute to the development of competences, both technical and transversal, which will allow engineers to mobilize their learning resources in the contexts of real problems.

According to (Zabalza, 2009), within curriculum development it is needed to define the professional profile that is expected and articulate it with the initial training, which will be materialized in the curriculum of an engineering program. So the curriculum will integrate several dimensions, e.g. methodologies, content selection, learning environments, and assessment, which must be aligned with the objective of development of competences (John Biggs, 1996; J. Biggs & Tang, 2011). One of the methodologies being recommended and implemented in engineering programs to integrate these dimensions is problem and project-based learning (UNESCO, 2010). Project-based learning (PBL) is a learning process characterized by the need to solve a complex ill-defined problem related with the professional practice, by a team of students, with the support of teachers (Graaff & Kolmos, 2003, 2007; Anette Kolmos, Graaff, & Du, 2009; A. Kolmos & Holgaard, 2010; Lima, Carvalho, Flores, & van Hattum-Janssen, 2007; Lima, Carvalho, et al., 2012; Powell & Weenk, 2003). These projects can be completely developed in the higher education institution or can involve some external agents like industrial companies (Aquere, Mesquita, Lima, Monteiro, & Zindel, 2012; Lima, Dinis-Carvalho, et al., 2014; Lima, Mesquita, & Flores, 2014).

The importance of transversal competences, as teamwork, creativity, or autonomy, is being pointed out by professionals (Lima, Mesquita, & Rocha, 2013; Meier, Williams, & Humphreys, 2000; Pascail, 2006; Sageev & Romanowski, 2001; Scott & Yates, 2002), but curriculum have been built mainly based on technical content. However, "non-technical skills cannot be taught isolated from the technical context in which they will be used. Integrated projects are a crucial tool for achieving such ends" (Martin, Maytham, Case, & Fraser, 2005, p. 179). The technical content is important, as the other dimensions of the curriculum, and although higher education institutions have been referring the importance of transversal competences, most of the time, they do not give them the formal institutional support. The teachers that are aware of the requirements to support the development of transversal competences refer the difficulties in the assessment of the related learning outcomes (Hattum-Janssen & Mesquita, 2011). This difficulty is linked, in part with the qualitative nature of the evidences but also with the selection of the right methods and definition of the right process.

In this work the authors intend to present an innovative assessment methodology for PBL based on a reference matrix that explicitly model the relation between transversal competences with the required professional profile. This will be the base for the implementation of an assessment process for the selected transversal competences in Project-Based Learning. Further, an application of this methodology will explicitly show its applicability and the type of assessment model and criteria that can be used in a specific PBL implementation.

2 Conceptual Background

2.1 Competences

The concept of competence is not new. There are historical and economical influences which support their description, execution and development. In this sense, contemporary authors extend the concept considering several of relationships and transformations at different levels and contexts (Dolz & Ollagnier, 2004; Le Boterf, 2003; Marinho-Araújo, 2004; Marinho-Araújo et al., 2010; Wittorski, 2007, 2012; Zarifian, 2001).

According to Stoof, Martens, van Merriënboer, and Bastiaens (2002, p. 351), "a definition of competence should be adequate for the situation in which it is being used". There are three main principles that can be identified in the definition of competence: temporality, validity and transferability. Developing competences requires space and time, in order to integrate resources and updated knowledge (temporality). At the same time, it implies changes of beliefs, values, concepts and contents. These are needed to be mobilized according to the cultural, contextual and social demands. In educational trajectory, the consolidation of competences entails a historical dimension, characterized by individual development, experiences, relationships, and perceptions. Thus, defining developing and assessing competences in teaching and learning contexts implies moments of discussion, reflection, monitoring and feedback, in order to create meaningful changes on students' development. The useful value of competences (relevance) occurs in action, and they are the result of mobilization of resources (knowledge, experiences, etc.) to solve a specific unknown situation or problem. Mobilizing these kinds of resources means understanding them as important components to put into practice in the situation or problem. Therefore, a competence must be developed in its diversity to make it possible to be used in similar circumstances. Thus, a fundamental characteristic of a competence is to be "transferable" to other contexts beyond the original context that provided the competence development (e.g. learning context to professional context).

In this context, the competences development is not limited to the task which will be performed. This purpose implies the person and all dimensions that are related with it (emotional, ethical, cultural, social, political, etc.). The importance of the "context" in competences development arises in this context. Thus, the meaning of competence is based on the resources (previous experiences and knowledge, for instance) which will support in problem solving and facing uncertain and challenging situations that demands a choice (Le Boterf, 2003; Wittorski, 2007, 2012; Zarifian, 2001). Be competent implies an intention in the mobilization of the resources in order to solve the problem within a specific context and this mobilization process involves the person as a whole and for that reason the competence meaning must be include the dimension of the human development.

Competences can be categorized in different ways, considering the authors perspectives. (Le Boterf, 2003; Wittorski, 2007) suggest individual and collective competences or technical and transversal from its use and the context in which they are required.

The transversal competences, also known as "generic", "core", "transferable", implies the mobilization of resources within contexts and situations which are similar in different areas (Cabral-Cardoso, Estêvão, & Silva, 2006). These competences involve critical thinking, autonomy, creativity, entrepreneurship, teamwork, organization, responsibility, negotiation, interpersonal relationship, amongst others. Considering the demands of the professional practice and societies, these competences need to be introduced in teaching and learning situations.

2.2 Assessment (Methods) in PBL

The focus on a curricula based on competences, strongly encouraged by the demands Bologna Process, requires changes in the organization of the teaching and learning process, and consequently, on the assessment methods, moments and participants. This implies that Universities enhance a novel mix of approaches to teaching and learning in order to encourage or allow the development of valuable qualities such as capacity for analysis and synthesis, independence of judgment, curiosity, teamwork, and ability to communicate. In student centred learning environments, such as project approaches (Powell & Weenk, 2003) or other cooperative learning environments, students are encouraged to develop these transversal competences while applying and reinforcing technical competences. Therefore, assessment methods and criteria for evaluating performance should consider not only knowledge and contents but also transversal competences, such as teamwork for example (Powell, 2004). This entails a shift from the traditional testing culture to an assessment culture which favours the integration of assessment, teaching and learning, through active student involvement and authentic assessment tasks which are based on a range of abilities and outcomes (Black & Wiliam, 1998; Sambell, McDowell, & Brown, 1997).

Today, one of the main challenges for assessment processes is to consider the importance of the development of competences, amongst other issues which are part of the assessment process. Assessment methods and tools need to reflect this understanding and therefore it is not possible to develop evaluation methods only from an individual perspective, but it must consider, above all, the collective dimension, relational and context of the educational action. It is necessary to investigate various aspects of teaching procedures; the organization of time, space and methods; the negotiation and sharing of responsibilities, in order to improve the educational process (Marinho-Araújo et al., 2010).

The use of a matrix as a guiding methodological tool to support the identification, development and assessment of competences can be sustained by literature review in this field (Deluiz, 2001; Depresbiteris, 2001). According to Deluiz (2001), the different epistemological models that supported, historically, the conceptual background of competences is anchored on the development of matrixes for the analysis and research on this approach. The author explains that the role of the matrices for professional competences development was linked to the theoretical and conceptual prevailing movements in certain historical moments, giving origin to several concepts: behaviourist; functionalist; constructivist and critical-emancipatory. This critical-emancipatory matrix has received great attention by authors in the field. Supported by the theoretical background of the critical-dialectical thoughts, this matrix conceives the notion of competence as multidimensional, involving aspects that range from the individual to socio-cultural, situational (context-organizational) and procedural issues. A matrix based assessment model will be developed and presented in this work, linking functions of professional practice with project competences, making the matrix operational construction and application more clear in the following sections.

3 Methodology

This study is an exploratory study which aims to develop an innovative model for the assessment of transversal competences in Project-Based Learning, based on the alignment between assessment methods and required project competences. The model will be based on a matrix, considering previous work with competence matrixes used in large-scale assessment methods, which relates required competences for a degree with the functions of professional practice (Barnett, 1994). In this work, these matrices concepts will be enlarged to establish a relation between the functions of professional practice with the transversal competences that students are expected to develop within the project. For a better comprehension of its application, the model will be used to describe the assessment of transversal competences in a specific case of PBL, at the School of Engineering, University of Minho, Portugal.

3.1 Context of the Study

The Integrated Master of Industrial Engineering and Management (IM-IEM) of the School of Engineering of the University of Minho, Portugal, has been implementing Project-Based Learning since 2005. This work focuses on the implementation of PBL in the context of the fourth year of the course. In this PBL case, teams of 7-9 students have to interact with industrial companies during a semester. The goal of the project is to analyse a part or the whole production system of the company and identify existing problems. After this diagnosis, and once the problem is defined, students must select some alternatives of improvement and design them with proper rigorous engineering support. This support will be made with the application of concepts, theories, methods and tools of the supporting courses' knowledge areas: Organization of Production Systems; Production Planning and Control Processes and Systems; Ergonomic Studies of Work

Stations; Simulation. It should be noted that the 5 supporting courses have the same number of 5 European Credits in the Transfer System (ECTS_EC, 2009) as the project course: Integrated Project of Industrial Engineering and Management II (IPIEM2). In this integrated project the students should tackle a real industrial problem, simultaneously applying the courses contents and developing deeper competences in those fields.

The development of transversal competences such as communication, teamwork, project management, or autonomy, strongly encouraged by the interaction with companies, have always been an important concern of the PBL model Student assessment in PBL includes some specific elements which aim to assess transversal competences that are integrated in the whole process. During the semester, supervisors from the different areas have weekly meetings with the 5 to 6 teams and give continuous formative feedback. The summative feedback is implemented in the 4-5 milestones of the project. In these milestones, students deliver written reports (in form of conference articles), make presentations and develop prototypes, in the form of simulation systems, business model processes, Excel-VBA solutions for specific problems, and/or information structures. Furthermore, each team identifies some criteria for Peer assessment with the main objective of assessing teamwork. This peer assessment component is used to transform the project group grade to an individual grade.

3.2 Data Collection and Analysis

In order to develop an innovative model for the assessment of transversal competences in Project-Based Learning, data collection was based on document analysis with the objective of identifying the indicators related with transversal competences and assessment methods regarding to those competences. The Table 1 summarizes the sources that were consulted as well as the information used to create the model described in this paper. The documents were organized in two dimensions. First, the criteria and standards defined by accreditation boards for engineering programs in USA and in Europe. Second, the documents from IPIEM 2 that refers to the context of this study.

Table 1: Documents used to develop the assessment model

	Sources	**Information**
Accreditation Boards	**ABET -** Accreditation Board for Engineering and Technology	Criteria – engineering programs
	ENAEE - European Network for Accreditation of Engineering Education	EUR-ACE® Framework Standards
IPIEM2	**Project Guide**	Learning Outcomes Competences
	Rubric	Criteria defined for: Presentations, Reports and Peer Assessment

The analysis of the information provides from the triangulation of data collected which seeks to address information derived from different sources and also from the triangulation of experts in order to reduce the influence and subjectivity of the researcher (Denzin & Lincoln, 1994). The output of this process is the assessment model that will be described in the following section.

4 Assessment Model for Transversal Competences

The assessment model of the transversal competences proposed in this work is based on the link between the professional profile and the corresponding required competences. This link is explicitly established using and assessment matrix. The links identified in the matrix will be part of the assessment process.

4.1 Assessment Matrix

The proposed assessment matrix must be based on the expected professional profile, and for this purpose, previous work will be used and referred below. A profile can be drawn from the literature on the subject area of research or from analysis, studies and categorizations with origin in documents, projects, and legislation. Interviews, observations and other methods can also support the development of the profile. Taking in account a profile definition, it is possible to identify the resources to be managed for the development of the expected competencies. One of the fundamental aspects of a profile definition is associated with the functions of professional practice, this is, what is expected from a professional in this field to be able to perform the expected functions, combining all its resources in multidimensional processes, which in this context are defined by the characteristics of the professional practice. These characteristics are not enough to define a complete profile but reflect a comprehensive picture of what is expected from a professional.

In the case of a PBL process, these profile characteristics can be defined by a combination of perspectives, simultaneously based on the general characteristics of the field and the educational program, and the specific characteristics for which the process intends to contribute to.

In this work context, the IPIEM2 process, we can consider the project planning documents, "Project Guide - IPIEM2", and additionally for the educational program, information from formal information, such as those that can be found at http://miegi.dps.uminho.pt. For the field as a whole the professional associations (ABET, 2013; APICS, 2009; EUR-ACE, 2008; IIE, 2012) and research projects (IIE-Ireland, 2012; Lima, Mesquita, Amorim, Jonker, & Flores, 2012; Lima et al., 2013; Mesquita, Lima, Flores, Marinho-Araújo, & Rabelo, 2015) can be used as a theoretical framework. Thus, in the specific case of IPIEM2, considering the information sources referred above and the specific objectives of the project related with the production system of the companies that collaborate with the project, the following profile characteristics (CH#) are suggested:

CH1. Analyse, describe and diagnose the Production system and the Production Planning and Control system, articulating concepts and methods in an interdisciplinary way.

CH2. Perform effectively in teamwork contexts, both as member or as a leader, to tackle open problems with incomplete information, characterized by technical complexity and uncertain contexts.

CH3. Characterize the physical environment of the work stations from the ergonomically point of view.

CH4. Develop creative and innovative solutions for Industrial Engineering problems.

CH5. Design changes for Layout and/or material flow of the company's Production System, considering productivity, ergonomically and management issues and concepts.

CH6. Specify information structures and processes for parts of a company's Production Planning and Control System.

CH7. Communicate in an effective and creative way with both interlocutors from the academy and professionals, respecting the ethical principles.

CH8. Manage time, both in project activities planning, execution and delivery, and in communication time management.

In order for an engineer to perform effectively in different contexts and scenarios of the professional practice, he or she needs to develop and apply the required competences. These competences involve both technical and transversal competences. For the purpose of this work only the transversal competences will be considered. Based on the IPIEM2 documents and observation the following set of transversal competences (TRC#) were considered in this study:

TRC1. Teamwork

TRC2. Communication
TRC3. Time Management
TRC4. Creativity and Innovation
TRC5. Scientific Rigor
TRC6. Interpersonal Relationship
TRC7. Making decisions with incomplete information.

These components will support the reference matrix from a multi-dimensional conception; its design resembles a table with vertical columns and horizontal lines that cross in cells. In the first column, the characteristics are distributed leading to the expected profile; the first line, provides up the various resources to be evaluated that mobilized in educational processes and training, make up the competences: knowledge, ethical and aesthetic choices, abilities, attitudes etc. Such resources can be categorized into large blocks, which may signal aspects of the context, of the relationships, of the institutional goals, guided by the profile characteristics to be formed. The interconnection of cells synthesize the evaluation objects or activities performed, allowing the crossing of each profile characteristic with the various resources to be mobilized (Marinho-Araujo & Rabelo, 2012; Rabelo, 2013). In the context of this study, the matrix for the assessment of transversal competences will be composed of the lists indicated above and shown in Figure 1.

		Transversal Competences						
		Teamwork	Communication	Time Management	Creativity and Innovation	Scientific Rigor	Interpersonal Relationship	Decision making
Characteristics	CH1							
	CH2	X					X	X
	CH3							
	CH4				X			
	CH5							
	CH6							
	CH7		X		X	X	X	
	CH8			X				

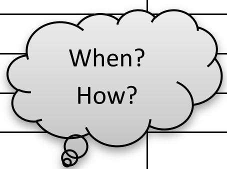

Figure 1: Reference Matrix for IPIEM2 project transversal competences

In the evaluation process, the matrix can be the basis for the construction of different types of instruments that should be applied in accordance with the planning and objectives of the project so as to contribute to the desired training. These tools may be qualitative or quantitative, such as questionnaires, surveys, tests, exams, checklists, workshops, reports, portfolios, and presentations. It should be noted that the instruments will investigate, at the same time, multiple features and profile characteristics, contributing to the assessment of several competences (Marinho-Araujo & Rabelo, 2012; Rabelo, 2013).

From the comprehension of competences presented in this article, authors highlight the multidimensional methodology of the reference matrix to, from the expected profile, identify the resources that make up the competences, involving aspects ranging from the individual to socio-cultural, situational (contextual, organizational) and procedural. The competence assessment based on the matrix can become an investigative tool that articulates educational, professional and socio-political dimensions.

4.2 Assessment Process

In order to clarify the application of the matrix for the assessment of transversal skills, some examples based on the IPIEM2 will be showed. One of the characteristics of the professional profile of graduates in this field is to be able to "perform effectively in teamwork contexts, both as member or as a leader, to tackle open problems with incomplete information, characterized by technical complexity and uncertain contexts" (CH2). This characteristic is linked with the expected learning outcomes of the IPIEM2, which is based on a PBL approach, strongly encouraging the development of transversal competences throughout its process. In this case, the transversal competence related to CH2 is Teamwork. In this way, it is important to develop assessment methods and tools which also assess the transversal competences because, by doing so, they are preparing graduates to meet the required characteristics demanded by professional bodies and organisations in their field.

In IPIEM2, the assessment of transversal competences can be described in Table 2. This table describes assessment moments, methods and participants used to assess transversal competences and at the same time establish a relationship with the characteristics of the profile, showing how they are highly linked.

Table 2: Process Elements of the Assessment of Transversal Competences in IPIEM2

What is assessed? *Transv. Competences*	**When is it assessed?** *Moments*	**How is it assessed?** *Methods*	**Who assess?** *Participants*	**Why assess?** *Characteristics*
Teamwork	Execution and End	Peer Assessment	Students	**CH2**
Communication	Start, Execution and End	Presentations	Academics	**CH7**
	End	Reports	Academics	**CH8**
Time Management	Execution and End	Peer Assessment Deliverables	Students Academics	**CH8**
Creativity and Innovation	Start, Execution and End	Presentation	Academics	**CH7**
	End	Prototype	Academics	**CH4**
Scientific Rigor	End	Reports	Academics	**CH1**
	End	Journal Paper	Academics	**CH1**
Interpersonal Relationship	Execution and End	Peer Assessment	Students	**CH2**
Decision Making	Execution and End	Peer Assessment	Students	**CH2**

To show an example, student's communication competences are assessed in several moments during the project such as at its start, throughout the project's execution and at its end *(when?)*. These competences can be assessed through oral presentations and project reports *(how?)*. The participants involved in the assessment process usually include lecturers and tutors *(who?),* usually in the final stage of the project. It should be noted that professionals give feedback but do not attribute grades. To support the assessment methods used, rubrics with assessment criteria were created to allow a common assessment framework, when assessing oral presentations and written reports. In these rubrics, criteria in regard to communication competences are specified and indicators of performance are presented to facilitate the assessment task.

5 Final Remarks

The challenges facing engineering teaching are complex and demands alternative ways to organize the learning process, namely by selecting the content of the course, planning the methods and strategies to students accomplish the learning outcomes, defining the assessment process, amongst other issues. The learning situations prepared by the teacher should include opportunities for students develop a combination of technical and transversal competences associated to their professional practice. The PBL approach make it possible by creating collaborative environments where students can link theory with practice, in order to solve engineering problems. The assessment is one of the main challenges for teachers.

In this paper was described a model for assessment of transversal competences. This model, represented by a matrix, includes the characteristics of the professional profile, the transversal competences that are expected that students develop within PBL context and the assessment dimensions (moments and methods). The link with professional profile highlight why these competences need to be considered in the curriculum development, allowing to analyse the teaching and learning practices. For example, from the observation of the matrix could be possible to identify a lack of assessment methods for required transversal competences.

The findings of this study point out issues that can be developed further, exploring the flexibility of the matrix, such as expanding it to technical competences; using other curriculum contexts, based on traditional teaching approaches, and compare with PBL contexts; defining and using alternative methods of assessment (e.g. scenarios that simulate real situations).

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Problem-Based Learning in a Virtual World: Assessing Self-Directed Learning when Using Simulation in Engineering Education

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Abstract

The focus of this study is on the students' levels of self-directed learning when using simulation in a virtual reality environment. This work was performed in the context of examining the effectiveness of simulation as an e-learning tool. Data were collected from three first year engineering courses in a Polytechnic in Singapore, that leverages problem-based learning (PBL). An existing validated method of measuring self-directed learning, Stockdale and Brockett's (2011) Personal Responsibility Orientation to Self-Direction in Learning Scale (PRO-SDLS), was tried initially, but found to be unsuitable in this context. An adaption of Spada and Fröhlich's (1995) Communicative Orientation of Language Teaching Observation Scheme (COLT) was more successful for a qualitative research.

This study describes an alternative, non-intrusive tool for the measurement of self-directed learning. This tool gains a high data resolution over time by recording and coding student-student and student-facilitator interactions. It specifically aims to assess the dynamics of self-directed learning within individual learning events, without using student input through surveys or self-assessment.

The findings of this study so far suggest that the use of simulation in PBL engineering education can improve self-directedness of students. It also indicates instances of good facilitation, conducive to high levels of self-directedness of the students when engaged in simulation exercises in a PBL environment.

Keywords: simulation, virtual reality, problem-based learning, self-directed learning, engineering education

1 Introduction

The use of simulation and virtual reality for learning, specifically in a problem-based learning (PBL) context of a Polytechnic in Singapore, has been in the focus of the authors for some time already (Schlag and Papayoanou, 2014; Schlag and Tan, 2014). High student numbers require considerable investments into laboratory installations. Simulation can take place in such setting, adding to cost for dedicated equipment, personnel and laboratory space. There are also PC or web-based tools, some with free access, that even qualify for distant learning. Educators must know about the effectiveness of these tools, their right mix and effective modes of engagement for student-centered learning.

Since self-directed learning has been declared a desired learning outcome for tertiary students by the Singapore Ministry Of Education (MOE), examining the effectiveness of simulation in a virtual reality environment as an e-learning tool eventually required a study of students' levels of self-directedness. Literature offers a variety of definitions for self-directed learning (Brockett and Hiemstra, 1991; Candy, 1991; Knowles, 1975; Leach, 2000; Teo et al., 2010; Tough, 1971). There are also several tools available, including validated methods for the measurement of self-directedness of students. There have been limited and scant studies found on the assessment of self-directedness among college students when using simulation. The findings of this study for the assessment of self-directedness through analyzing student-student and student-facilitator interaction intend to fill this gap.

This study was guided by three research questions: (a) Does the use of simulation in a virtual reality improve self-directed learning? (b) Can self-directedness be measured during simulation? (c) How does the facilitator performance influence the students' self-directedness when learning in a virtual environment? Research was undertaken in regular classes and workshops of the aerospace engineering and aerospace management courses of the School of Engineering, involving 120 students and their facilitators.

2 Literature Review and Definitions

2.1 Self-directed learning

Literature was examined for definitions of self-directed learning under due consideration for demarcation from self-regulated learning, self-motivation and others (Saks and Leijen, 2013). Leach (2000) shares that although a large volume of literature discusses its definition, principles and practice, there seems to be no single, accepted definition of self-directed learning.

Self-directed learning has its origins in Western adult education (Tough, 1971), and has become one of the key features of student-centered learning in the educational community. Self-directed learning is referred to as "the ability to learn on one's own" and "a process in which individuals take the initiative, with or without the help of others" (Knowles, 1975). Self-directed learning is therefore being deemed as a solitary, independent activity. Schmidt (2000) refers self-directed learning to "the preparedness of a student to engage in learning activities defined by him- or herself, rather than by a teacher". This definition addresses the motivational component of having the willingness and ability to engage in learning activities. It is believed that "learning environments that foster self-directed learning will promote deep-level processing in which learners seek meaning in the subject matter rather than surface-level processing where learners are engaged in rehearsal and memorisation" (Candy, 1991). Brockett and Hiemstra (1991) define self-directed learning as "a process in which the learner assumes a primary role in planning, implementing and evaluating the experience". Candy (1991) considers self-directed learning as a goal and process, and defines four dimensions of self-directed learning: personal autonomy, self-management in learning, the independent pursuit of learning, and the learner control of the situation.

It was later argued by Brockett and Hiemstra (1991) that "it is a mistake to automatically associate self-directed learning with learning in isolation or learning on an independent basis". Self-directed learning includes learning in association with others. Therefore, they define self-directed learning as "a process in which the learner assumes a primary role in planning, implementing and evaluating the experience".

The authors of this study implemented a definition adapted from the literature on self-directed learning for easy use in an engineering education process: During the process of self-directed learning the learner takes ownership of both the learning content and the learning method.

On a larger scale, this includes the following activities: identification of learning need, goal setting and task analysis, implementation of the plan, and measuring of learning (Teo, et al., 2010). It may exhibit the following traits: motivation, goal orientation, locus of control, self-efficacy, self-regulation and metacognition. This definition omits issues concerning the purpose of learning and it assumes that self-directed learning does not exclude teamwork and effective facilitation.

Based on this definition, methods were studied to measure self-directedness of learning in the PBL environment and particularly when using simulation.

2.2 Virtual Reality-Based Simulation

Educators aim for students to be able to apply knowledge and skills learnt in a classroom in relevant situations in the real world. A simulated environment allows the students to practice such transfer in a protected setting; hence the use of simulation in education has become increasingly popular. Simulation, coupled with technology, has a rich history in aviation (Helmreich, 1997), while in recent years simulation has become popular in other fields, such as health care education (Buchanan, 2001). Therefore, many studies have been carried out to evaluate the effectiveness of the use of simulation as an educational tool (Buchanan, 2001; Harder, 2010; Scalese, Obeso and Issenberg, 2008).

Simulation is defined as “tools that facilitate learning through practice in a repeatable, focused environment. Additionally, simulations are safe, flexible, resource efficient, globally accessible when web-based, and effective in helping students develop visual and conceptual models” (Aldrich, 2003). The use of simulations represents the natural way of “learn by doing” (Stančić, Seljan, Cetinić and Sanković, 2007). Children engage in simulation activities by role playing, while adults use computer simulations in order to understand complex systems and situations or dynamic processes. Computer simulations also allow us to analyze situations or processes that would be difficult, impossible, dangerous, too long or too expensive to be performed in real life (Lunce, 2006).

For the purpose of this study, the authors adopt the following definition: Simulation is a process where real people act in accordance with assumed roles in a virtual reality. The virtual reality is formed through a combination of a virtual environment and one or more virtual entities to penetrate it.

2.3 Measurement of Self-directed learning

There are a number of validated instruments for measurement student’s self-directedness in use (Bartlett and Kotrlik, 1999; Guglielmino, 1978; Oddi, 1984). In this research, an attempt was made to use the Personal Responsibility Orientation to Self-Direction in Learning Scale (PRO-SDLS), a self-declaration questionnaire containing 25 test items, each based on a five-point Likert scale. PRO-SDLS was developed by Stockdale and Brockett in 2010 and is the newest instrument currently in use (Stockdale and Brockett, 2011). It is compatible with the definition of self-directed learning governing this study.

3. Methodology

3.1 Educational context

This study was conducted in a polytechnic in Singapore. Learning typically takes place using a PBL approach where problem scenarios are presented to a class of 25 students, who work in small teams of five alongside their assigned class facilitator, once a week over a period of 15 weeks. The same process is replicated for other modules in the week. Each PBL day is typified by a schedule of three meetings with facilitator interaction, and interspersed by two periods of self-study or teamwork (Yew and O’Grady, 2012). This format is known as One-Day-One-Problem. For the Aerospace related courses, certain lessons are conducted in the Airbus A320 Flight Simulator, where students are introduced to the concepts of aerodynamics and flight control, aircraft systems and avionics. In addition, an online wind tunnel simulator has been utilized and problem scenarios have been played out as simulation of a call center. The School of Engineering also possesses an Aerodrome simulator, which in this study was used in a workshop setting.

3.2 Participants

The participants in this study were Year 1 students enrolled in the Aerospace Engineering and Aerospace Management related diploma courses. Groups of students have been observed over a 15-week semester, exclusively conducted in a One-Day-One-Problem PBL context. Student activities were observed during their regular classes when engaging in simulation and during workshops conducted as extra-curricular activities with voluntary participation of the students. 120 students out of 450 in this cohort have been observed each throughout a number of learning events.

A lecturer was assigned to each of the 15 classes for the entire semester. Lecturers possessed both working experience in the Aerospace industry, as well as formal training and experience in facilitation of learning in this unique PBL context. Three of them had specific experience with simulation (two as former airline pilots, one as air traffic controller).

Ethics approval for the research was sought from, and granted by the relevant authorities at the institution. Both, students and staff participating in the research were assured of anonymity and all individual data were de-identified in the data sets for analysis.

3.3 Instrument A

The initial aim of this study was to identify existing validated methods, such as Stockdale and Brockett's PRO-SDLS, for use in a PBL environment and particularly in simulation and work with virtual reality. Consequently, the PRO-SDLS questionnaire was distributed electronically to 450 students[1].

3.4 Analysis A

For this study, return rates were disappointingly low (22 responses). However, this problem only added to previously considered limitations. Thus, analysis was attempted, but after initial examination of the data the researchers decided to discard this method due to the following reasons.

Using PRO-SDLS it was found that, as most forms of self-declaration, it carried a number of disadvantages which made it unsuitable for the process of simulation in Engineering Education. The situation is not helped by a general survey fatigue of students, especially in institutions with high research activity. Surveys and self-declarations either assess a situation summarily and in retrospect or need to be used in an interrupting way, where students' work is disturbed by appraisal. Since self-directed learning is not a skill which can be tested, but rather a complex ability slowly acquired by students, trends and developments need to be observed over a period of time. Therefore, surveys would have to be repeated, possibly for a number of times. With low return rates it becomes difficult to reach a sufficient number of respondents who would be willing to follow up on the same survey again and again. Alternatively, a real-time self-assessment requires disruption of the learning process. In the case of self-directed learning such method would be most intrusive and not conducive to the learning process. Thus, a sufficient resolution of data over time was not achieved.

[1] The questions were slightly modified in order to adapt them to the context of the school and the specifics of engineering education.

Secondly, there were indications that students tended to try to make sense of the survey questions and thus anticipate researchers' expectations. The effect is known as social desirability bias (Fisher, 1993). Often, survey respondents sub-consciously try to meet expectations of the researchers and tend to aim for "good answers". Since self-directed learning is a declared learning outcome of this institution, students were tempted to answer the questions with that goal in mind and trying to portray themselves and the polytechnic in a more favorable light.

Thirdly, the use of a typical five-level Likert-type scale, as used in the PRO-SDLS tool, has got its own short comings, of which the central tendency bias, as the tendency of respondents to avoid extreme positions, shall be mentioned as most prominent (Podsakoff, MacKenzie, Lee and Podsakoff, 2003).

3.5 Instrument B

In order to find a more suitable way to assess the self-directedness of the students under observation, simulation related learning activities were video recorded, using tripod-mounted camcorders and Swivl robot (i.e. turn table stand) mounted with tablet computers. Especially in the flight simulator, recording with the Swivl device had been beneficial, since it allowed the researchers to see the students and the trainer from the front, which is usually rather difficult. While there is limited space for conventional recording equipment in an aircraft cockpit, the Swivl robot with the tablet computer or smart phone as recorder can be positioned on the dashboard in front of the pilots while the camera's orientation is remotely controlled by the researchers.

In addition, the researchers had access to the students' daily reflection journals and, for some exercises, asked them to complete dedicated reflections following specific questions.

3.6 Analysis B

In the quest for the development of non-intrusive tools for the measurement of self-directed learning with a high resolution over time (i.e. better discrimination of instances of SDL within one learning event), experiments were conducted with a modification of Nina Spada's COLT – Communicative Orientation of Language Teaching Observation Scheme (Spada and Fröhlich, 1995). In this setting, video recordings of learning activities were subjected to fine-grained descriptive, interactional, and discourse analyses (Luke, Freebody, Shun and Gopinathan, 2005) in order to identify different patterns and relationships of communication. While COLT was developed for use in secondary language classes, its basic concept was found useful for engineering classes as well. Therefore, the coding framework was adapted for this study, while a discussion of its validity is not intended here.

Similar to COLT, a coding scheme as shown in the appendix, contains four categories: participant organization, initiation-response-feedback exchanges, facilitator verbal interaction and student verbal interaction. Communication (both verbal and non-verbal) is classified as student-student and student-facilitator interactions. Typically, such interactions would start with an Initiation (I), followed by a Response (R) and possibly Follow-up (F) activities. Thus, exchanges are identified, classified and counted. Other than the traditional IRF exchanges, they can extend to more than one follow up (F) response and include more than two contributors (the modified tables are called Y-codes for this study).[2]

[2] In a later development, the coding tables were modified for the analysis of the work of student teams without facilitator (S-codes). All IRF activities now can be attributed to individual students.

Following the identification and classification of exchanges, an analysis of the content of the communication takes place. This analysis follows different patterns for the facilitator and for the students. In the case of the facilitator, it is distinguished whether the communication is procedural, off-task or in order to close an information gap. In the latter case it has to be declared whether information is provided or requested by the facilitator.

For students' communication, the analysis starts in the same manner, distinguishing whether interaction was off-task or a discourse initiation. If the intention of the interaction was to close an information gap, distinction is made whether information is provided or requested by the student(s). Interactions linked to the learning process are now discriminated for either timing, method, segment, environment, occasion, or intensity related content.

Both facilitator interactions, as well as student interactions are classified as minimal (i.e. brief) or sustained.

Using a Microsoft Excel sheet, the coder indicates the occurrence of the above features with check marks in the appropriate categories. Analysis of the data is based on the relative occurrence and non-occurrence of the categories coded. Results pertaining to each of the major categories form the basis of the discussion in the subsequent section.

4 Results and Discussion

Analyzing the interactions allows to identify instances when students, according to the researchers' definition, show evidence of self-directedness. Students were always working in small groups of typically five members and therefore had rich opportunities for peer exchanges.

It shall be remarked at this point that the analysis strictly follows qualitative research principles. It specifically aims to assess and describe the dynamics of self-directed learning within a learning event. At this stage of the research, the coding schemes do not allow a quantitative analysis for lack of validation.

The following section describes the observations made when researching coded recordings for behavioral patterns of such exchanges.

4.1 Ownership of the learning process

During the analysis of IRF exchanges, this study looked into the atypical initiation of an interaction by students as an indication of taking or maintaining ownership by the learners (Sunderland, 2001). Likewise, it is suggested that sustained interactions indicate ownership of the learning process by the students. Students reported awareness of their self-directedness in debriefings following learning events with simulation and when rated higher, typically the analysis showed more student-initiated IRF exchanges.

It was also observed that with repetitive exposure to learning with simulation of the same kind, IRF exchanges where more frequent and lasted longer.

4.2 Facilitator involvement

The best indication for self-directedness, as well as effectiveness of facilitation, is a repetitive fading of facilitator involvement. Hennessey, Deaney and Ruthven (2005) describe "fading" as the ultimate goal of the teacher: "Fading then involves a gradual abbreviation and withdrawal of help, and learner participation increases as independent thinking and skills are developed" (p. 267).

The researchers have observed distinct differences in the behavior of individual facilitators with changing groups of students. It appeared that good facilitation often showed low involvement of the facilitator in IRF interactions after the initiation stages. More so, over the course of a simulation event, a gradually reducing involvement of the trainer in the IRF interactions was seen for good instructors[3], while facilitation perceived as sub-optimal showed a more sustained participation of the facilitator both in individual IRF interactions, as well as for the duration of the event. Generally, less experienced facilitators seemed to reduce IRF interactions mainly to facilitator initiation and a single student response. Student-initiated interactions were in such circumstances rarer and also short-lived occasions.

In their reflections, facilitators pointed at learning events perceived as successful and others as not so good. As indicator for successful learning events it has been reported that students would take clues and then proceed on their own, while in less successful learning events students required constant guidance and directions in order to perform the simulation work. An expression has been that "students needed to be dragged along." For the latter case, facilitator involvement seemed to be increased and continuance of interactions shortened in such instances.

Noteworthy insights emerged in instances of a temporary absence of a facilitator. This did happen for the use of the web-based wind tunnel simulator during the self-study periods, for the flight simulator when instructors had to leave the room temporarily and in the case of the virtual aerodrome simulator, which is housed in two separate rooms[4], when the instructor attended to the students in the other room. The three-dimensional simulators (i.e. flight simulator and aerodrome simulator) typically registered a surge of student interaction. The web based simulation typically saw an initial reduction of activity, often followed by a gradual return or increase over time.

4.3 Ownership of learning content

Ownership of content can be seen with more distinction through the analysis of students' verbal interactions, specifically through the content analysis (i.e. timing, method, segment, environment, occasion and intensity related content). An overweight of off-task and procedural interactions suggest low levels of content ownership (Sunderland, 2001). Likewise, an agile exchange of content information between students or between students and facilitator, particularly when inquiry is initiated by students, indicates a higher level of content ownership.

However, coding of process related interactions appears to be the biggest challenge for the coder.

4.4 Role playing and real world artefacts

Observations have been made that simulation with intense roleplaying (i.e. taking on a position in a crew, such as captain, copilot or air traffic controller, accepting a real world responsibility in a simulated situation, as seen in the call center simulation), increases IRF activities and reduces the off-task interactions. At this point an additional analysis of social media activity of the students seems to be desirable, though has not been executed yet. It has been seen that when the facilitator also takes an active part in roleplaying, the above tendencies are amplified.

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[3] Students', as well as facilitators' reflections were used to identify "good instruction".

[4] One room replicates the control tower with two working stations and another room is dedicated to vehicle control with three working stations.

Equally, the use of real world artifacts (such as checklists, charts, manuals etc.) increases the immersion of the students in their task and thus the level of self-directedness. This observation may explain why the use of the web based wind tunnel simulator heralded less indications of self-directedness than the other simulations.

5 Conclusions

The study was governed by three research questions: (a) Does the use of simulation in a virtual reality improve self-directed learning? (b) Can self-directedness be measured during simulation? (c) How does the facilitator performance influence the students' self-directedness when learning in a virtual environment? The coding schemes were developed in order to measure self-directedness of students during learning events using simulation.

At first glance, the above described method seems to have the capacity to deliver answers for the first and the last research question. In the PBL process of this institution, daily reflection journals are submitted by the students. For the groups of students observed in this study, specific questions have been asked about the usefulness of simulation and the development of their personal learning habits. Though a full analysis has not been accomplished at this time, first impressions indicate a possible correlation between subjectively perceived usefulness of the learning with simulation and the clues derived from the coding schemes. Therefore, both questions can be answered with the research material gained in this study, though this has to be the content of another research study.

With reference to the second research question: Can self-directedness be measured? In a strictly qualitative manner this question can be answered in the affirmative. Self-directedness, in accordance with the researchers' definition, can be detected or denied. Further research needs to aim for the validation of the data in order to assess the usefulness of the method for qualitative research.

However, it needs to be admitted that the coding process is labor intensive and time consuming. Thus, the method does not have the potential for a real-time self-directedness indicator. It also needs to be acknowledged that, while having a good resolution over time and therefore a good capacity to analyze individual learning events, the coding schemes are less useful to indicate the global status of a learner (i.e. the learner's competency for self-directed learning and the ability for its application). This is the domain of questionnaire or test based inquiries. Knowing this limitation is important, since self-directedness is a global learning outcome of tertiary education and as such there is a need for assessment. Thus, both approaches (i.e. testing or self-reporting and observation) should be taken in parallel when investigating self-directed learning.

The described method indicates the presence of, but does not distinguish the specific cause for self-directedness of students. It is assumed that PBL improves self-directed learning. Therefore, it can be argued that PBL students would learn in a self-directed manner even without the use of simulation. To clearly make that distinction, further analysis of the self-study periods (i.e. absence of a facilitator) and a comparison of learning with a real wind-tunnel versus learning with a simulated wind-tunnel will be performed based on the existing material.

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Appendix

Time	Participant Organisation						IRF Exchanges							Total Turn Count	Facilitator Turns	Student Turns	Facilitator Verbal Interaction						Student Verbal Interaction											
	Class		Group		Individual														Information Gap		Sustained Speech				Information Gap		Sustained Speech		Process					
	T to SC	S to SC	Same task	Different tasks	Same task	Different Task	IRF	Initated by Facilitator (1m)	Initated by Student (2m)	Response by facilitator (1m)	Response by student (2m)	Feedback by facilitator (1m)	Feedback by student (2m)				Procedural Talk	Off Task	Giving	Request	minimal	sustained	Off Task	discourse intiation	Giving	Request	minimal	sustained	Time	Method	Segment	Environment	Occasion	Intensity

coding scheme rubrics

Assessing student individual performance within PBL teams: findings from the implementation of a new mechanism

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Abstract

This paper reports on the experience of the implementation of a new mechanism to assess individual student contribution within project work, where students work in teams to solve a large-scale open-ended interdisciplinary project. The study takes place at the University of Minho, with first year engineering students, enrolled in the Industrial Management and Engineering (Integrated Masters) degree. The aim of this paper is to describe the main principles and procedures underlying the assessment mechanism created and also provide some feedback from its first implementation, based on the students, lecturers and tutors perceptions. For data collection, a survey was sent to all course lecturers and tutors involved in the assessment process. Students also contributed with suggestions, both on a workshop held at the end of the project and also by answering a survey on the overall satisfaction with PBL experience. Findings show a positive level of acceptance of the new mechanism by the students and also by the lecturers and tutors. The study identified the need to clarify the criteria used by the lecturers and the exact role of the tutor, as well as the need for further improvement of its features and procedures. Some recommendations are also issued regarding technical aspects related to some of the steps of the procedures, as well as the need for greater support on the adjustment and final setting of the individual grades.

Keywords: Project-based learning, peer assessment, individual performance, engineering education.

1 Introduction

Project-based Learning (PBL), also known by Project-Led Education (PLE), is an active learning methodology, which, when adequately applied in higher education, improves student motivation and learning (Powell & Weenk, 2003; Graaff & Kolmos, 2007; Moreira et al., 2011; Fernandes, 2014). According to Powell & Weenk (2003) PBL can be feasibly applied on large open-ended projects which are tackled by teams of students with the support of academic staff, that performs both as a lecturer of the Project Supporting Courses (PSCs) and as a tutor of a team of students.

At the University of Minho, a PBL methodology has been implemented in the first year of the Industrial Management and Engineering (IME) degree program since the 2004/2005 academic year, and revealed positive results in terms of improving student learning and motivation (Powell, 2004). In the IME PBL project, students work together in teams of 8 to 9 members, to solve large scale open-ended problems, which require the application of contents from all subject areas involved in the first semester of their study plan. The deliverables for each team are assessed by the group of PSC lecturers who, altogether, provide a quantitative evaluation for each team, i.e. the final grade for the team. Assessment of teamwork and of transversal competences, developed within this cooperative learning environment, have always been an important concern when setting up the assessment model for each PBL edition. Teamwork in PBL is mainly assessed by peer assessment processes. Students in a team assess each other's performance using a predetermined list of criteria focused on teamwork competences. The quantitative result from this process is called a “Correction Factor” (CF). At the end of the semester, the CF distinguishes each team member and the final grade achieved in the project, i.e. the individual grade is shifted up or down accordingly. However, the average of CF within each team must be equal to 1.0, which translates into individual grades average equal to the group grade. Another mechanism in place, to assure no fuzzy deviations occur on individual grades, is a written exam focused on each team’s project. However, the use of this mechanism on previous editions was prompt to strong criticism by the students.

This paper seeks to describe and evaluate a new mechanism to assess students' individual performance in PBL teams. The previous model led to a number of students’ complaints and also a growing awareness that the mechanism was not fully recognizing each individual contribution. The new mechanism which we propose here involves an open reflection made by all course lecturers in regard to each team member, considering each student´s individual performance in the project along the semester. Teachers collectively discuss and agree on the relative position of team members performance, e.g. below or above the group average. This translates into a quantitative result, which is used as an individual correction factor (FC2) to obtain the student's final grade.

In this paper, students’ and teachers’ perceptions on the adequateness and reliability of this new mechanism are discussed and analysed, in comparison with previous findings and research carried out within this case study. Suggestions for improvement and ways to strengthen the assessment process are also explored.

2 Assessment of individual performance within teams

Team work is a practice that has been widely used in teaching/learning context. With students of younger ages or with undergraduate students, learning by groups emerges as an opportunity for collaborative learning and individual development. Despite its benefits, the difficulty arises in the moment of the definition of the individual grade (Johnston & Miles, 2004). As Zhang & Ohland (2009) state: “the assigned marks should accurately reflect each individual’s knowledge or skills in the assessed content domain. This, by no means, is easy to achieve as it is hard to evaluate how much knowledge or skills one individual student has demonstrated from doing a group project” (Zhang & Ohland, 2009, pp.291). Since much of the team work occurs outside formal teaching sessions, the individual inputs and the output are not clear into team assignments (Johnston & Miles, 2004). As Nepal (2012) pointed out “there is a need for a balance between a ‘good’ and a ‘fair’ distribution of individual marks and a teamwork exercise” (Nepal, 2012, pp. 398). Lejk & Wyvill (1996) reported nine different methods of assessing groups of students:

Method 1. Multiplication of Group Mark by Individual Weighting Factor
Method 2. Distribution of a Pool of Marks
Method 3. Group Mark Plus or Minus Contribution Mark
Method 4. Separation of Process and Product
Method 5. Equally Shared Mark with Exceptional Tutor Intervention
Method 6. Splitting of Group Tasks and Individual Tasks
Method 7. Yellow and Red Cards
Method 8. Assessment of the Information Systems Group Project (ISGP)

Method 9. Deviations from the Norm

More recently, Nepal (2012) considered the existence of three methods to allocate individual marks by adjusting a team mark: (1) distributing the pool of marks by adding differentials; (2) adding a mark to or subtracting a mark from the team mark, based on an individual contribution, which is determined via process assessment; and (3) multiplying the team mark by a factor derived from an individual's contribution.

Since 1974, at Aalborg University (AAU), Denmark, all programs are based on problem-based or project-based learning (PBL). The objectives of PBL include technical, contextual knowledge and process skills which are ought to be developed cooperatively. Therefore, it seemed natural that project exams were carried out by using group-based assessment methods with individual grading (Kolmos & Holgaard, 2007; Dahl & Kolmos, 2013). Until 2006, the formative, the summative assessment and exam of the project were peer or group-based (Kolmos & Holgaard, 2007; Dahl & Kolmos, 2013). An overview of the process is as follows (Kolmos & Holgaard, 2007): each group of six elements gives an oral presentation based on a written report, followed by a discussion with the supervisor and an external examiner. There are three time breaks during discussion, when the examiners discuss and vote the individual grades. They also discuss whether some students should receive extra attention. In that case, those students must respond individually by request, but always in the presence of all team mates. At the end, there is a final voting and grading. In 2006, in Denmark, it was banned by law to assess students in a group setting, so the oral presentation and the subsequent short discussion were included as the final part of the project, and not considered for grading. After a break, each student was questioned alone with the supervisor and the external examiner. At the end, each student had an individual grade (Kolmos & Holgaard, 2007). According to Dahl & Kolmos (2013), some studies revealed that both students and supervisors preferred the group-based exams. In 2012, there was a new change in the law, which enabled, once again, the possibility to assess students with group exams. The new setting for those exams, defined as mandatory that they were partly based on individual assessment. After the oral presentation and the group discussion, each student is individually asked to answer questions about the project in the presence of the other elements of the group. The grade of each student reflects the examiners' assessment (the supervisor and an external examiner) on all three parts of the exam (Dahl & Kolmos, 2013). The external examiner can be someone from outside the AAU or another member of the academic staff, as determined in the study regulations. As publicized by the AAU, targeting future students: "Although you will be evaluated on the basis of your individual performances, being examined alongside your group mates can add more perspectives to discussions and you can supplement and support each other during the examination." (AAU, 2015). Internationally, peer assessment is a method often used, to assess PBL, to differentiate individual contributions in group projects. However, in Denmark, peer assessment is not legally allowed as an assessment method for grading and is only used for motivational and learning purposes (Triantafyllou & Timcenko, 2014).

Project-based learning is an instructional approach that is gaining increasing interest within the engineering education community. The literature advocates active team learning and supports individual assessment models. These require the development of tools and strategies for effective assessment in PBL, which is known to be challenging. Since the tasks involved in PBL are so diverse, there are several methods that may be used together to assess student learning. Self-assessment, peer assessment, personal reflections or portfolio assessment, are some of the strategies frequently used, to consider to reach a final grade. PBL projects do involve synthesis for different artefacts and it is likely that both individual and group grading will be found in many PBL projects. Although peer and self-assessment methods may be seen by some as biased, they are considered relevant in the context of a PBL environment and offer useful insights, which would be, otherwise, overlooked. Its use has become increasingly popular with the success of PBL.

Presently there are numerous software applications available that allow the teacher to engage the students in reviewing each other's products and to assess the value of each other's contributions (Fernandes, S., Flores, A. & Lima, R., 2007).

According to Bogaard & Saunders-Smits (2007), "peer and self-evaluations are an excellent way to monitor and evaluate group skills in project based design work. Peer evaluations allow faculty to differentiate in individual grading of group work and prevent free-riding." In this paper the authors compare the system developed at Delft University of Technology with existing systems in Eindhoven and Sidney based on their functionality and cultural dimensions. Bronson et al. (2007) focused on the development of an assessment template (designed to be given to each student individually and filled out anonymously) for peer assessment, that was implemented on the first year of engineering degrees at Vitoria University, Melbourne. Students evaluated their peers using 5 major criteria and the results were used by staff to help in assessment of teamwork skills. Mitchell & Delaney (2004) also describe an assessment strategy which includes self-assessment for grading individual students in a small group PBL setting in software engineering education in National University of Ireland. In 2011, Triantafyllou & Timcenko (2011) studied and reported the opportunities and challenges for student and educators in applying different peer assessment strategies in a PBL engineering program, including computer assisted peer assessment. Portfolio assessment also provides one way to summarize a longer and larger body of work. Doppelt (2005) suggests the use of student portfolios as an assessment method, which is based on records of students' activities. The portfolio might consist of items, such as written material, computer files, audio and video media, sketches, drawings, models and pictures. Cockayne et al. (2003) present a tool for assessment based on a model of taxonomic classification in the School of Engineering at Stanford University.

3 Context of Study

The first semester of the first year of the Master's on Industrial Engineering and Management (IEM) from University of Minho holds the curricular structure as depicted in Table 1

Table 1: Semester 1 of the first year of the Master's on Industrial Engineering and Management (IEM).

Regime				ECTS
Year 1	Curricular Unit	Scientific Area	Acronym	60
S1	Algorithmics and Programing	CB	AP	5
S1	Calculus EE	CB	CALC	5
S1	General Chemistry EE	CB	GC	5
S1	Integrated Project in Industrial Engineering Management	CE	IPIEM1	5
S1	Linear Algebra EE	CB	LA	5
S1	Topics of Industrial Engineering and Management	CESP	TIEM	5

All the Curricular Units from the semester are PSCs, i.e. give support to the development of the interdisciplinary PBL IME project, conducted by six teams, with 8 to 9 student members each. The PSCs belong to two different schools, the Sciences and Engineering schools from University of Minho. The PSCs have the support of five distinct lecturers from four departments: mathematics, chemistry, information systems and production systems. All five lecturers also give support to the IPIEM1.

The assessment mechanism for evaluating the teams' projects is shown on Figure 1. As the figure shows, each project is assessed based on four distinct deliverables: (1) preliminary report; (2) final report; (3) presentations; (4) prototypes. All lecturers participate in grading the deliverables (1), (2) and (3).

Deliverable (4) is graded by TIEM and AP lecturers. The Team Grade is calculated given the relative weights for each one of these deliverables, which is also represented on the same figure.

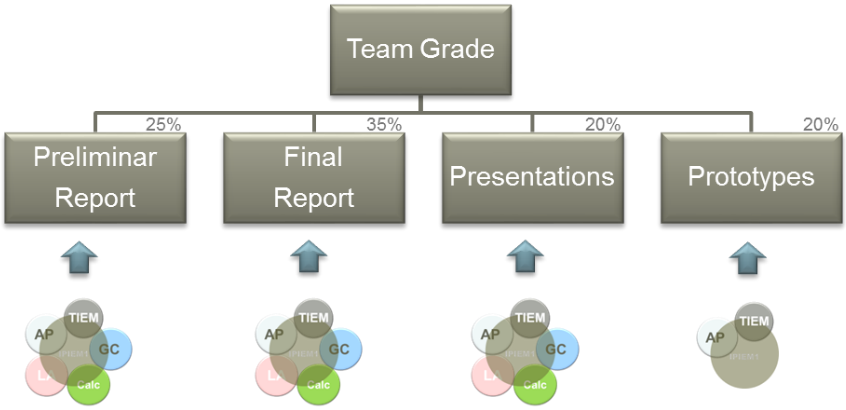

Figure 1: Assessment model for the PBL IME teams.

Previous editions of the PBL IME considered the following mechanisms to grade individual members on each team: (1) peer assessment; and (2) individual written exam on the project. Given prior and consistent criticism to mechanism (2), along a number of PBL IME editions, a new mechanism was designed and implemented on the 12th edition (2014/2015 academic year). Mechanism (1) remained unchanged on assessing individual performance. This rests on three distinct assessments along the semester, whose average results in the FCI1 (individual correction factor 1) parameter. The new mechanism (2) is explained on the following section.

3.1 Design of the new mechanism to assess individual performance

The new mechanism (2) fully replaces the individual written exam. The team of lecturers is responsible for granting the FCI2 (individual correction factor 2) parameter, as illustrated in Figure 2, which is determined in a single meeting after all deliverables were fully handed over. The overall FCI (individual correction factor) is a simple average of FCI1 and FCI2.

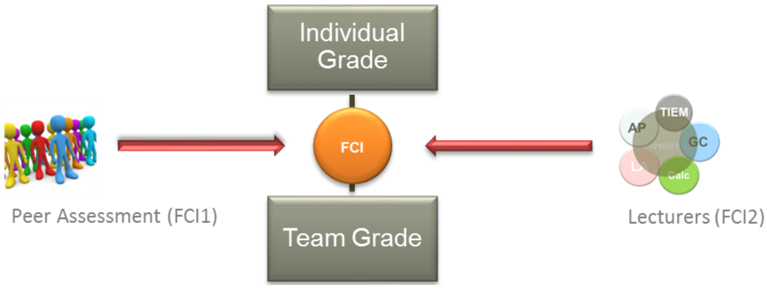

Figure 2: Assessment model for the PBL IME teams.

The procedure of the mechanism (2), whose output is a quantitative value (percentage) of FCI2 for each student, will now be described in detail.

The full team of PSCs lecturers meet and analyse each one of the student teams. For each team a 4 step procedure is conducted:

Step 1: Positioning
Step 2: Adjustment
Outcome: **Initial proposal for FCI2**
Step 3: Tutor (agreement /discrepancy)
Step 4: Setting
Outcome: **Final proposal for FCI2**

This includes the input from each team tutor, which, at step 3, intervenes, in order to corroborate, or otherwise disprove or give new insights into the initial setting, i.e. the initial proposal for FCI2 (just after step 1 plus step 2). Figure 3 illustrates the mechanics of the procedure.

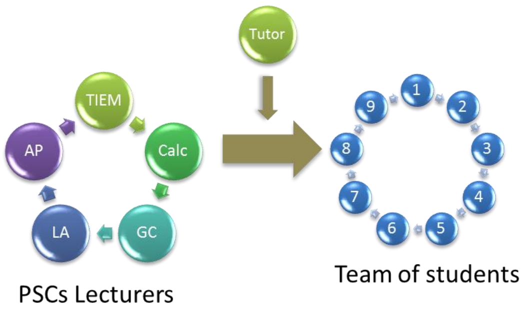

Figure 3: Mechanics of the procedure.

The input from the tutor helps the team of lecturers to understand in a deeper manner, eventual team dynamics, which somehow were not recognised by all lecturers, potentially giving new insights into the positioning and adjustment for each (or some) student within the team. This allows for a new setting and for fine tuning the FCI2, on step 4. Given that the qualitative assessment of each student has to be translated into a quantitative parameter, and that the average of the parameters inside a team has to be equal to 1.0 (in a similar fashion to that of FCI1), step 4 also requires a considerable work on adjusting the parameters to satisfy such requirements. A representation of the 4-step procedure is shown in Figure 4.

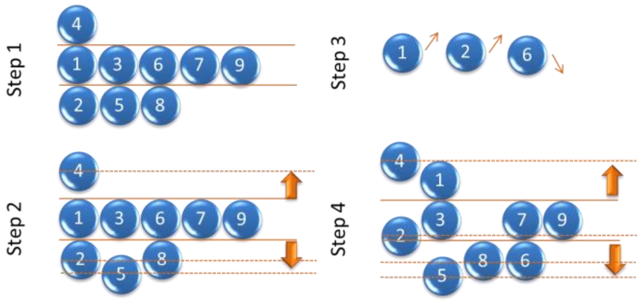

Figure 4: Illustration of the steps required, as defined in the procedure.

3.2 Implementation of the new mechanism to assess individual performance

Step 1 was executed using small photos of each team member. Here an initial positioning was done in a straight line, and photos were moved up and down, by the team of lecturers, meaning a positive or negative, or eventually neutral, contribution to the project by each individual. Perceptions of individual lecturer on each individual contribution were constructed, giving the prior interaction with the team and the individual (e.g. presence on meetings and quality of interaction), performance on the project presentations, demos of work-in-process tasks and prototypes, among others. Step 1 was rather interactive among lecturers (strong communication), as they gave input on individuals that justify their positioning opinion. After Step 1, fine review of the positioning was done, in order to further identify differences among students that were initially positioned on the same level. When the lecturers were comfortable with this positioning, the tutor was called-up to give his opinion on the outcome of the two first steps. This resulted on the maintenance of the initial positioning/adjustment in some cases, and discussion on others, in order to produce a revised version of it.

A number of unplanned situations occurred during the implementation stage worth mentioning. Two lecturers and one tutor were not available to join the meeting. Additionally, the absent tutor was unable to give useful feedback on the contribution of the respective team members on the project. The absent lecturers were subject to consultation, via email, after the meeting, in order to provide the required feedback on the team members for each one of the teams. The consultation was feasibly executed, although it took much longer and required a number of new interactions among the PBL IME coordination team, so that a final quantitative and consensual grading system could be obtained. In consequence, the procedure had to be adjusted to the above circumstances, which required not a linear set of sequential steps, but a number of iterations, not only on each step, but also among different steps.

3.3 Results achieved with the application of FCI2 Model

An example of the results of FCI2 for one team is shown on Table 2. The last column (FCI) is the average of FCI1 and FCI2. FCI is the team grade multiplying factor for each individual member.

Table 2: Results of peer assessment (FCI1) and of the new mechanism (FCI2).

Team A	Peer1	Peer2	Peer3	FCI1	FCI2	FCI
Student 1	98.20	100.10	102.70	100.33	97.50	0.989
Student 2	103.60	106.20	110.80	106.87	102.50	1.047
Student 3	94.50	86.90	87.80	89.73	94.17	0.920
Student 4	101.70	95.50	98.80	98.67	94.17	0.964
Student 5	109.70	113.90	112.70	112.10	110.00	1.111
Student 6	99.90	100.60	97.90	99.47	102.50	1.010
Student 7	99.00	101.30	99.30	99.87	102.50	1.012
Student 8	89.40	83.30	79.60	84.10	94.17	0.891
Student 9	104.00	112.20	110.40	108.87	102.50	1.057

As can be observed, FCI2 holds some similarities to that of FCI1 for some students, e.g. student 5 (the student that outperformed all the others), but rather distinctive results for others, e.g. students 1, 6, and 7.

4 Methodology

This study aims to give answer to the following research questions:

1. What are students, lecturers and tutors perceptions about the FCI2 Model?
2. What are the main problems or constraints of the implementation of FCI2 Model?
3. How can the FCI2 Model be improved in further PBL experiences?

In regard to the research design, the study followed a mixed model approach, using mainly qualitative data, although complemented with quantitative results achieved from a questionnaire used every year to collect feedback from students in regard to the PBL experience (Alves, Mesquita, Moreira & Fernandes, 2012). A survey was developed to collect feedback from lecturers and tutors, including open-ended questions based on four main themes: positive/negative features of the model FCI2; reliability/effectiveness of the model and its results; main difficulties and ways to overcome them; overall satisfaction and suggestions for improvement. In total, 9 teachers participated in this survey, 5 of them were course lecturers and 4 performed the role of tutors. Besides this, data from students was also provided by information from a questionnaire, applied at the end of each PBL edition. In total, 20 students (out of 51) participated in this questionnaire. The items from the questionnaire which focused on the new FCI2 Model were analysed and results will be presented to show students rating [likert scale from 1 to 5 - totally disagree / completely agree] in regard to their satisfaction with the new FCI2 model. Qualitative data was also collected from students through an open discussion held at a workshop aimed to evaluate the PBL semester, after its end. Several suggestions were pointed out by students to improve the method.

5 Results & Discussion

5.1 Students' perceptions about the FCI2 Model

Based on the questionnaire used to collect students’ perceptions, item 29 (*The FCI2 is a valid instrument to assess each team member*) and item 30 (*My score on FCI2 reflects my overall performance within teamwork*) it is possible to outline the following results, as shown on Figure 5. The average answer to item 29 was 3.15 out of 5, which is a moderate agreement to validity of the FCI2. The average answer to item 30 was 2.85 out of 5, which is also a moderate acknowledgement to the FCI2 grade reflecting their own performance as team members. On item 29 the results cover the full scale, i.e. results vary from “*totally disagree”* to “*completely agree”.*

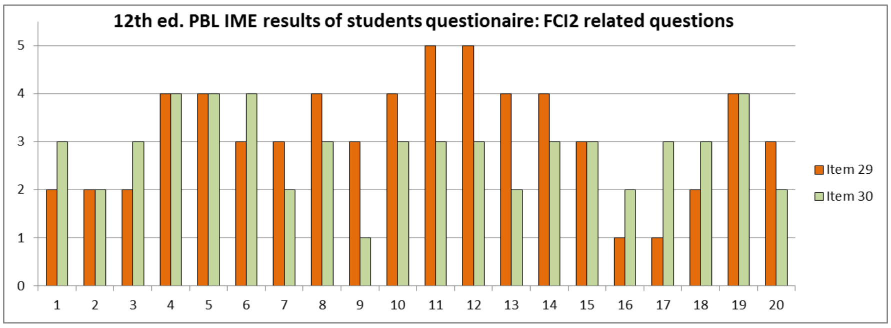

Figure 5: Results from students’ questionnaire (item 29 and 30).

A final IME PBL workshop was conducted at the end of the semester, aiming to discuss various aspects of IME PBL project. Based on a short presentation made by a team of students that reflected on the assessment model of the 12th edition of the PBL IME project, which included the FCI2 mechanism, and based on the open discussion, that followed, the following major issues were identified: (1) the students agree that the PSC lecturers should be involved on the assessment of individual members of the teams; (2) the students argued that the criteria for FCI2 assessment process needed to be clarified; and, (3) the role of the tutor within that process was not clear.

Although positive, the results achieved on items 29 and 30 of the questionnaire, seem to favour, but not, unequivocally, the new mechanism. On the one side, students tend to compare the results of FCI2 with those of FCI1 (although some students do not fully agree with the results of FCI1 as well), and on the other, some aspects of teamwork, which are somehow clear and valued by the students, were not considered, were undervalued or were simply invisible to the eyes of lecturers and tutors. The lack of clarification of the criteria to be used for the FCI2 assessment process may have reinforced this aspect. These issues require further investigation, namely a detailed comparison of FCI1 and FCI2 results.

5.2 Lecturers' and tutors' perceptions about the FCI2 Model

5.2.1 Positive/Negative features of the FCI2 Model

Based on lecturers and tutors perceptions, it is possible to stress the importance of the model to provide an overall view of each member performance inside the team, using teachers' opinions to sustain that decision, and also the advantages related to the visual characteristics of the model (recognizing each student by a photo), allowing an immediate result in distinguishing students in the same team. However, teachers point out the risks involved in using this type of mechanism, which clearly needs to be consolidated and improved in the future. The lack of experience and of explicit criteria, for both lecturers and tutors involved, as well as for students, were some of the less positive issues identified.

Table 3: Semester 1 of the first year of the Master's on Industrial Engineering and Management (IEM).

	Positive Features	Less Positive Features
L1	With the model it is possible to assess students in different moments (an exam does not allow this); It provides feedback to students about their performance; It allows students see their engagement in the project according to each student's goals.	Lack of experience in the application of this model; Students do not understand that the perception that teachers have of their performance can be different from what they consider their own performance.
L2	It allows an immediate perception of the overall contribution of each team member in the project, by several inputs given from a diverse group of lecturers and tutors; The model is very visual and its application is very quick.	The model is not consolidated yet in terms of criteria used and the level of differentiation of students; The overall result is too dependent on a large team and on each of the participants' opinion (lecturers and tutors); The absence of a participant could compromise the validity of the positioning of each team member and could even jeopardize the validity of the assessment of one or more other elements of the team.
L3	The possibility to differentiate students' grades in the same team; The different weight average given to the opinion of different teachers involved.	The criteria used by teachers to differentiate students are not clearly understood by students.
L4	Reflection on students' performance; Different contributions of students in the project can be identified.	It is not easy to have a clear perception on the real contribution of each team member; we need to identify objective elements for assessment.
L5	The possibility to exchange other teachers' opinions with our own; Flexibility in regard to the classification criteria.	For the case of students which we do not have a clear vision of their performance, there is an attempt to put them in a more passive role in the assessment process; The risk of underestimating students which are less communicative.
T1	Overall view of the team; Opportunity to highlight some students through using a visual tool.	It could be more advantageous to assess all teams of students simultaneously; Students without a visual profile can be penalized.
T2	I can't see any positive aspects...	I think the tutor rarely has elements to assess the students' performance in the team. Another negative aspect is that the tutor should play the role of a partner in the team, not the role of an evaluator.
T3	It avoids that the individual correction factor is not only a part of students' responsibility; It avoids recurring problems with the project exam in previous years.	The difficulty to eventually distinguish team members with very similar performance in the team; The effort to assess each student individually (especially in the lecturers case), with the risk on not being totally fair in some cases (due to the lack of information).
T4	It allows to correct students' individual grade based on teachers perception on their performance; It could avoid certain student results based on criteria such as friendships.	It is based on perceptions; It has a certain risk related with making wrong decisions.

5.2.2 Effectiveness of the model and difficulties encountered by teachers

In regard to the reliability and effectiveness of the model FCI2, findings indicate that the model allows tutors' and lecturers' perceptions to be included in the assessment of student performance, which can make a balance with the results of peer assessment process (FCI1). Lecturers also point out the difficulties concerning the previous mechanism used (written exam), referring that this new model solved some of the existing problems with the exam. When asked about the fairness of results achieved with this model, the opinions of teachers are not equally shared. A tutor refers that the role of the tutor should be of a partner of the team and that if the tutor needs to assess, this role is compromised. Also, some agree that it is not possible to have a partial opinion on students' performance.

> Because it takes in account students' work throughout the semester and not only measure its expertise on a given theme. (L5)
>
> It brings together contributions from lecturers and tutors in the same assessment tool. A written test can hardly evaluate important elements in teamwork, such as leadership. (T1)
>
> Despite the problems that it revealed, the model allows the possibility to include lecturers and tutors views in the process. (T3)
>
> On the one hand, results are consistent with the opinion of a large team of teachers and the corresponding team tutor. Moreover, unless absolutely exceptional cases, results are also in accordance with those achieved through FCI1 (peer assessment). When using the written exam, these discrepancies were recurrent. This does not mean that there needs to be no adjustments to improve the model, including the search for tools to validate the results of FCI2 assessment work. Possibly using other information and including the participation of the group itself. (L2)
>
> [Disagree with the model] Because it distorts the tutor's role should be a group of partner... (T2)
>
> With this model, results are not very fair because the vision of teachers on the overall work of the students is partial. (D4)

5.2.3 Overall satisfaction and suggestions for improvement

In general, teachers and tutors were satisfied with the use of the FCI2 model, despite some of the difficulties encountered during its implementation. Both lecturers and tutors are clear in recognizing that the model is not perfect and needs to be improved. Some suggestions were provided. The main idea was related to the need for an agreement on assessment criteria and ways to register/collect information from students, in a continuous way throughout the semester. These criteria and the whole assessment process need to be clarified to students, for this was one of the main complaints presented by students in the open discussion which took place during a workshop at the end of the PBL semester. Students were not informed of how the FCI2 model was going to be applied to establish the differentiation of their grades inside the team. Some of the reasons for this situation can be justified by the fact that the FCI2 model was still under construction during the PBL semester and, therefore, it was not possible to provide a clear definition of the model at that stage.

> It is an interactive model that allows teachers to follow students' progress throughout the semester. It allows the evaluation of each student's performance without the need of putting students in situations that may cause them great tension, such as the written exam. It also allows the review, in a focused way, of the most relevant aspects involved in the project course in connection with the project supporting courses. This is particularly relevant since students reported sometimes the existence of gap between what their project was and what was requested of them in the project exam in regard to their own project.(L1)
>
> Better clarification of the model and ways to apply it. The importance of all lecturers and tutors being present in the meeting to apply FCI2. Defining consensual criteria and ways to collect information from students throughout the semester. Use of a support tool for the allocation of the distance to differentiate each student within each team. Clarify to students how the FCI2 result is achieved. Develop a document, similar to the explanation FCI1, to make available for students, explaining the assessment process. (D2)
>
> You need to develop objective elements for evaluation. (D4)
>
> Maybe pre-define a set of criteria (different depending on whether you are a teacher or a tutor) to provide teachers and tutors a standard and objective basis for assessment. (T3)

One possible technical improvement, to one of the challenges identified during the implementation of the FCI2, relating the estimation of the relative distance among individual team members, is the use of a proved technique. The steps 2 and 4 of the FCI2 instrument can be compared with a Visual Analogue Scale (VAS). Several authors addressed the advantages of the use of VAS, regarding the evaluation of different phenomena, such as thermal sensation (Lee, Stone, Wakabayashi, & Tochihara, 2010), anxiety (Abend, Dan, Maoz, Raz, & Bar-Haim, 2014), peer conflict (Campbell & Skarakis-Doyle, 2011), usability (Beauchamp, 1999) and pain (Harland, Dawkin, & Martin, 2015). The VAS methodology relies on 100 mm in length line with anchors at its extremes. Some authors present an extra midpoint anchor like the VAS presented in Figure 6. The evaluation/decision should be done by bisecting the VAS with a single vertical mark.

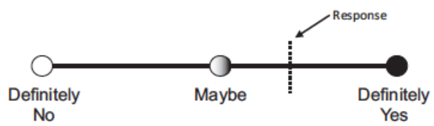

Figure 6: Example of a VAS with three anchors, image adapted from (Campbell & Skarakis-Doyle, 2011).

Future developments of the FCI2 instrument can rely on the relative position of the team members, as used in steps 2 and 4, as if they were responses in a vertical aligned VAS. For that matter, for each position, the numerical value (in millimetres) could be obtained by measuring the distance from the scale's start point to the upper edge of the team member representation.

6 Conclusions

A new assessment model was designed and put in place on the 12th edition of the first year PBL IME project at University of Minho. The assessment model uses peer assessment and a new instrument, supported by a team of lecturers, to establish the differentiation of the student grades within a work team. Details of the new instrument were given and results of its application presented, along with the difficulties encountered during the implementation stage. A study on the perceptions of students, lecturers and tutors, on this mechanism was issued, encompassing three distinct elements: (1) an open questionnaire targeting lecturers and tutors perceptions; (2) a closed questionnaire targeting the students' perceptions; and (3) a final PBL IME workshop, which included a focus group reflection and an open discussion on the subject. Findings of the study show that students acknowledge the validity of application of such instrument, and the assessment model used, but a number of aspects need to be addressed, namely the clarification of the criteria used by the lecturers and the role of the tutor within it. Although one tutor exhibited disbelief in the process, the team of 9 lecturers and tutors, generally recognize that it brings together multiple views of the team's dynamics and individual performances, and enables a consistent perspective, which is a positive achievement. In general, the lecturers and tutors also acknowledge that there is room for improvement and for further clarification of its procedures. The application process seems robust enough, but needs to be put in place accordingly, i.e. requires a different level of recognition of its importance by all the team members of lecturers and tutors. Some technical aspects regarding the FCI2 mechanism also need to be improved, namely the need for a software application, on steps 1, 2 and 4, supported by proved embedded techniques, such as the Visual Analogue Scale, for supporting the adjustment and final setting of the individual grades.

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Self-Directed Learning Development in PBL

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Abstract

Lifelong learning is an emphasized graduate outcome for engineering professionals at the international level by the Washington Accord and at the United States national level by ABET. When a new engineer enters the profession, she will be expected to acquire new technical knowledge in order to solve a problem or create a design. Unlike her experience in college, there will not be a professor to guide this learning. The planning, execution, monitoring, and control of this learning will now fall to the new engineer. The level of the ability to succeed in this self-directed learning modality will be a function of the extent to which the lifelong learning outcome has been met. This paper studies the importance of this graduate outcome and the development of self-directed learning as the way in which the outcome is achieved. Quantitative measures are taken using the Self-Directed Learning Readiness Scale. Quantitative results show a statistically significant difference between the developments of self-regulated abilities by students in a two-year PBL curriculum as compared to students who did not undergo the PBL treatment.

Keywords: lifelong learning, PBL, self-directed learning, metacognition, self-regulation

1 Introduction

Engineering outcomes have been at the forefront for the past two decades. Upon graduation from university, new engineers entering the field of practice are expected to perform well across a variety of engineering skill domains. Some of the knowledge necessary to succeed in these domains will have been acquired during their formal education, and the graduates will have some capacity to transfer the knowledge to the new situations. However, much of what they need will be acquired as it is needed in their new capacity. Further, during this informational age, new knowledge is rapidly being created and disseminated, meaning new learning will be a continual event throughout a 30- to 40-year engineering career. The authors of this paper are involved with a PBL engineering program. Following is a story that the recruiter for the program often tells potential students:

> "I'd like you to visualize your first day of work after graduation. Let me tell you two things that are not going to happen on that day… two things your new boss isn't going to say. First, she won't say, '*Greetings John, welcome to ABC Engineering. We are glad you are here. I would like to introduce you to Dr. Jill. We have hired her to be your professor. When you need to learn something new, Dr. Jill will be here to teach it to you*.' The second thing she is not going to say is, *'Here are some text books. Each week, your job is to do the problems at the end of each chapter. If you get them correct, we will issue you a paycheck. At the end of each month we will give you some written exams. Your performance on the written exams will determine the amount of your bonus.'"*

This story resonates with the potential students. To this point in their engineering education, nearly all of their learning has been one-directional from an instructor, and nearly all of their performance has been through the completion of chapter problems and written exams. They know this is what they neither expect nor want as the duties in their profession, and they struggle with this misalignment of activities during college with expectations after college.

Lifelong learning, self-directed learning, self-regulated learning, and being metacognitive are all terms used, often interchangeably, to address the outcome expected of new graduates. New engineering graduates are expected to be able to acquire new knowledge efficiently and effectively and be able to use it to solve complex, ill-defined, problems quite different than those at the end of a chapter in a textbook.

Following are statements from a variety of organizations detailing the importance of this topic:

"The fundamental purpose of *engineering education* is to build a knowledge base and attributes to enable the graduate to continue learning and to proceed to formative development that will develop the competencies required for independent practice." (International Engineering Alliance, 2013)

"Lifelong learning - Preparation for and depth of continuing learning: Recognize the need for, and have the preparation and ability to engage in independent and lifelong learning in the broadest context of technological change." Washington Accord Graduate Outcome 12 (Washington Accord, 2015)

"A recognition of the need for, and an ability to engage in lifelong learning." ABET Graduate Outcome L (ABET, 2015)

This study was conducted on students in a PBL program. Following are the published performance indicators for students in that program. 1) "In learning journal, demonstrate effective learning principles. 2) Develop and communicate personal learning model. 3) Apply metacognition techniques to improve individual learning." (IRE, 2015)

This study considers the development of these outcomes in engineering graduates and measures the development of students in a PBL engineering program.

2 Lifelong Learning, Self-Regulated Learning, Self-Directed Learning, and Metacognition

Lifelong learning has multiple goals and fundamental principles (UNESCO Institute for Lifelong Learning, 2015) (Medel-Añonuevo et al., 2001). Among them are "leading to the systematic acquisition, renewal, upgrading, and completion of knowledge, skills, and attitudes made necessary by the constantly changing conditions in which people now live" and "be dependent for its successful implementation on people's increasing ability and motivation to engage in self-directed learning activities" (Cropley, 1979). These descriptions, which come from the UNESCO Institute for Education, focus on the importance of lifelong learning for engineers as they must constantly acquire, renew and upgrade their knowledge in their technical workplaces with themselves being the drivers to initiate and carry out these processes. Candy (1991) considers this relationship between lifelong learning and self-directed learning as being reciprocal with "self-directed learning (being) viewed simultaneously as a means (to) and an end of lifelong education."

In the relevant research on self-directed learning (SDL) in engineering education, Candy's book (1991) is often cited (eg. Stolk et al., 2010). Candy describes SDL as consisting of both process and product, each of which, he again subdivides. "Self-direction… refers to four distinct (but related) phenomena: 'self-direction' as a personal attribute (personal autonomy); 'self-direction' as the willingness and capacity to conduct one's own education (self-management); 'self-direction' as a mode of organizing instruction in formal settings (learner control); ‘self-direction’ as the individual, non-institutional pursuit of learning opportunities in the ‘natural social setting’ (autodiaxy)” (Candy, 1991). Personal autonomy and self-management would be the products of having attained some level of being a self-directed learner; whereas, learner control and autodiaxy would be processes of using self-directedness in learning in both formal and informal settings. If an outcome of engineering education is to have students ready to face the workplace as self-directed learners, there would seem to be a desire to have them acquire the attributes of personal autonomy and self-management, in order for them to learn autodidactically in their engineering workplace.

Pintrich is heralded as a major leader in the development of self-regulated learning (Schunk, 2005). Pintrich defined self-regulated learning (SRL) as “an active, constructive process whereby learners set goals for their learning and then attempt to monitor, regulate, and control their cognition, motivation, and behaviour, guided and constrained by their goals and the contextual features in their environment”(Pintrich, 2000). Zimmerman (2002) depicted this process as a three-phase continuous loop. The phases are forethought, performance, and self-reflection. In the forethought phase, the learners set goals and make strategic plans. In this phase, the learners’ self-motivational beliefs of self-efficacy, outcome expectations, and task interest impact their actions. In the performance phase, the learners exert self-control through choice of task strategies, focusing their attention and performing self-instruction; whereas, they practice self-observation through self-recording and metacognitive monitoring. In the self-reflection phase, the learners judge their learning through self-evaluation and causal attribution, while they also judge the extent of their self-satisfaction (Zimmerman, 2002). To move from one phase to another, and thus from the completion of one cycle to the initiation of another, requires the learners to have adequate motivation and appropriate attitude. Lacking either of these, the next steps simply are unlikely to occur or be fruitful. From these definitions, self-regulation can be seen as much more focused then self-directedness. It is a process where goals are set, implemented, monitored, and reflected upon. From Candy’s definition of SDL, effective self-directed learners might exert their personal autonomy and self-management to use a SRL process in learner controlled or autodidactic learning.

In 2011, Tarricone published *The Taxonomy of Metacognition* (Tarricone, 2011). It is a comprehensive model for breaking down metacognition into logical order. This framework allows for the understanding of metacognition as the knowledge and as a set of actions that empower a person to learn. It is knowing how learning works by understanding the impacts of the individual, the learning task, the learning strategy, and then understanding the mechanisms that monitor and control learning. Knowing about the person, about the tasks and strategies available and how to use them is essential. The act itself then must be analyzed, monitored, and controlled (Tarricone, 2011). In the taxonomy, metacognition is broken down into six increasingly detailed levels. The first sub-division creates two categories: knowledge of cognition and regulation of cognition. Metacognitive knowledge is in regards to knowledge of the person, the tasks, and the strategies. With regards to each of these, there is declarative knowledge (knowing about knowing), conditional knowledge (knowing when, where, and why), and procedural knowledge (knowing how to know). Metacognitive regulation subdivides into executive functioning and metacognitive experiences. Executive functioning includes monitoring, control, and regulation of the person, the tasks, and the strategies. Metacognitive experiences are the personal judgments of feelings about the person, tasks, and strategies (Tarricone, 2011). In their *Handbook of Metacognition*, Hacker, Dunlosky, and Graesser connect metacognition to the concept of agency, where successful students take charge of their own learning. “At a minimum, taking charge requires students to be aware of their learning, evaluate their learning needs, generate strategies to meet those needs, and implement those strategies” (Hacker, Dunlosky, and Graesser, 2009). To connect metacognition to the context of lifelong learning, self-directed learning, and self-regulated learning, it can be considered as the knowledge and processes used by the self-directed learner in the self-regulated learning cycle (Winne and Nesbit, 2009). The more sophisticated the levels of use of metacognitive knowledge and quality of the metacognitive procedural implementations, the greater the impact of the learning. Higher levels of metacognition result in improvement of transfer of knowledge (Cornoldi, 2010), problem solving ability (Cornoldi, 2010), and quality and speed of learning (White, Fredriksen, and Collins, 2009).

In summary, lifelong learning is a desired outcome for new engineering graduates. An important aspect of lifelong learning is the non-formal learning the engineer will do in the workplace as he renews, upgrades, or acquires learning across the technical, professional, and design domains of engineering. Self-directed learning includes the attributes and actions the engineer will use to initiate and carry out the learning. Self-regulated learning and metacognition intertwine (self-regulated learning includes metacognition and metacognition includes self-regulation) as the processes used by the self-directed learner. The higher the levels of sophistication of the attributes of self-directedness and the processes of self-regulation and metacognition, the more efficient and effective the learning will be.

3 Self-Directed Learning in Engineering Education

Litzinger et al. (2003) used Guglielmino's (1977) Self-Directed Learning Readiness Scale (SDLRS) to study self-directed learning in engineering students. Using 400 randomly selected engineering students across semesters 1-8 in the bachelor's program, this research group sought to identify differences in self-directed learning readiness across students in the different levels of their education and also between genders. "…there were no statistically significant changes in average SDLRS scores among students in first through eighth semesters…. The study did not show any significant differences between male and female students." A follow-up study of 600 students was performed and this time extended to students in semesters 9 and 10. Again, there were no significant increases in SDLRS. In 2005, Litzinger et al. (2005) published a study, from the same original data, in the Journal of Engineering Education. By this time, they had discovered a weak correlation between year of study and SDLRS score. Yet, they still concluded "that academic year is a poor predictor of SDLRS score." In an additional study published in the same JEE article, Litzinger's team investigated the effect of PBL on SDLRS scores by having 18 third-year engineering students complete the assessment before and after a two-semester PBL sequence. "The average pre-test score was 216…The average post test score was 227. The difference between them was shown to be statistically significant and the research team concluded, "the problem based learning approach used in IME, Inc. (the PBL program) was effective in increasing the SDLRS scores of the students" (Litzinger et al., 2005).

In 2006, Jiusto and DiBiaso published "Experiential Learning Environments: Do They Prepare Our Students to be Self-Directed, Lifelong Learners" (Jiusto and DiBiaso, 2006). In this article, the authors relate the emerging focus on lifelong learning with the publication of the ABET 2000 criteria in the late 1990's. They also cite Litzinger et. al's work showing that traditional engineering programs seem to have no effect on increasing students' capabilities for self-directed learning. The focus of their work was to determine the impact of experiential learning environments on students' self-directed abilities. They used triangulation from the SDLRS, another self-report instrument called IDEA (http://ideaedu.org/services/student-ratings), and faculty review of project reports. 259 students took the pre-test, 198 students took the post-test, 138 student samples were paired pre to post (there were no statistical differences between the paired vs. total sample results). The SDLRS scores increased from 219 (pre) to 222 (post), which was shown to be statistically significant ($p=0.06$). The conclusions of their study, when incorporating the other two methods, were that the experiential learning experience did result in slight improvements in lifelong learning capabilities. They noted some instances where the capabilities decreased pre to post. Examples were students who had initially high SDL capabilities before the experience and students whose experience happened to be in a non-English speaking environment.

Stolk et al. have been studying the development of self-directed learning abilities since 2007. They published in the International Journal of Engineering Education in 2010 (Stolk et al., 2010) and their continued works were presented at the Frontiers in Education (FIE) conference in Madrid in 2014 (Stolk et al., 2014 and Burger et al., 2014). First, 295 mechanical, electrical/computer, and general engineering students, were surveyed using 5-point Likert quantitative survey with 3 additional short-answer questions. 197 students completed the survey, with 159 completing the short-answer questions. There was gender balance in the respondents, as well as balance across the four academic years. Olin College uses PBL across its curriculum. The three short-answer questions were: 1) Provide a definition of self-directed learning, 2) List the features of self-directed learning that you think make it effective, and 3) List the features of self-directed learning that you think make it challenging. Results were coded into a 4 x 4 matrix, with the horizontal axis depicting phases of self-direction (intention, forethought, monitoring, and reflection) and the vertical axis depicting areas of self-direction (cognition, motivation, behavior, and context). Students paid little attention to both reflection (column) and context (row) in their responses. The most frequently mentioned area of self-direction was cognition and the most frequently mentioned phases of self-direction were planning/forethought and monitoring/control. The research group used their conclusions to make three recommendations for implementation in curriculum design: 1) consider ways to give students control, 2) include self-reflection assignments in all courses, 3) provide appropriate scaffolding for SDL skill building. Further conclusions were that motivational aspects were frequently mentioned as positive outcomes of SDL, and behavioral aspects, such as time management, were most frequently noted as the negative attributes of SDL (Stolk et al., 2010). In an additional study (Burger et al., 2014), Stolk et al. connected the importance of self-reflective abilities in the development of SDL capacity, and then used grounded-theory to analyze how students develop SDL abilities in the first two years of an engineering curriculum. The study included subjects from both a large traditional engineering program and a small PBL program. The results of the work identified the following barriers to self-reflective development: 1) lack of freedom within course content, 2) perceived poor performance on traditional assessments, 3) lack of agency developed in traditional classrooms. The primary conclusion from the study is that “environments with high levels of cognitive autonomy as well as non-traditional learning environments seem to develop deeper reflective practices” (Burger et al., 2014). In a third study by Stolk and colleagues at Olin and California Polytechnic State University at San Luis Obispo, self-directed learning capabilities were studied in first year engineering students longitudinally over the first two years of their education (Stolk et al., 2014). Approximately 50 students were studied using quantitative and qualitative methods. The quantitative results are published in this study. The qualitative results are, as of yet, unpublished. The quantitative measures were used to study academic motivations, goal orientations, conceptions of learning, metacognitive knowledge and metacognitive strategy use. Results highlighted similarities and differences between PBL students and traditional students. In academic motivations, traditional students were significantly different from PBL students in their higher levels of external regulation. In goal orientations, both groups reported high learning orientation vs. grade orientation. However, the PBL students reported significantly higher levels of learning orientation attitudes, behaviors, positive regard for instructors, and negative regards for easy, irrelevant learning. The entering students at both institutions were similar with regards to conceptions of learning with the exception that the PBL students showed a higher regard for peer learning. At the end of the two years, this higher regard for peer learning remained and an additional attribute of a higher regard for knowledge construction emerged. Further, at the end of the second year of learning, students in both groups had “not completely embraced self-direction and were not yet confident in their ability to learn without an instructor’s guidance and evaluation” (Stolk et al., 2014). With regards to metacognitive awareness, both groups entered college at similar levels and left after two years with no recognizable development. Two conclusions of the work are that there are measurable differences between the PBL students and traditional students (from both the perspective of those who chose to enter each model, as well as by the developments within the model) and that students’ SDL abilities remained stable across the two years of their engineering study, with a further notice that gains that arose during year 1 of education disappeared by the end of year 2.

Beyond the works cited here, very little is reported in the literature regarding self-directed learning and engineering education. The articles that are available are tangential to the topic of developing self-directedness and thus not of value in this context. To summarize the findings reported above, there are indications that self-directed readiness does not change across the traditional engineering education process, whereas there are indications that PBL experiences do cause an increase in self-directed readiness in engineering students.

4 Method

4.1 Instrument-SDLRS

The self-directed learning readiness scale was established by Dr. Lucy Guglielmino in 1977. It is copyrighted and offered as an on-line assessment tool for purchase. The instrument has been validated and has been used in research in over 90 PhD dissertations and hundreds of research publications (lpasdlrs, 2015). Additionally, over 70,000 adult learners have taken the instrument. Figure 1. is the information provided by Gugleilmino regarding interpretation of SDLRS scores.

Your score is a measure of your current level of Self-Directed Learning Readiness.

If your score is between:	Then your readiness for self-directed learning is:
58-176	Low
177-201	Below average
202-226	Average
227-251	Above average
252-290	High

The average score for adults completing the questionnaire is 214. The standard deviation is 25.59. The SDLRS measures your readiness for self-directed learning.

Persons with high SDLRS scores usually prefer to determine their learning needs and plan and implement their own learning. This does not mean that they will never choose to be in a structured learning situation. They may well choose traditional courses or workshops as a part of a learning plan.

Persons with average SDLRS scores are more likely to be successful in more independent situations, but are not fully comfortable with handling the entire process of identifying their learning needs and planning and implementing the learning.

Persons with below average SDLRS scores usually prefer very structured learning options such as lecture and traditional classroom settings.

Figure 1. Interpreting SDLRS (lpasdlrs, 2015)

4.2 Experiment set-up

In spring 2011, a longitudinal study began. Instruments from a variety of research domains were administered to students entering the PBL upper-division program (final two years of bachelor's degree) and then again upon their completion. (For this study, only the SDLRS instrument results were used. Other studies are using the other instruments.) At the same time, a comparison group was identified. Most of the PBL students entered as graduates of Itasca Community College in Minnesota, U.S. The comparison group was their peers at that community college who transferred to a different university for upper division. This group took the instruments both before and after their upper division experiences. In all cases, students from the entire populations were asked to take the instruments. Participation rates averaged 70% for students before they transferred to another college to 40% after, whereas the PBL student groups were at 80% entering and after. The SDLRS is taken on the lpasdlrs.com website. Results from the survey were downloaded into excel spreadsheets for data analysis.

Beginning in the spring of 2011, students graduating from Itasca Community College and transferring to regional traditional engineering university programs took the instrument upon completion of their lower division studies. This took place over four years (2011-2014). Identified as **comparison-pre-nonPBL**, 40 students took the SDLRS. Upon completion of their upper-division studies (bachelor's degree achieved), this group, now known as **comparison-post-nonPBL**, also completed the instrument; 23 students took the SDLRS.

Also beginning in the spring of 2011, entering students for the PBL program began taking the instrument prior to upper division studies, and again at graduation. These groups are known as **pre-PBL** (n=52 SDLRS) and **post-PBL** (n=27 SDLRS). Table 1 details the number of students completing the instrument.

Table 1: Number (n) of students completing instrument.

	Comparison Group		PBL Group	
	pre-nonPBL	post-nonPBL	pre-PBL	post-PBL
SDLRS (n)	40	23	52	27

For each data set, averages and standard deviations were calculated. Using a t-test and two-tailed p-value ($p<0.05$) statistical significance was sought from prior to upper-division experience to after upper-division experience.

5 Results

Table 2: SDLRS results for PBL and comparison groups.

	Non PBL comparison group		PBL group	
	pre	post	pre	post
n	40	23	52	27
Average	223	231	225	237
Standard Deviation	21	23	20	16

pre-post T-score	1.452	2.700
pre-post two-tailed P-value	.1510	.0085

6 Discussion

The previous literature indicated that non-PBL students in traditional engineering programs showed little if any gains in SDLRS score. The results of this study agree with the previous studies. There were no significant gains for students from entering to leaving the non-PBL traditional engineering program (T=1.452, P-value=0.1510, not significant at p<0.05). It should be noted that there is a difference in n between the post groups and pre groups. This has been accounted for in the statistical calculations.

The literature also indicated that PBL experiences could result in statistically significant gains in SDLRS score. Again, the results of this study agree with the previous studies. There were significant gains for students in the PBL upper division (last four semesters of bachelor's degree) engineering program (T=2.700, P-value=0.0085, significant at p<0.05).

The commercial aspect of the SDLRS and the fact that its averages are the result of over 70,000 adult responses, enable there to be some comparisons between the results of this study and the previous studies that used the same instrument. In Litzinger's study of 1000 undergraduate engineering students, the average score at bachelor's completion was 222.5 (Litzinger et al., 2005). The students who showed PBL gains in Litzinger's study had post scores of 227 (Litzinger et al., 2005) Jiusto and Dibiaso (2006) had an average post score of 220.4 for all respondents in their experiential program. The scores for students entering upper-division for both the PBL and non-PBL were 225 and 223 respectively. These scores align with the scores from other studies and would be in the "average scale" described from Guglielmino in Figure 1 above. The post PBL treatment score average of 237 is in "above average" from Figure 1. Of the earlier data, only Jiusto reported averages with standard deviations and n's. Comparing Jiusto's post treatment group with the PBL treatment group from this study results in statistically significant differences between groups (T=3.298, P-value=.00056, significant at p<.05).

7 Conclusion and Future works

Returning to the story the engineering program recruiter tells to potential students, self-directedness is a valued and necessary engineering graduate outcome as the new engineer enters and proceeds in the professional workplace. The growth of self-directed learning abilities during the engineering education process is desired and should be explicitly taught and measured. Indications in the literature and confirmed by this study are that there is not significant development of SDL abilities in traditional engineering education student experiences. The literature indicated that significant growth could be achieved in project-based learning environments. This study provides further evidence that PBL leads to increases in self-directedness of engineering students. The research question we ultimately hope to answer is "How do students in a PBL environment develop as self-directed learners?" This quantitative study has only shown that PBL students do develop as self-directed learners and from a perspective using one instrument. Future planned work is to perform a qualitative phenomenographic study to gather knowledge about how the PBL experience results in development of self-directed abilities as well as to analyze from other quantitative perspectives.

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Application of cooperative elements as part of programming students' engagement in project-based learning

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Abstract

According to the United Nations Educational, Scientific and Cultural Organization (UNESCO), students should focus on various skills such as problem solving and critical thinking to help them become responsible global citizens. One of the aims of higher education is to enhance such skills to enable students to solve complex problems and to obtain real-life experiences in a specific domain. Project-based learning (PBL) is a strategy that promotes innovative learning by answering a driving question and producing a product. PBL also provides students with various opportunities to practice 21st-century skills as part of team work with regard to collaboration, knowledge sharing, decision-making and collaborative reasoning. The purpose of the current research was to report on results regarding the application of elements of cooperative learning such as positive interdependence, individual and group accountability, promotive face-to-face interaction, personal interaction and communication, and group processing to enhance students' engagement in PBL. This research was based on social constructivism and employed a qualitative methodology. Ninety-two second-year Computer Science students participated in this research and worked cooperatively in teams of two to develop a C# programming project. Data collection involved development of a project and manual as well as the submission of various narrative reflections. Qualitative data analysis comprised the coding of data and the development of themes. Findings indicate that the application of cooperative elements enhanced students' engagement in PBL.

Keywords: cooperative elements, higher education institutions, programming, project-based learning, student engagement

1 Introduction

One of the main responsibilities of higher education institutions (HEIs) is to prepare students for professional practice and to empower them through high-quality teaching and learning to develop as responsible life-long learners (Bagheri, Ali, Abdullah & Daud, 2013; Francom, 2010). The United Nations Educational, Scientific and Cultural Organization (UNESCO) states that students should focus on "transferable skills, such as critical thinking, problem-solving, advocacy and conflict-resolution, to help them become responsible global citizens"(UNESCO, 2014:36).

Project-based learning (PBL) is a teaching–learning strategy that provides opportunities for solving real-life problems and developing professional practice (Grant, 2011; Helle, Tynjälä & Olkinuora, 2006). Problem orientation or inquiry is the driving force of PBL where students are expected to address an ill-defined problem, complex question or challenge and obtain deeper knowledge (Grant, 2011; Larmer & Mergendoller, 2010). Although both problem-based and project-based learning are organised around a driving problem, it varies to a certain degree. Problem-based learning is defined by solving ill-structured problems to provide a context for learning whereas project-based learning refers to a full-scale project, planned and developed by students over time and requires a high degree of self-direction (Kolmos & De Graaff, 2007a).

When solving a real-life problem, collaboration in a small group is an excellent preparation for professional practice (IJCLEE, 2015). Although students are used to collaborate informally by using social media, distinctive and well-defined skills are involved when collaborating with group members in a formal setting, for example when developing a project.

Cooperative learning (CL) refers to a way of collaboration where students work together towards the same goal and accomplish a task in a particular way to share the benefits thereof (Concise Oxford English Dictionary, 2004; Gunter, Estes & Mintz, 2010). Cooperative learning is formally outlined as an instructional approach that includes the following five key elements: positive interdependence, individual and group accountability, promotive face-to-face interaction, personal interaction and communication, and group processing (Johnson & Johnson, 2013). The application of cooperative learning results in a more productive group where positive relationships among group members are developed (Johnson, Johnson & Holubec, 2014). In a practical case of computer engineering, Pérez, García, Muñoz, Alonso and Puche (2010) compared cooperative learning with project-based learning. They rejected the hypothesis that academic success achieved by first year students was higher when CL was applied than in those cases where PBL was applied. Yusof, Hassan, Jamaludin and Harun (2012) developed a framework regarding *cooperative problem-based* learning in a sample case study in engineering education, and their results affirm the need for supporting students to learn in teams when focusing on problem-based learning. Consequently, the purpose of this paper is to report on the integrated and combined role of cooperative learning and project-based learning in a large population of programming students.

This paper is organised as follows: the conceptual-theoretical framework is overviewed in Section 2 and the empirical research is outlined in Section 3. Sections 4 and 5 provide a description of the respective qualitative findings and a discussion thereof, while Section 6 consolidates the research.

2 Conceptual-theoretical Framework

This section outlines the philosophical point of departure and the theoretical overview.

2.1 Philosophical point of departure

Social constructivism is a sociological theory that advocates the collaborative construction of knowledge (Lodico, Spaulding & Voegtle, 2010; Patel, Gali, Patel & Parmar, 2011). The nature of social constructivism requires that teaching activities focus mainly on students' engagement and responsibility to construct the learning content in a collaborative manner (Patel *et al.,* 2011). The application of social constructivism in teaching and learning provides therefore a focal point for interaction, effective communication, shared responsibility, interdependence and collaborative reasoning.

2.2 Theoretical overview

The aim of higher education does not only include obtaining knowledge but also providing high-quality teaching and learning opportunities to prepare students for innovative and future demands. In this regard, Darling-Hammond (2012:22) mentions that we need to prepare students "for jobs that do not yet exist using technologies that have not yet been invented to solve problems that we do not even know are problems yet". Additional dimensions of learning are therefore required to prepare students for professional practice and life-long learning. These involve students taking responsibility for their own learning, applying high-level cognitive, reflective and innovative skills and working collaboratively to address future challenges (Bagheri *et al.*, 2013; Grant, 2011; Johnson & Johnson, 2013). In this regard, Kolmos and De Graaff (2007b) emphasise that a change in higher education is required with the focus on student-centred learning and the development of life-long learning skills. Garrison and Akyol (2009) concur as they mention that there is a shift in higher education to collaborative knowledge construction with the aim to enhance reflective, critical thinking and meaningful learning experiences.

Project-based learning (PBL) is a teaching–learning strategy that provides opportunities for students to learn much more than initially anticipated. PBL is an innovative and instructional approach in which students work mainly collaboratively to solve a real-life problem or answer a driving question and provide an artefact (Bell, 2010; Grant, 2011; Helle *et al.*, 2006). In applying PBL, the lecturer serves as the subject expert, guide or facilitator of teaching–learning activities to keep students on track whereas students need to solve real-life problems themselves by managing their own learning activities and project development (Gunter *et al.,* 2010; Helle *et al.*, 2006). Some elements of PBL include problem orientation and inquiry, student-centredness, collaboration and communication, responsibility and accountability, problem solving, critical thinking and reflective thinking, management of the learning environment, integration of technology, knowledge creation and innovative construction, assessment integration, and performance feedback and evaluation (Havenga, 2015).

A project refers to the development of an artefact with a unique purpose that requires various planned activities, skills and resources and which has a definite beginning and end (Hughes & Cotterell, 2009; Schwalbe, 2010). Project requirements are ill-structured, involve uncertainty and are sometimes difficult to develop (Hughes & Cotterell, 2009; Schwalbe, 2010). The development of a project is therefore an intense task where goals, accountability, knowledge and skills are shared among team members. As teams are intent on carrying out a joint project as part of PBL, they cannot function effectively if members do not apply interpersonal and small group skills, such as knowledge sharing, decision-making and collaborative reasoning (Bagheri *et al.,* 2013; Nussbaum, 2012; Rotherham & Willingham, 2010).

Johnson and Johnson (2013) focused in their research on collaboration, and gave prominence to cooperative learning where they identified five key elements, namely positive interdependence, individual and group accountability, promotive face-to-face interaction, personal interaction and communication, and group processing. Below, each of these elements is outlined in more detail. *Positive interdependence* involves that success of the group is dependent on the success of every group member. Therefore, if one member fails, all fail; *individual and group accountability* refers to a member's personal responsibility and feedback to the group regarding individual performance; *promotive face-to-face interaction* includes engagement and support of each other's learning; whereas skills such as active listening, conflict management, leadership, decision making and trust are part of *personal interaction and communication*. *Group processing* comprises reflection on each member's contribution to the group as well as celebrating group success.

Mentz, Van der Walt and Goosen (2008) assert that working in groups without applying these five elements will most likely lead to non-effective learning in the group. Furthermore, Johnson *et al.* (2014) are of the opinion that the five mentioned elements should be incorporated in group work to ensure the accomplishment of shared goals and maximal learning of every individual group member.

Since collaboration is an important part of real-life experiences (Bagheri *et al.*, 2013), the application of cooperative elements may scaffold students in project development as they bring along a variety of skills, responsibilities and experiences during teamwork. The aim of the research was therefore to explore whether the mentioned cooperative elements could enhance students' engagement in PBL. The research question central to this paper was:

How can the application of cooperative elements enhance programming students' engagement in project-based learning?

3 Empirical Research

The methodology and implementation of empirical research are discussed in this section.

3.1 Methodology and research design

A qualitative research methodology was followed in this study. The research design involved an intervention as well as student's narrative reflections on their cooperation and PBL experiences. During the intervention, students completed documents and developed a software project (Table 1).

Table 1: The research design used in this study

Intervention (team completion – 7 weeks)	Narrative reflections (individual completion)
1) Plan the project by including team completion of a detailed time schedule 2) Submit weekly project sheets electronically to indicate progress of design and development 3) Submit a software program and electronic manual as deliverables	Reflections regarding: student's experiences with PBL and project development as well as their cooperation

3.2 Participants

A population of 92 second-year BSc students with a major in Computer Science participated in this research to develop a programming project as part of the intervention. Most students worked cooperatively in groups with two members, although some groups had three members. Students selected the team members themselves and made their own decisions regarding their roles and responsibilities. This research was part of a larger research project for which ethical approval was obtained.

3.3 Data collection

Students were required to develop an integrated C# and database programming project regarding any selected topic, for example the management and purchase of sports gear. Prior to project development, the lecturer provided students with the project requirements, assessment as well as a brief description of cooperative learning. The project was done outside of class time where students worked in project teams.

Data collection (Table 1) comprised completion of 1) a time schedule, prior to starting of the project, 2) weekly project sheets (Havenga, 2015) that outlined the detailed development and progress of projects, 3) project deliverables, namely a computer program and electronic manual, and 4) reflective narratives regarding students' cooperation and their experiences with project development as part of PBL. The aim of the weekly project sheets was to enable students to indicate their planning, challenges as well as their individual and group contributions towards project development. Although realistic allocations had been made to enable students to complete the weekly project sheets, they were required to submit these electronically on time as electronic locks were set in the students' learning environment for each week.

3.4 Data analysis and assessment

The data were analysed and manually coded. Concept-driven coding (Gibbs, 2010) was mainly used where the thematic ideas came from the literature, time schedule, weekly project sheets and reflective narratives. As a result, the findings were categorised by developing sub-themes and themes.

The project, manual and related documents were assessed according to specific rubrics based on the initial project requirements. Assessment criteria used to judge the manual included an introduction explaining the purpose of the program, a brief literature overview regarding databases, snap-shots of the program, resources used as well as a summary and a complete list of references. The project was assessed using the following criteria: application of various menus and at least four forms to display the information, search and update of data, use of four different queries and inclusion of message boxes for user-friendliness. Participants obtained marks for their time schedules, detailed weekly project sheets and narrative reflections regarding their cooperation and activities involved in project development.

After project closure, the teams were required to apply group assessment where they judged each member's contribution towards all aspects of project development. The following scale was used: 0 = Made no contribution; 1 = Contribution was less than average; 3 = Made an average contribution; 5 = Made an above average contribution. The best team obtained 91% for their project, manual and related documents.

4 Qualitative Findings

As part of the qualitative analysis, six themes emerged, representing students' PBL experiences during their programming activities. The themes were based on thematic ideas (see 3.4) as well as additional codes that emerged from the empirical research. The following themes were identified: Theme 1: Teams' responsibilities,

Theme 2: Member's responsibilities,

Theme 3: Assistance and team support, Theme 4: Social skills, Theme 5: Achievement of teams' aims, and Theme 6: Reflection and additional skills (collaborative reasoning, time management, resources).

Theme 1: Teams' responsibilities

Team members mentioned their detailed planning, responsibilities and their commitment to work on specific tasks. Some exemplars are included (number(s) in brackets refer to specific participants).

> *We summarised all the requirements. We both had our tasks to do to ensure that the program works* (P10, P37).

> *We planned the project thoroughly and assigned a time frame for each part of the project* (P12, P61).

What information do we want the users to see? How does [the] information get into the database? What data will we use for testing? (P14, P74).

Theme 2: Member's responsibilities

Team members were individually responsible for specific tasks. They divided the project in sections and determined what each member should do.

We divided the project into smaller sections and determined what each member should do to plan and develop [the project] (P45, P58, P89).

[I] managed team meetings, did research regarding various programming activities and [the] user interface. Did the main programming (P27).

[I was] responsible for program documentation and interviewed people in industry regarding the project. [I] supported team members with administration, project development and search of information (P76).

I studied C#, database connections, obtained information regarding networks, managed administration and supported the development of the program (P80).

Theme 3: Assistance and team support

The assistance and team support theme unveiled the fact that team members used a variety of skills to assist and support each other.

We supported each other where possible and ensured that no one of the team members was overwhelmed with the tasks (P33, P79).

I helped P10 with possible options for the goal of the program, and aided in the final decision. P10 assisted me in setting up a realistic time frame and advised optimal due dates for key milestones throughout the project (P10, P37).

We reviewed each other's work and gave feedback. We started to program in pair programming so we helped each other in ways (P14, P74).

Theme 4: Social skills

The spontaneous comments below indicate students' attitudes, their interaction and communication regarding members' efforts.

Communication was good. We reached a decision to meet … and double-checked everything (P31, P60).

We commented on each other's ideas and formulated the best possible solution (P10, P37).

Sometimes we differ however we solved this with a positive attitude (P27, P76, P80).

Theme 5: Achievement of teams' aims

It is notable that teams discussed how they achieved their planned objectives and finalised the project. One team experienced some hardware problems.

We managed to execute all our planned objectives … did unforeseen tasks that were also necessary (P10, P37).

We achieved what we set out to do … everything was read, checked and finalised by the group (P31, P60).

We discussed everything to ensure that the program satisfied the assessment criteria (P21, P90).

One student experienced storage problems and needed to start all over again.

P5's external disk was broken and he was required to start again (P5, P29).

Theme 6(1): Reflection and additional skills (collaborative reasoning)

Participants interpreted their problems and learned from their mistakes. Team members discussed their differences, brainstormed possible pitfalls and collaboratively constructed and criticised various arguments.

We debated which forms should be connected and the easiest way to manipulate the SQL (P55, P77).

We did not agree on the amount of security the login form should provide. There was a dispute about the different forms' design (P12, P61). *There was a misunderstanding … we helped each other in ways* (P14, P74).

Theme 6(2): Reflection and additional skills (time management)

P10 assisted me in setting up a realistic time frame and advised optimal due dates for key milestones throughout the project (P10, P37).

The program was completed on time (database, text files and Excel spreadsheets). We therefore had enough time to finalize the project (P9, P26).

Theme 6(3): Reflection and additional skills (resources)

We used WhatsApp, Skype and Dropbox to enable each team member to have access to the program (P1, P57*).*

5 Discussion and Implications

The focus in this research was on the application of cooperative elements in PBL. Regarding this objective, qualitative findings are discussed in this section to answer the research question: *How can the application of cooperative elements enhance programming students' engagement in project-based learning?*

Table 2 gives a summary of cooperative elements (Subsection 2.2), and exemplars obtained from the qualitative findings (Section 4) that give an indication of students' engagement in PBL activities (Subsection 2.2).

Table 2: Exemplars from qualitative data to indicate the application of cooperative elements and students' engagement in PBL activities

Cooperative elements	Exemplars from qualitative data	Engagement in PBL activities
Positive interdependence	Theme 1: Team's responsibilities: We *summarised all the requirements. We both had our tasks to do to ensure that the program works* (P10, P37).	Responsibility and ownership (Bell, 2010).
Individual and group accountability	Theme 2: Member's responsibilities: *We divided the project into smaller sections and determined what each member should do to plan and develop [the project]* (P45, P58, P89).	Taking responsibility for own learning (Bell, 2010). Student centeredness (Kolmos & De Graaff (2007b).

Promotive face-to-face interaction	Theme 3: Assistance and team support: *We supported each other where possible and ensured that no one of the team members was overwhelmed with the tasks* (P33, P79).	Teamwork and support (Markham, 2012).
Personal interaction and communication	Theme 4: Social skills: *Communication was good. We reached a decision to meet … and double-checked everything* (P31, P60).	Communication (Murray-Harvey *et al.*, 2013).
Group processing	Theme 5: Achievement of teams' aims: *We achieved what we set out to do … everything was read, checked and finalised by the group* (P31, P60).	Achievement. Developed a project (Markham, 2012). Construction (Grant, 2011).

Table 3:

Reflective and additional skills	Exemplars from qualitative data	Engagement in PBL activities
Reflection, decision making, collaborative reasoning	Theme 6(1): Reflection and additional skills. Collaborative reasoning: *We did not agree on the amount of security the login form should provide. There was a dispute about the different forms' design* (P12, P61).	Collaborative reasoning (Murray-Harvey *et al.*, 2013; Nussbaum, 2012).
Time management	Theme 6(2): Reflection and additional skills. Time management: *P10 assisted me in setting up a realistic time frame and advised optimal due dates for key milestones throughout the project* (P10, P37).	Project planning and time management (Markham, 2012).
Resources	Theme 6(3): Reflection and additional skills. Resources: *We used WhatsApp, Skype and Dropbox to enable each team member to have access to the program* (P1, P57). *[I] supported team members with ... search of information* (P76) (Theme 2).	Management of resources (Markham, 2012).

When developing a project as part of PBL, there are several ways to operationalise team dynamics. Since cooperation plays a strategic role in teams and results in a more productive group (Johnson *et al.,* 2014; see Section 1), its role was explored in PBL. It was evident that all elements of cooperative learning were present when participants designed and developed the artefact (Table 2). These included positive interdependence (Theme 1. We s*ummarised all the requirements. We both had our tasks to do to ensure that the program works* (P10, P37)); promotive face-to-face interaction (Theme 3. *We supported each other where possible and ensured that no one of the team members was overwhelmed with the tasks* (P33, P79)); and personal interaction and communication (Theme 4. *Communication was good. We reached a decision to meet … and double-checked everything* (P31, P60)). Team members added shared value in terms of the application of knowledge and skills, conflict management, problem solving and decision making. In addition, team members were required to solve the problem jointly and to submit the final project (Theme 5. *We achieved what we set out to do … everything was read, checked and finalised by the group* (P31, P60)).

Hence, as part of cooperative learning, each member was also responsible and accountable for specific tasks (Theme 2. *We divided the project into smaller sections and determined what each member should do to plan and develop [the project]* (P45, P58, P89)).

Additional skills also emerged as an important part of PBL, as indicated in the theme Reflection and additional skills with reference to collaborative reasoning (Theme 6(1). *There was a dispute about the different forms' design* (P12, P61)). Students also managed their time, as indicated in their reflections. (Theme 6(2). *…setting up a realistic time frame and advised optimal due dates for key milestones throughout the project* (P10, P37)). Participants employed various resources and technologies during project development. (Theme 6(3). *We used WhatsApp, Skype and Dropbox to enable each team member to have access to the program* (P1, P57)).

The findings indicate that team members shared mutual responsibility and ownership, they applied various elements of cooperative learning, and they addressed the question of inquiry.

Results obtained in this study are in line with those obtained by Johnson and Johnson (2013) who concur that the five elements of cooperative learning should be incorporated to ensure the achievement of shared goals and maximal learning of every member. As a result, the participants were engaged in PBL where both individuals and team members were responsible and accountable for project design and development. Application of the five elements of cooperative learning therefore provides capacity for the development of 'social strength' within a team. The researcher is of the opinion that the cooperative and social construction of knowledge is the strongest link in PBL in cases where more than one member is involved in project development.

Based on the integrated literature and the results, some implications are outlined regarding the application of cooperative elements in PBL that may prepare students for professional practice:

<u>Cooperate strategically</u>. Apply all elements of cooperative learning to ensure accomplishment of shared goals, maximal learning (Johnson & Johnson, 2013) and accountability for project development – both as individuals and as team members. *There was continuous support from team members when we were uncertain. Therefore we shared the responsibility* (P9, P26). Be involved in collective ownership and sign a contract of agreement (Havenga, 2015).

<u>Collaborate in reasoning, argumentation and problem solving</u>. Reason, construct and evaluate arguments collaboratively (Nussbaum, 2012) to address pitfalls and solve a project problem. *There was a dispute about the different forms' design* (P12, P61). *There was a misunderstanding … we helped each other in ways* (P14, P74).

<u>Carry out a joint innovative project</u>. Develop an innovative end product jointly to address the question of inquiry (Bell, 2010; Grant, 2011). *We started with the designing of the database and discussed as well as implemented the layout for our program* (P10, P37).

<u>Collaborate in reflection, assessment and evaluation</u>. Reflect as individuals and as team members on all phases of project development. Critically assess and evaluate the final project as a team before submission. *We achieved what we set out to do … everything was read, checked and finalized by the group* (P31, P60).

<u>Communicate effectively.</u> Good communication to share ideas and feelings in a secure environment may contribute to the success of the project. *Communication was good. We reached a decision to meet … and double-check everything* (P31, P60).

6 Conclusion

The purpose of this research was to report on results regarding the application of elements of cooperative learning to enhance students' engagement in PBL. Qualitative findings indicate that employing cooperative learning in a project-based task provides additional opportunities for students to succeed in a project as a result of their strategic cooperation. In addition, some implications were outlined which can be applied as recommendations for higher education to prepare students for professional practice.

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“That’s me being stupid”: Using discursive psychology to analyse self-deprecating humour as a means of constructing group cohesion in PBL

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Abstract

One of the most consistently studied constructs within group dynamics and small group literature is that of group cohesiveness; the extent to which individuals within a group feel connected (Greer, 2012). This may be of particular importance for those involved in problem-based learning (PBL), as its over all effectiveness can often rest on the quality of student interactions. Members of strongly cohesive groups are more inclined to participate readily and stay with the group (Dyaram & Kamalanabhan, 2005), so it is imperative to discover how students ‘do being cohesive’.

The current paper falls under the theme of ‘PBL process and student engagement’ as it takes a fine-grained approach to understanding student interaction in the PBL tutorial. Past research has highlighted a need for more qualitative analyses into PBL, and so the current study uses real time data to identify how cohesion is socially constructed in the group setting. Thirty-one students across nine PBL groups from two UK universities were video-recorded as they partook in PBL in a psychology programme and an interdisciplinary science programme. The resultant eighty-five hours of data was examined in order to create a corpus of laughter instances, before being analysed using discursive psychology, a relatively unique methodology in PBL research. As ‘attractiveness to the group’ is widely accepted as the conceptualisation of cohesiveness, the current paper is focused on instances of interaction in which a group member self-deprecates; positioning themselves as an *un*attractive group member compared to the others, and how this is dealt with through laughter by the rest of the group to construct a sense of solidarity and cohesion.

Although the project was based in psychology, findings are not discipline-specific and can be disseminated across subjects.

Keywords: PBL, discursive psychology, laughter, group cohesion, humour

1 Introduction

1.1 Group cohesion

As one of the most consistently studied constructs within group dynamics and small group literature, group cohesiveness research is vast. Historically, cohesion has been considered the most important variable in small groups (e.g. Lott & Lott, 1965), but it is also an extremely complex entity to evaluate, with ongoing controversy regarding not only how to define it, but also how to measure it (e.g. Budge, 1981; Keyton, 1992; Greer, 2012).

Early literature on group cohesion was influenced by Festinger, Schachter & Back (1950) who interpreted cohesiveness as, “the total field of forces (based on the attractiveness of the group and its members, and the degree to which the group satisfies individual goals) that act on members to remain in the group” (pp.274). Although this model was influential for its time it has since received much criticism, and there is currently no single accepted definition, with descriptions of cohesiveness pertaining to feeling “connectedness” (O’Reilly & Roberts, 1977) within a group, having uniformity and mutual support between members (Hogg & Vaughan, 2008) and “sticking together” (Mudrack, 1989). Cohesiveness, therefore, can be thought of as both a descriptive term but also a psychological term describing individual psychological processes (Hogg & Vaughan, 2008).

Due to the inconsistencies and difficulties regarding definition and measurement, theorists have pleaded for more empirical attention to be paid to the dynamics by which cohesion evolves in groups (e.g. Chiocchio & Essiembre, 2009). In particular, there is little research that uses qualitative methodologies to analyse group cohesion as historically cohesiveness has been ‘measured’ through individuals’ subjective opinions in order to draw conclusions about the group (Carron, Widmeyer & Brawley, 1985; Mudrack, 1989). This seems to present somewhat of a conundrum though, as individuals cannot be cohesive by themselves; the cohesiveness comes as a result of interaction with others and as such there is need to study groups in process. Group cohesion can therefore be thought of as a social accomplishment, and one way in which to investigate this is through research into group laughter.

1.2 Laughter

Laughter is a natural phenomenon, universally shared by humans. Historically, research has focused on the individual doing the laughter, as opposed to those receiving it, therefore neglecting the important interactional properties of laughter. As stated by Provine (2004, pp.215), “the necessary stimulus for laughter is not a joke, but another person”, which has garnered support from the likes of Holt (2011) who determined that research in the area should no longer focus on trying to explain why people laugh, but instead look at what actions are being performed when they do.

As it is a primarily social construct, it is important to consider what function it serves in interaction. Laughter has been shown to be important in the social setting as it shows affiliation with others (Glenn, 2003), and as detailed by Greatbatch & Clark (2003), empirical research into laughter has identified that it serves five primary functions; one of which being to create and maintain social cohesion and group solidarity, which is the focus of the current paper.

Research into laughter and cohesion covers a broad spectrum, with most studies classifying the ‘type’ of laughter under investigation. For instance, group cohesion has been reported as the result of shared humorous experiences and stories, enhancing a feeling of ‘similar things happen to others too’ (Hay, 2000; Kotthoff, 2006). Similarly, laughter resulting from teasing and joking has been reported to enhance cohesion in a group (e.g. Norrick, 1994; Holmes, 2006). A 1997 publication by Boxer and Cortés-Conde, for instance, demonstrated how joking can “bond”, by analysing teasing and joking as instruments through which social control is exerted and social identity is displayed. There is still a need, however, for a closer look at how exactly cohesion is established. There is little research pertaining to the fine-grained detail of how laughter can facilitate cohesion, of the sequential organisation of talk in interaction that is inherent although often overlooked that allows cohesion through laughter to take place. It is useful, then, to exemplify what more detailed research has the potential to show.

As one of the founders of conversation analysis, Gail Jefferson is well known for her work documenting the systematic workings of laughter in a variety of interactions (e.g. Jefferson, 1979; 1984; 2004). Jefferson's conversation analytic work demonstrated that, contrary to beliefs that it is spontaneous and involuntary, laughter is organised and precisely placed, deployed to manage moments in interaction and to help achieve actions. For instance, Edwards (2005) investigated the phenomenon of complaining, and showed through close analysis of interactional features of conversation how laughter can create cohesion even though a real complaint is being made due to the manner in which it is delivered, demonstrating that it has the ability to achieve a goal; i.e., in this case, that 'this is something I would not usually moan about' (Edwards, 2005). Other research has looked at, for instance, the processes involved in orienting to laughter (Holt, 2011), silence where laughter is expected (Drew, 1987), and how interaction is impacted by laughter within words (Potter & Hepburn, 2010).

Research like this highlights the value of using in-depth analysis methods to understand how laughter is treated in interaction. As such, the current paper aims to progress research in the area, by using discursive psychology to closely examine incidences of laughter within PBL at university, aiming to expand on past conversation analytical work, and demonstrate that laughter is not random but is highly sequentially organised to perform certain functions within social interaction, such as enhancing group cohesion. Since past research has shown that the overall effectiveness of group work can often rest on the quality of student interactions and that members of strongly cohesive groups are more inclined to participate readily and to stay with the group (Dyaram & Kamalanabhan, 2005), it is imperative to discover how individuals 'do' being cohesive. The research question for the current study therefore is, how can 'doing self-deprecation' construct cohesion in a group?

2 Method

2.1 The data corpus

The data used for this study are taken from naturalistic video footage of student groups working in problem-based learning tutorials, a form of student-centred group work which encourages collaborative knowledge construction, independent learning and intrinsic motivation (e.g. Dolmans & Schmidt, 2006). The data was collected between October 2012 and December 2013, from thirty-one students comprising nine groups across two UK universities, totalling eighty-five hours of video-recorded interaction. Informed, written consent was gained from all participants, and the study received full ethical approval at university level. Each group either set up the cameras themselves, or it was done in advance by the researcher. Data was collected on memory sticks, before being downloaded onto a password-protected computer within the University of Strathclyde, and kept in a locked office with only the named researchers having access to recordings. The video data was transcribed to words-only detail in the first instance, before a data corpus was compiled and those extracts chosen for further analysis subjected to Jeffersonian transcription notation (see appendix).

2.2 Analytical procedure

A discursive psychological approach was used to analyse the data (Wiggins & Potter, 2008). As advocated by Holt (2011), laughter is not simply a reaction to humour but an action in its own right, and as such, this is the best methodology for analysing laughter because it treats it as 'in the moment'. The approach draws on the ethnomethodology of Garfinkel (1967) and the conversation analysis of Sacks, Schegloff and Jefferson (1974), focusing on how psychological phenomena are constructed and understood in interaction.

Discursive psychology does not align with the more 'traditional' values of social psychology, in that individuals' speech reveals attitudes and behaviour regarding some construct; rather it assumes that talk has an action orientation and that language is used to perform particular social functions, achieved through a variety of rhetorical strategies. The approach begins with psychology as it faces people living their lives. It studies how psychology is constructed, understood and displayed as people interact in everyday situations, through analysing talk-in-interaction (Wiggins & Potter, 2008). Discursive psychology has been used previously to analyse student tutorial talk (e.g. Koschmann, Glenn & Conlee, 1997; Attenborough & Stokoe, 2012), critiquing the way topics have been traditionally conceptualised in psychology by treating them as interactional entities, as opposed to individual ones.

As such, a data corpus was compiled of laughter extracts stemming from an in-depth transcription which identified laughter particles (Jefferson, 1984), which were broadly categorised in the first instance and included clusters such as 'sarcasm-', 'joking-' and 'exaggerating-laughter'. The researcher was particularly interested in those laughter instances pertaining to self-deprecation (where an individual in the group portrayed themselves in a negative manner somehow). Doing so is potentially problematic for a group, as it would appear to negate the 'attractiveness to the group' facet of group cohesion, however, as we will see, this doesn't necessarily happen.

3 Analysis

The current analysis aims not to consider self-deprecating utterances as a mere reflection of a cognitive state separate from the interaction at hand, but to show how group members manage the somewhat sensitive nature of self-deprecation, and in doing so, how social actions such as enhancing cohesion within a group may be demonstrated. Specifically, episodes of self-deprecation which are oriented to with laughter are the key focus here. Laughter as a response to self-deprecation allows for the discomfort of agreeing or disagreeing with a detrimental claim to be avoided. As identified by Pomerantz (1984), orienting to self-deprecation with an agreement or indeed a disagreement is tricky to manage. If a recipient(s) is to agree with a critical statement, they are endorsing prior criticisms as their own, which is potentially problematic for group dynamics. For instance, if an individual was to make the assessment, "I'm an idiot", and someone in the group agreed, this could cause tension to arise between the self-deprecator and the respondent, and thus have the potential to create a divide within the group. Conversely, if group members disagree with an individual's self-deprecation they demonstrate support, in that they actively voice their opposition to the claim. However, this too is not always straightforward and is tied up with issues regarding ingratiation (Jones, 1964).

Therefore, the analyst was interested in what comes after the laughter; how does a group deal with an instance of self-deprecation and simultaneously demonstrate cohesion within the group, without it turning into a counselling session for the individual disparaging themselves? To investigate this, instances of self-deprecation which were oriented to with laughter were analysed. Such utterances were found to be sequential; typically following a period of 'trouble' within the interaction and highlighting a problem that the group must resolve before returning to the task at hand. The following brief analyses aims to demonstrate the construction of cohesion as it happens.

In the first example, a group of six psychology students are brainstorming ideas for a PBL task in which they must produce a psychology research proposal which does not have to adhere to today's ethical standards as set by the British Psychological Society. We join the interaction as the group have been deliberating a number of possibilities.

3.1 Analysis 1: "I rudely interrupted her"

Kate: ah like the smokin' one so far=
Raymond: [°smokin' one sounds good°
Kate: =[ah think that's a really good ↓one
Kim: 'cause you could [do it in quite a short period
of time
Ava: [I jus' thought it was good
because that's a thing that affects life now
anyway like [people-
Kate: *((to Erin))* [were you here when [Ava said that
Erin: *((shakes head))* [heh heh
Kate: say it again Ava
Erin: heh .hh
Ava: I sai- I said like- >Abi was talkin'< an' I
£rudely [interrupted her £and said-
Kate: [ha [ha [ha
Abi: [heh heh heh
Raymond: [heh heh heh
Erin: [ha ha ha
Isla: [ha ha
Ava: 'cause I HAD LIKE an (.) idea >I was like<
'↑ooh, got to say it'
Kate: a ha ha [ha
Ava: [em: but I thought >you could have
like< one groupa children an' you could expose
them to like second hand smoke

The extract begins with group member Kate's assessment of her preferred topic to focus on which incites other group members to align, until a problem is encountered on line 9, whereby one member (Erin, who arrived late), was not present when Ava was presenting her idea for the proposal to the group, and as such presumably does not understand what the group is talking about.

In order to rectify this trouble in the interaction, Erin needs to be informed of the idea, and as such, Ava is directed by Kate to reiterate. We can see at line 13 she begins to state her idea (which is not actually revealed until line 27), but repairs her utterance in order to preface it with the 'true' order of events; that someone else was talking and she interrupted them. This is the episode of self-deprecation, as Ava states that she "rudely interrupted", classifying herself as "rude", to which, none of her peers overtly agree or disagree, but instead laugh.

At this point, Ava could have completed what she was going to say, thus enlightening Erin of her idea and orienting the group back on-task. However, instead, Ava goes on to account for her rudeness, and it is this turn which I argue demonstrates cohesion within the group.

There is abundance of conversation analytic research regarding the practice of interrupting, stemming from Sacks and colleagues' (1974) seminal work on the organisation of turn-taking in conversation, and by recognising that she interrupted a fellow group member, she is addressing that this is an unusual occurrence; perhaps in that she regards all group members as of equal placing with no one considered more important than another, and therefore it was inappropriate in usual group interaction dynamics for this to happen. She therefore went out with the boundaries of normal group interaction. Her 'active voicing' (Wooffitt, 1992), where she almost parodies herself, brings her storytelling to life, emphasising her urgency and suggesting why she interrupted her fellow group member. She employs a number of techniques such as raising her voice and speaking quickly (line 23), to ensure she gets her point across without, ironically, being interrupted by someone else.

Through this self-deprecating, Ava shows that she considers herself at that moment in time – when she interrupted her peer – she was "rude", but now that the situation is over, she is not that anymore. In doing so, she highlights to the rest of her peers that as a group, they are all of equal importance, and she jeopardised they group dynamic by behaving in a way that could be interpreted as she thought she was more important; evidenced by her interruption. Acknowledging this is important for the group cohesion, so Ava can reiterate her idea, but in a way that 'corrects' what she did earlier.

In this second example, a group of students must pick between two topics – masculinity and place identity – to focus on for a PBL task in psychology.

3.2 Analysis 2: "The conversation might flow a bit better with me"

```
Nadia:      I don't mind I'm not bothered about which one
            (3.0)
Nadia:      but if you two are-
Regina:     I would struggle with place identity=
Nadia:      =d'you ↑think
Regina:     I think so [but-
Ally:                  [°masculinity might be easier (.)
            gender [(inaudible)°
Jackie:            [but like (.) how would it be easier
            then so like what would you say about that
Ally:       I think it would be quite easy to talk
            about though
            (1.0)
Regina:     the conversation might flow a bih beh'er (.)
            wi' me anyway [heh (if we) d(h)o [masculini'y
Nadia:                    [heh heh heh
Ally:                     [((smiles))
Jackie:                   [((smiles))
Susan:                                       [hm hm hm
```

46 (1.0)
47 Regina: but I don't- it's fine I'll go with whatever

The group have been discussing which of the two topics they should select, with no firm decisions being made as they cannot achieve a consensus. Despite this, the group are actually demonstrating that they are on-task 'doing' PBL, by discussing what they each want to do, and making reasoned arguments as to why. For this reason, the 'trouble' the group encounter stems from Regina's utterance at line 29 that she would "struggle" if they choose one of the topics over opposed to the other, because it is the first indication that a decision will have to be made, based on the preference of one individual instead of the whole group. In short, the group are going to have to go with this suggestion unless they demonstrate that they do not care about Regina's opinion.

The episode of self-deprecation comes at line 39, where, orienting to Ally's prior turn, Regina takes the opportunity to again assert her preference by formulating Ally's prior turn as a self-deprecating utterance, in that if they don't choose the topic she wants, her contribution to the conversation will be limited. Although it is not as obvious as in the previous extract, the self-deprecation is directed at Regina in the future; that if the group choose this topic, Regina won't be as good at it and as such, will be a less valuable member of the group.

As in the previous extract, Regina's self-deprecation is oriented to with laughter and smiles. This reaction is perhaps not as vocal as in the last extract – in that not everyone audibly laughs – but pivotally, all group members at least acknowledge the self-deprecating turn. It is at this point in which group cohesion begins to be constructed, as Regina treats the lack of response to her utterance as problematic in that she receives no assessment of her suggestion from any of her group members. No one takes over talking, and as such, Regina interprets this as resistance since she then completes a radical U-turn in which she states that she will "go with whatever" topic the group choose (line 47), even though she has spent this extract fighting to pursue the topic of 'masculinity' as opposed to 'place identity'. This contradicts Pomerantz's (1984) suggestion that when no overt disagreement is made, the self-deprecating party tends to treat the self-deprecation as implicitly confirmed, or in other words, that the hearers of the self-deprecating utterance agree. It could therefore be suggested that Regina's 'giving in' is treated as enhancing the group cohesion; to show her group that she is not going to be the troublesome one and although she has a preference – and a valid reason for it, in that she would 'struggle' with the alternative – maintaining harmony in the group is more important.

From an external perspective, it seems almost counter-intuitive that cohesion within this group is being constructed due to a group member's willingness to withdraw an opinion, when a major component of problem-based learning is revolved around the ability of groups to work together. However, this could also be interpreted that in asserting that she will "go with whatever" decision the group makes, she is 'doing being collaborative' in that she is putting aside her personal opinion to be more aligned with the group and thus promote cohesion within it.

3.3 Analysis 3: "What kind of language am I speaking in?"

In the final extract, a psychology PBL group are jointly transcribing an interview they conducted, in which group member Jackie was the interviewer.

```
                   ((recording plays: 9 seconds))
    Nadia:         ((to Jackie)) have you got this [bit
    Jackie:        ((looking confused))            [£WHA'KINDA
                   LA(h)NGUAGE [AM AH SPEAKIN' [IN heh
    Ally:                      [heh heh heh
    Jocelyn:                                   [((smiles))
    Nadia:        ((impersonating Jackie))     ['eh eh [lalalala
    Ally:                                              [((smiles))
    Nadia:         la(h)' [heh
    Jackie:               [right
    Jocelyn:       heh heh .hh
    Jackie:        um (.)
    Nadia:         ((smiles))
    Jocelyn:       heh
    Jackie:        I-
                   (1.0)
    Jackie:        go back to 'routine' (.) 'cause I did say 'like
                   so yeah like so(h)' £hm hm
```

The 'trouble' in this extract stems from the fact that the recording has been playing for nine seconds without any group member commenting on or re-verbalising what is being said. The usual procedure they have been following is that Nadia would play the audio, and Jackie would repeat what was being said as she typed it, while the other two group members helped clarify the audio. In this instance however, Nadia looks repeatedly between her phone (the audio) and Jackie (the typist) during this period of "silence" (although the audio is playing), as the usual dynamic has changed; Jackie's lack of typing is being treated as problematic.

It is at this point that Jackie self-deprecates by expressing that she doesn't understand what she is saying on the recording. Although her actual verbalisation, "what kinda language am I speaking in?" is technically a question, the way that she formulates it (by looking confused, raising her voice and gesturing animatedly) indicates that she may feel just as perplexed as the rest of the group – even though it is her voice they are listening to – and as such, shouldn't be held accountable for not understanding because she feels the same as everyone else. We see from later in the transcript that the issue regarding the difficulty in understanding the audio stems from Jackie's over-use of discourse markers (e.g. Schiffrin, 1986) – uhm's and ahh's – hesitancies and fillers when she was conducting the interview, and as such it is difficult to make out what she is saying. Jackie therefore verbalises the problem the group have on their hands; that if even she as the speaker can't understand what she is saying, how can the group continue transcribing?

The group members' responses to Jackie's self-deprecation are of interest because although she is literally asking a question, she does not receive an answer. While Ally laughs and Jocelyn smiles at Jackie's utterance, it is unclear whether this is in reaction to what she is actually saying (i.e. the deprecation) or for another reason, such as Jackie's reaction to the audio. Nadia's response, however, is quite different in that she impersonates her and her over-use of fillers (lines 54 and 56). This is a somewhat dangerous thing to do, in that the group dynamic is very much dependant on Jackie's response; if Jackie takes offence at this impersonation, it could be disastrous for the group dynamics as there would be tension between two members.

Nadia's impersonation of Jackie constructs cohesion within the group. Had Jackie taken offence, it is likely that she would have responded appropriately, but she doesn't acknowledge Nadia at all and instead re-focuses on the task. Soon after, Jackie shows that she may even accept Nadia's interpretation of her by agreeing and emphasising that she "did" (line 64) utter a string of fillers, thus validating Nadia's claim. This may show cohesion between Nadia and Jackie, but Ally and Jocelyn's responses show that are included too, due to the timing of their laughter. The fact that they smile (line 55) and laugh (line 58) in response to Nadia's impersonation indicates that they feel comfortable enough in the group to join in with the mocking. Although they don't verbally state that they agree that Jackie was speaking nonsense, the timing of their affiliative laughter and smiles suggest support of Nadia. Had they been wary of upsetting Jackie they may have suppressed this but openly aligning with Nadia in front of Jackie shows they consider the group as a whole as cohesive enough to take this 'picking on' one member.

4 Discussion

These examples, although brief, aim to demonstrate how cohesion can be constructed in real-time interaction. Group cohesion has been identified as the most important aspect of small group research (Lott & Lott, 1965), and as such, it is vital that student groups are supported for cohesion to take place. One of the difficulties of researching a phenomenon such as cohesion is its vague nature; even if all group members report that they felt 'cohesive', this does not necessarily mean that cohesion was accomplished. While past research has tended to focus on measuring cohesion by asking group members how they feel about the group and the task (e.g., Carron et al., 1985), more discursive-type research has the potential to show how cohesion is constructed naturalistically as it happens in real-time interaction.

In the first analysis example, cohesion was constructed through a group member's recognition of an instance in which she violated the usual group dynamics. By acknowledging this through self-deprecating, she demonstrates her understanding that she created a problem for the group and thus holds herself accountable for what she did, but does so in a humorous way which incites laughter from her peers. By responding to her in this way, her group display that they can put this problematic situation behind them, and get back to the task at hand.

In the second analysis example, a group member self-deprecates a future version of herself, in that if the group as a whole make a decision within their PBL task that opposes her own opinion, she will be a less adept group member, which is potentially problematic for the rest of the group. Through laughing, her peers don't have to agree or disagree with this claim, but in doing so, the self-deprecating group member interprets this as resistance and as such retreats from her assertion of what they should do. Thus, cohesion is constructed within the group due to one group member re-formulating her contribution to ensure she doesn't upset the harmony by forcing a decision to be made, even if it hinders herself.

In the final extract, we saw cohesion being constructed through an episode of mocking. Self-deprecation is more acceptable in interaction since the disparagement is self-administered; however, when directed at someone else it can be troublesome, depending on how the recipient takes it. Here, we saw a group member make fun of herself for the way she spoke on a recording, before she was impersonated by a fellow group member. The aligned laughter from the rest of the group in response to this impersonation suggest that they find it humorous, and as such, it could be construed that they whole group are laughing at one member in particular. Cohesion, however, is constructed through this, as the 'mocked' group member's ability to 'take' the impersonation and laughing indicate that as a group, they are able to do this without overstepping the mark and turn it into more insulting or bullying behaviour.

Of course, we must consider too the drawbacks of this type of research. One of the difficulties of researching a phenomenon such as cohesion is its vague nature. Whereas there are robust tests to reliably measure, for instance, psychological behaviours, there is no one way to demonstrate for certain that cohesion within a group has taken place. Even if all group members report that they felt 'cohesive', this does not necessarily mean that cohesion was accomplished. In addition, those groups that chose to take part in the research and thus be recorded were aware of this very fact, and as such it could be argued that they possibly behaved in a way on-camera that portrayed themselves as – for instance – overly humble through self-deprecating, in order to come across as a particularly appealing student.

This paper is part of an on-going study investigating cohesion in student groups. As researchers working with student participants, it is crucial to recognise what we can do to better support students in higher education. The current research can go some way to help those involved in group work teaching or facilitating, by helping them be more aware of the intricate interactions taking place at the group level. As such, future research in the area may consider other stereotypically negative facets of group interaction – such as teasing, or going off-topic – as demonstrating the pro-social outcomes of these can inform PBL research.

The types of interactions that have been analysed can be found in groups across a broad spectrum of disciplines and it can be useful to focus on the non-academic talk in environments such as these to get an insight into the social processes that can often hinge on the relative success or failure of group work. As educators, we want to encourage students to leave university valuing the skills they have learned through such processes as contributing to group work so that they are prepared for life after university and are not just focused on their final degree classification. Looking at laughter stemming from self-deprecation may seem a counter-intuitive way of analysing cohesion, but if we can demonstrate benefits that come from less desirable aspects of the group work, we are better positioned to support students who may experience such settings and be unsure as to how to deal with them.

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6 Appendix

6.1 Jefferson notation system

((action))	non-verbal action
(.)	Just noticeable pause
(1.0)	Timed pause
.hh	In-breath
wor-	Cut-off word
>word<	Faster speech
WORD	Louder speech
°word°	Quieter speech
word	Emphasised speech
£word	"smiley" speech
wo(h)rd	(h) denotes laughter bubbling within word
wo:rd	: denotes stretching the preceding sound
A: word=	= denotes no discernible pause between two speakers' turns
B: =word	
A: word [word	Overlapping talk
B: [word	

*Adapted from system developed by Jefferson, printed in J.M. Atkinson and J. Heritage (eds.) (1984) *Structures of social action; studies in conversation analysis* (pp.ix-xvi). Cambridge University Press.

Experiences from a change to student active teaching in a deductive environment: actions and reactions

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Abstract

Courses in engineering often require deep learning ability such as explanations argued using evidence and individual conceptions of the topic (Entwistle, 2000). Since the frequency of completed exam has gone down at Higher Educations engineering institutions in Sweden (report UF 20 SM 1303, Swedish higher education authority) the level of the general student's ability seems to be decreasing. Also the number of students has gone up by 20 % from 2001 to 2010 in the first year (registered students on the faculty of engineering at Uppsala University) which calls for other teaching methods and ways to generate conceptual knowledge and learning.

The methodology of the study is a narrative inquiry part of a mixed-methods research in a social constructive perspective on achievements and reactions of students who becomes responsible for their own learning in a teaching model based on student active methods like flipped classroom and problem based learning (PBL) with a clear conceptual focus. Since the main goal of the inquiry was to get their responses without leading questions and put it into perspective of my 25 years of experience in teaching adults on different levels, I have decided that the best way to analyse the data is within a narrative approach. In interviews students from a bachelor and a master program in electrical engineering indicate how they experience the differences, benefits and flaws, and how it affected their learning, awareness of their ability to learn, i.e. self-efficacy, motivation to learn more and how it developed during the course. The study reveals the factors that make the student passive instead of following and taking part of the working plan and also contains an analysis on what drives students to make the decisions on their attendance and effort.

Keywords: Motivation, conceptual learning, facilitation in terms of supervision, PBL, flipped classroom.

1 Background

Experiential learning theory (ELT; Kolb 1984) aims to help the learner "to learn how to learn". With ambitions to continuously improve following the recursive cycle of experiencing, reflecting, thinking and acting, the learning power can increase. The development of you as a teacher comes from the simple fact that you see yourself as a learner (Kolb & Kolb 2009).

From a teaching career of 25 years, 15 of them at university level, I have experienced a change in attitude where the students has gone from accepting a structure and the teaching, to where the students require and demands more teaching and showing less prior knowledge which has led to a big change in the structure for the courses. The passing rate has gone down and the students feel less motivated to get a grip on their own learning and realize that it is up to them if they will succeed or not. In my experience it looks like the general opinion has turned from them knowing they have to learn by themselves to a belief that the teachers shall do the learning for them. Maybe this is just a grumpy old man's declining ability to create learning opportunities for the students. I have also experienced the transition from independent to more “demanding and needy” students that are formed in “old school teaching”, a deductive approach of lectures, lessons in terms of a tutor solving textbook problems, and laboratory experiments to clarify the theory described in the textbooks. The constant request from the students has been for more teaching. In this model that is what they are familiar with. This leads to reactions and negative energy which moves the objective from learning the content to formal issues about “too difficult courses”, “impossible exams”. As a result, instead of studying hard students start to search for possibilities to pass the exam in other ways, for example by requesting alternative examination and/or demanding another examiner. For me personally that entailed a transition from being a very popular lecturer to a suspected one and I experienced the frustration of feeling insufficient in my tutoring and guiding of the students towards the required knowledge. Therefor I have tried the last three or four years to move the focus from the teaching process to learning in the classroom. The key aspect has been to raise the conceptual level of the teaching in the classroom and focus on *discussing* problems and its´ solving in contrast to just presenting the theory behind it and *showing them* how to solve problems. “Learning takes place through the active behaviour of the student: it is what he does that he learns, not what the teacher does” (Biggs and Tang 2011). In 2013 a pilot study was made in a course in electronics, introducing preparatory lectures and a focus on problem solving during class. In my pilot study I came across lots of new concepts and strategies to encourage the students to prepare for my teaching in class. I introduced micro teaching, flipped classroom, PBL and other methods to make the learning process more effective and the students more active. The main focus was to make the time with the students more efficient. The students’ responses were in general positive, but the results on the exams were not significantly better. Therefore I was motivated to find out more about student active teaching and how to implement it. From my experience I reflected over the results, the students’ evaluations and many hours of discussions in the lecture hall as well as the laboratory with the students and came up with a teaching model that would even more increase the activity in class. One particular field they experienced difficult was the step from discussing real world problems to be able to solve them themselves. Therefor I introduced another step of problem solving confirming the theory instead of jumping directly to the real world problems. Besides analyzing their exams and conceptual development I interviewed them to get feedback on how they experienced the teaching model and their own development during course. The results of this study are reported below.

2 Introduction

The study took place at a course in electronics the second year on two engineering programs in electronics at Uppsala University, a bachelor and a master. After a first year where 80% (37/46) of the students’ passes 50+ out of 60 credits, many of them (69 % on the first exam) fails and finds the course so much more difficult to complete. The course consists of four parts; one is analogue electronics coupled to a number of assignments (=second part), the third is digital electronics in project form and the last is a project they decide on their own what to do related to the course content. It is especially the first part that causes the problems. The third and fourth part of the course is project based and it has been quite clear that the passing rate is much higher on that part, mainly because they work so much harder in projects together.

I am the lecturer of the course and have been that since the course started in 2010. The course started with 46 students that had the necessary entrance qualifications. The students were divided into six groups of maximum eight in each and were encouraged to work in this group during the course, which lasted the whole semester. The later part was dominated by two major projects. The first part was mostly theoretical and the second parts assignments came from the content of the first. The assignments were individual but they were allowed to work on them together.

Table 1: The content of the course.

Theorethical part (5+5 hp)		Project part (5+5 hp)	
Analogue electronics	Assignments	Digital electronics	Their own project
OP-amplifiers Feedback Filter design and analysis Semiconductors (mainly transistors)		Design of a sequential circuit based on a given problem.	

A number of laboratory experiments were given on an optional basis. The planning of the theoretical part was rigid on a weekly basis with clear goals each week and contained the following:

- Web lecture and test of the fundamentals
- Conceptual lecture focusing on problem solving
- Lesson directly after the lecture where they were encouraged to work on simpler problems leading them towards basic understanding and applications of the topic.
- The above was then repeated the next day completing the week's theme.
- Time for them to work on their own under facilitation of the teacher. They were encouraged to work in the selected groups. This part included eight scheduled hours in class.
- A follow up ended the week where they either could take part of an optional lab or take a seminar with the teacher discussing what came up during this week's work.

The theoretical (i.e. the first half) part ended with a smaller project before a written exam where they built a rather complex device and implemented it on a pcb (printed circuit board). In the third part it started with a crash course of the fundamentals to give them some basic knowledge of the field, followed by a large project. After the crash course all scheduled time was for the project under facilitation. They were to design a control system for a small elevator that was handed to them. Otherwise the instruction was quite open for them to decide the futures their solution should cover. The problems that arose were to be solved with facilitation from the teacher. The approach was inspired on the PBL at Aalborg University in their engineering programs (Kolmos, Fink, Krogh 2006).

This study examines how students act and react when they are exposed to teaching separated from the normal structure (see "old school teaching" above) and what I as a teacher can do to make them perform at their best.

3 Research questions

How do students adapt and react to an inductive teaching model and how does it affect their motivation and experienced conceptual learning?

4 Theory and definitions

Flipped classroom - Jonathan Bergmann and Aaron Sams recorded lectures and posted them online as a service to absent students. They noticed to their surprise that also present students used the lectures as rehearsal and came up with the idea to use the time in the classroom more efficiently. The time in class could now be used to work with problems and communicate with the students individually (Tucker 2012).

Blooms taxonomy – A categorization of the levels of reasoning skills in the classroom. They are knowledge, comprehension, application, analysis, synthesis and evaluation in the order he proposed (Bloom 1956).

Self-efficacy - A person's estimate of their own ability to perform a task.

5 Methodology

5.1 Narrative inquiry

This is a narrative study of actions and reactions from the students based on 45 individual interviews. Narrative inquiry is a way of understanding experience (Clandinin & Connelly 2000, p. 20). They developed a narrative view of experience from Dewey's two criteria of experience, interaction and continuity. The first criterion, interaction, implies that people are individuals and has to be seen in a social context (p. 2). Continuity: Everything we experience develops into new experiences from our previous. So from Dewey's theories of learning by doing and experience there is a strong connection on a narrative approach to research. The experiential learning is inspired by the work of Dewey, Lewin and Piaget (Kolb 2014). All three of them are similar using experience and concepts to reflect and act upon to develop the concept. In the chapter of The process of the experiential learning he summarizes the process by defining learning as: "… the process whereby knowledge is created through the transformation of experience." So by filtering my students' experiences through my own knowledge I suggest further development in the process of creating student active learning and teaching in the mostly deductive environment. Well in harmony with the experiential learning cycle (p. 51).

5.2 The interview process

The planning included an icebreaker (Creswell 2009 p. 183): "How did you experience the course and its content?" followed by a number of more specific questions. The purpose was to hold the first question open to find out what first came to their mind and me influencing them as little as possible. They should quite freely put their mark to create an opinion. When they had respond to the icebreaker I focused on the comparison between the theoretical and the project part and asked them to compare them and put them into perspective of their previous courses. The common first answer "Really good course" is not accounted for in this paper since I wanted them to develop their thoughts more and explain what made it so great. The Icebreaker showed very clear what came to their mind. The results in this paper are interpreted from the interviews and all conclusions and future developments are solely based on what came up through the interviews.

6 Results

Four different topics stood out from the interviews, namely flipped classroom, the advantages of working in projects, the benefits and flaws from having all the teaching on a voluntary basis and the need for structure. The results are organized in order of the most significant responses and the headlines of the subsections derive from the concerned topics. I've included some theoretical background in some of them to clarify the thoughts behind each part of the learning environments that were mentioned and analysed.

6.1 Flipped classroom

To create an analysing and creative environment in my teaching I try to stimulate the students to move through the six stages of Blooms taxonomy. In my planning I lifted out the knowledge and the comprehensive level to reach the application level in the lecture hall. To make sure they understood I prepared a couple of questions on basic applications that was handed out at the end of the lecture. They were then invited to work with these problems during facilitation sessions. All this was done the first day of the week (and repeated the second). If they got past this they could more easily work with more complex applications and analyse as well as synthesize their new found knowledge during the week's facilitation hours in class. There is little doubt in students learn more if they come prepared. Fulton (2012) listed among other advantages using flipped classroom that classroom time can be used more efficiently, and teachers can see that the students' achievement, interest and engagement is raised.

More than 50% (24) identified the preparing lectures as an example of the really good thing with the course. They felt they could really benefit from the fact of being prepared and understand the conceptual strategy on the live lectures. Out of 47 registered students on Scalable learning (See http://test.scalable-learning.com/#/ for more information) at least 35 prepared by watching the web lecture and the reason was mainly the fact that the effort required no more than 15 minutes and no thinking what so ever how to prepare. It wasn't necessary to register to see the films since they are available on Youtube so there were more than 40 views/film before each lecture. The submitted tests however decreased in popularity since they first of all felt too hard, and second didn't come with a correct answer when they responded wrong. This was a future I wasn't aware of but there were explanations on the wrong alternatives why they weren't right. An additional asset was the use of the web lectures as rehearsal before the exam. Many of them claimed to have returned to them repeatedly.

Conclusions: In order to keep the preparation short and simple three or four very basic questions is enough to give them feedback that they can understand. Is it possible then to use the flipped classroom technique with tests of conceptual learning? Yes, and you should use it as a closing of the week's theme. The advantages are several: First of all the students get direct feedback of the week's work put in and if they learned what's been taught. Second it gives you the opportunity to be even more clear on what you as a teacher think is the most important to know, and third, it gives you a good base for a quick summary of this week's work and an opportunity to close the bag on the first lecture of next week considering the result of the conceptual test.

Future development: More videos not just on the basics but also on specific more complex parts where a short web based lecture is applicable. It is not necessary to invent the wheel again since there are a lot of instruction videos on Youtube, online teaching sites for free, and even apps to your phone (for example: Everycircuit) which you can refer to and use as preparation and study material.

6.2 The structure

In 1790 Johann Gottlieb Fichte started lecturing without a prewritten manuscript. The knowledge was created on the podium instead of being tied to a textbook or another text. This is the breaking point between the Middle Ages authoritarian text reading to where the lecturer himself creates the knowledge.

Morton (2009, p. 59) suggests that the lecturer shall:

- Share their passion for the subject by explaining their passion for the field
- Linking to actual events and illustrate it with real examples
- Show the connection to the students prior knowledge

- Use rhetorical questions to make the student alert and follow
- Use the web to show the contents actual relevance

To create knowledge and deep learning you have to complement the above with one or two clear goals on what to understand and learn, and the ability to directly apply the gained knowledge in an upcoming lesson where the students work with problems on the application level (Bloom 1956). A clear goal unspoken for the students was to create an environment where they are stimulated not only to take notes but also to be enough aware of the lectured content so questions come up spontaneously.

Creating an inductive environment helps the students to gain a more comprehensive knowledge and develop learning on a much deeper level than the purely deductive approach (Prince & Felder 2006).

The main goal for this teaching is preparing the students for their own work. Ralph Tyler (1949) wrote:"Learning takes place through the active behaviour of the student: it is what he does that he learns, not what the teacher does." Sounds easier than it is: The teachers (only) goal is therefor to put the students to work with problems that get them ready for the exam, or at least make them aware on what to learn. Their own studying took place as two four hour sessions, me facilitating the students when working together in the groups.

In the facilitation part they meet with the tutor twice a week. Their way of communication is the tutor's responsibility to make sure that the problems are solved satisfactory. They must put themselves into the students problem solving context and just not correct there errors (Lampert, 2001). Therefor the questioning to correct a misconception among the students is critical; a method is the reflective toss (van Zee and Minstrell 1997) in order to engage the student in the process of evaluating their proposal and refine the thinking towards a previously known model.

The structure of the first theoretical part was mentioned by half of them (23) as a significant improvement of the teaching and pedagogy. They knew from day to day what to expect and that was highly esteemed. They appreciated the teaching forming a clear thread covering the basics, the conceptual view, learning the concepts, and the facilitation process solving problems repeated each week. 18 of them, 14 expressed as the group work and 4 their own work, lifted the facilitation lessons with the clear conceptual focus in problem solving as most contributing to their learning. 11 of them relished the follow up lessons on the live lecture learning the concepts of the new area covered. One of the students rose from being 'average' to a 'top grader' and motivated the improvement with great interest and the structure. Still many of them failed to get a grasp of the content enough to pass the exam and issues like motivation (personal) problems (3), the lack of deadlines of the assignments (7), and no one pushing them to get going (4) were stated. An example of the mixed reactions was the two students who expressed the lectures as being "fuzzy".

Conclusions: Since almost half of them experienced difficulties working in the noisy environment during facilitation lessons an idea is to help them facilitate themselves by preparing more videos (see above) and a clear guide on how to use the internet and the many sites and programs available for analysing electronic circuits, in an attempt to make the groups an automatic cell working on its own but still with a facilitator around the corner. In order to make the working load manageable for the teacher their own studying in facilitation class should encourage them to process their problem solving skills in the groupings and meet the facilitator on specific times. A more rigid structure at the start of the course is helpful to several who fail to get going from the start. One solution may be: Make them hand in one or two assignments in the first two-three weeks, offer a test after three weeks, or use the flipped classroom to give them tests on a weekly basis that becomes the foundation of the summing up starting each week as a closure on last week's theme. This is a golden mean between taking responsibility of your own learning and progress, and the need for structure proven by the statements above.

6.3 Time spent by students

Establishing their effort in working hours in the first half there was more than 50 % that estimated their working hours/week to less than 40, and as many as 35 % under 30. Most of the top performers (see below: Benefits and flaws…) saw the first part as eight hours working day, 5 days a week, but there were all kind of working hours among the ones that failed although less work guaranteed not passing the exam of course. In the project phase however they all were surprised how much time they had put in, many of them claimed "all the time awake". Less than five claimed no change and blamed illness or work beside their studies the reason not working as hard as the others.

The projects were highly appreciated, especially following a rather tough theoretical part. Here they really felt that what was previously taught was applied to real world problems. There was a significant increase in the working hours where only five of them still claimed to be working less than 40 hour, compared to more than half of them on the first part. That was even clearer in the passing rate that was as low as 14/45 (31%) on the first part and 38/45 (84%) on the second.

Conclusions: One way to motivate them to work harder is to give the group a responsibility towards all the participants. This could be done by letting them hand in a critical analysis of the week's work and what they did and did not learn and how they experienced the effort put in. That gives you as a teacher a good foundation for the summing up of the week's theme and an opportunity to stress what they experienced as hard to learn or work with. A conceptual test on individual level complements the feedback from the group. This can easily be done in Scalable learning.

6.4 Benefits and flaws from having almost all the teaching voluntary

Teaching at the university is mostly on a voluntary basis with compulsory assignments and laboratory experiments, sometimes put together in reports. I consider it to be one of the beautiful things with tertiary education that it is a smorgasbord for the students where they are supposed to create their own planning from all the information and education given, and the excellence in knowledge from the lecturers and researchers available. It is only the knowledge examined that counts, whether there is from written exams, oral presentations and/or completed projects. Therefor it was very important for me to do all the teaching and learning facilities available on a voluntary basis where the motivation and the urge for knowledge driving them to participate or not. The teacher is not going to be the attendance secretary, but the inspirator for the students to seek knowledge.

Looking at the performance in terms of grades almost all of them with a 4 or a 5 really liked the concept that all scheduled teaching and learning were voluntary and the fact that it was up to them to organize their studying. It was also obvious that many of them who failed the first part were quite aware of the responsibility on their own and that all the information and opportunities were there, but their laziness failed them. The need for deadlines and clear goals in terms of assignments and the teacher forcing them towards exam was apparent. One of them stated: "Voluntariness is evil". In the projects parts the grouping influenced them to work harder as seen in figures on the outcome of the test.

The students' ability to learn and their performance and effort put in are summarized in their self-efficacy. During the phase of creating an inductive model of teaching it has become clear to me that the curriculum has to consider what state of mind the students are in. It is easy not to take that into consideration since the responsibility of their studying is all on the students. However to allow for that there are students not 100 % motivated and prepared for the course given and let that influence the curriculum can turn the pendulum around and help the students not only to set the necessary goals on their achievement, but also to, from without their situation in real life, be realistic and for that reason find motivation to overcome issues that bothers them in terms of performance and effort. An individual with high self-efficacy works harder and longer than one with low self-efficacy (Wood Bandura 1989)

During the interviews it became clear that there were four types of students in terms of performance and effort. I have chosen to call them the leaders, the followers, they who got lost and failed to catch up, and the lazy ones who couldn't sort it out. Of course most of the best performers were to be found in the leaders group, but not all of them. The followers didn't feel that they contributed with ideas and were the ones driving the group; one of them described his part as "I contribute by being nice", but accepted the role and functioned well as it seem (from their point of view). One of them who took a clear leading role failed the 1st exam even in his 2nd attempt. Still he sent me a letter and thanked me for a brilliant course. Also one of the lazy ones who didn't study at all on his own passed both exams with good grades. Elsewhere the top performers were to be found in the leaders group and the followers managed to get by, some of them via the rest exam on the 1st part. Not one of them who failed to sort it out, 9 there is, passed the course. In the third group 7/12 managed to finally pass via the rest exam.

Conclusions: The categorisation is set to make it easier to determine what is to be done in helping them towards exam. Therefor you can set goals and plan for each of them to reach a reasonable goal and adapt your teaching with their character in mind. The difference here is that it is fairly easy to show what's necessary to reach specific grades, but seldom has the suggested curriculum considered what state of mind the students are in.

The 1st part saw a very high participation on the web lectures as well as the live lectures and the following conceptual lessons. Although many claims to have been studying in the facilitation lessons no more then 40-50% was present in the classrooms that were scheduled for the group work. They argue that the volume was too high and preferred to sit elsewhere. The concluding seminar and voluntary labs at the end of the week didn't work as planned. The seminars didn't become the forum for discussing the weeks work and therefor they ceased to exist and the focus on Fridays was in the laboratories. My conclusion is that the seminars is pointless since they have so much time with a teacher anyway so to partly get them going better from the start, and partly be more effective, assignments including laboratory experiments to be done at the end of each week combined with the already mentioned online test of the week's knowledge should be tested as improvement of the teaching model.

6.5 The awareness of knowing the whole

The course included a very well prepared study visit at a large company that evaluates their own electronics, and a guest lecturer from an advanced sound improving company corresponding well to a parallel course in signal processing. Together with the projects and opportunity to realize their own ideas many (25-30 %) of them expressed in different ways how the course helped them understand the role of the engineer and what's expected from them in the real life.

When asked to evaluate their own learning from without the learning processes six of them described themselves as "mathematicians", and more surprisingly five of them expressed they experienced trouble with maths! Many of them made the connection to some courses in the 1st year and four of them meant that the token has fell down. More than a third (17) expressed their understanding of electronics in context and finally they understood what they were supposed to learn in the 1st year. This was in particular shown that a lot of them started their own projects. They were definitely more aware and asked questions on a level I seldom get from more than one or two per year. That was encouraging and what really surprised me was the willingness to put in so many extra hours creating circuits “off topic”, just to discover more. One specific project became constructing a functioning radio circuit which came out of the fact that we had discussed stability in terms of feedback, and oscillators using feedback to create an unstable circuit. There were three groups that worked really hard to solve this problem, almost like a contest, on which one succeeded first in sending and receiving music and talk in the FM band. Some of them (7) started their own projects, and two groups even “over-worked” one of the projects just for the fun of it. Other electronic problems on a fundamental level, for example what is really happening in the transistor when Ohms law ceases to apply, how come the feedback of an operational amplifier can vary from being stable to create an oscillator when the two inputs seem to be the same, were discussed, questions that rarely occurred during the years. This was by no mean restricted to the top performers or even the followers.

One of the students said “The most important role for a teacher is to engage and pull strings rather than being a reference book in a subject.”, and continued: “This together with the fact that you know all of us by name and sit down and discuss whatever matters us, makes the communication on a whole different level then before (=previous courses).” To stimulate the communication during lecturing to reflect on questions that are raised is there for appreciated but some reactions came also that thought the lectures became “fuzzy” and made the lecture notes a little hard to use and see a clear thread in them. So here a delicate question rises on what to pick up and what to neglect, in order not to inhibit the students to state their reflections on the content and create a conceptual environment during teaching in the lecture hall, on the expense of stringency and follow a prearranged script.

7 Summary

The development of the model is appreciated by the students. Both the structured theory part and the project based. To get the lazy students that failed starting right away there should be some assignments to hand in the first weeks. This could be combined with the suggested laboratory experiments mentioned above. Some well guided projects towards a very specific goal works well in larger groups (6-8/group), but in the project phase where the students are more responsible for the goals set and even what to construct there is a risk that students feel more like assistants to the more driven student and therefor, to secure a creative environment for everyone, the groups shouldn’t contain more than 3-4 at the most to prevent that some of the group members fall between two stools and becomes passive during the creative process. The more open projects could also include regular meetings with the tutor to secure that they thought the process through before starting the construction work. This is by no mean a necessary requirement but more as another learning environment to consider in the process.

The teacher (tutor) has an important role to communicate with the groups what to be expected from their work. The dialogue shall help the group to set goals and a plan to reach them. The group is held responsible for their members and that they fulfil their goals; this has to be clear from the very first day.

Since the students experience a very high motivation in the project based part it is important for the facilitator to be the oil that makes the smooth engine run even more effective by encourage them avoiding hick-ups like malfunction equipment, difficulties finding time in the laboratories, a good system for them to order and find the necessary components, and, most important of all, be encouraging and supportive in their efforts and considerations.

To create the awareness there is so important to point out for the students that a huge part of the learning process is to find out how you, YOURSELF, can learn the most. How shall I plan my studying, what computer aids are available, which projects are suitable for me to dig in to? If you combine theory with a suitable project they design you can not only make them solve a more conceptual problem, you also most likely inspire them to get a grip on their understanding and awareness of what to learn. Not just to move further, but also how to gain the necessary confidence in the field making they maybe not reach the feeling of master the area, but a way to reach a level of understanding and a feeling of knowing where to find the knowledge. This must be a serious teacher's main goal in the planning of a course. Give them the necessary knowledge presented of course, but also how to get there, how to get the necessary conceptual understanding, and how to move on and be automatic in your future progress.

Further conclusions regarding the course development and more generalized suggestions about improving the weekly planning will be processed in another paper.

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A Project Based Learning organization in deliverables, assessment and on line tracking groups using LMS and on line tools, based in a nine years PBL experience

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Abstract

In this paper, we present the results of our Project Based Learning experience of 9 years in a computer graphics subject in computer engineering. We present the PBL methodology used and the organization based on three main aspects: firstly, defining our PBL approach, how we have organized our PBL methodology and some examples of project proposals and their learning objectives, secondly, defining the different deliverables as indicators of student assessment and feedback, and finally establishing assessment criteria based in group and individual indicators. These deliverables are sent and received by means of the Learning Management Systems (LMS) Moodle. An interesting idea of our experience is that PBL requires a significant face to face follow-up of student's group work. Internet communication and LMS allow remote group meetings and on line communication. According to that, in the last year we have applied a remote "non-classroom" student activity tracking. We have used the OpenMeetings tool within a Moodle 2.0. These results are not good, and we must to improve the use of these tools to the students. As results of our PBL experience in these years we report registration rates (from 55 to 155 students) in PBL modality in different years, as well as, evaluation surveys on students about PBL methodology, teacher opinion about the course, and finally some ideas to discussion. Our main conclusion about this PBL experience is very positive, and we want to improve our PBL organization and methodology in the future. Also we offer our PBL documents, deliverables and experience to teacher community.

Keywords: Monitoring and assessment in PBL, PBL on line, Virtual Resources to cooperative learning, Moodle, OpenMeetings

1 Introduction

In recent years, information technology, Internet and mobile devices among others have revolutionized teaching methods in all areas, especially in college education. Easily accessible and free information has changed the role of the university teacher as the only path to knowledge. Formal lectures in the classroom are no longer vital to the acquisition of knowledge. The MOOC (Massive Open On Line Course) are starting to offer online knowledge that can be acquired whenever the student wants it, not only within the hours of lectures, so they can decide when and how to learn, thus creating the student 2.0.

One methodology that aims to address these changes is PBL (Problem or Project Based Learning). There is extensive literature on the bases and pedagogical foundations of PBL (Barrow, 1986, Albanese, 1993), that was first used in the field of medicine (Barrow 1980) as well as experience in all the areas of knowledge and in different universities, some of them using this methodology in all their degrees, as in the case of the University of Aalborg.

Our experience in PBL started the year 2004 based on two important facts: First, a stay of Dr. Luis Branda from McMaster University (Branda, 2009) to our university, he is one of the pioneers in promoting this methodology. The second was that teachers began to notice some exhaustion of the teaching methodology based in the traditional lecture in their courses in computer engineering at UAB, which was revealed by repeated absences of students in these classes. In contrast, Practical and problem oriented classes, which had higher interaction with the teacher, had a higher ratio of attendance. These facts motivated focusing our research and efforts in the application of PBL to our engineering courses, in particular computer graphics. To do so, we reported experiences in engineering like the one from Aalborg University and others

In this paper we show the results of our PBL experience in the Computer Graphics course for engineering studies. The goal ids to present the different improvements made to the methodology during the years 2004-2013 with feedback from the experience of faculty and student opinion obtained by surveys. The methodology used to validate the proposal is based on the feedback provided by students and the insight of faculty in the process.

The paper is structured as follows: in section 2 we introduce the context of the subject (degree, credits, contents). In section 3: how we currently organize this using PBL, justifying our proposal as much as possible. One of the latest developments undertaken is online or offline monitoring group meetings using the *OpenMeetings* tool (OpenMeetings 2015), also using it for not face-to-face tutorials. We explain in some detail the deliverables we ask students to produce and the evaluation criteria. In section 4 we show objective evidence such as enrollment's date and the number of students who choose the PBL itinerary, as well as students' assessments on their learning and work done. Finally, in section 5 we discuss the opinions of teachers and tutors as well as some further discussion topics in the field of PBL.

2 The Subject

Computer Graphics 2 is an elective course in year 4 of the Computer Engineering degree. It has 6 ECTS, and students have to attend presencial weekly classes, 2 hours of theory, 1 of problems and 6 practical classes of 2.5 hours.

The contents of the course are basically topics on 3D graphical display, ranging from geometric transformations and visualization, through 3D modeling, rendering algorithms (hidden surface, lighting models, ray tracing and radiosity algorithms, textures, transparencies, shadows) and computer animation techniques, especially animation of rigid and articulated objects. There is plenty of basic literature on the subject, from which we highlight (Hearn et. al. 2006) since it addresses these issues using graphics library OpenGL (Open Graphics Library) (OpenGL 2015), that we use in our practical classes.

Since 2004-05 we have implemented a PBL organization, based on our experience in receiving a course of PBL given by Drs. A. Font and L. Branda (Font et. al. 2004), making it compatible with a classical theory itinerary with problems and practices, giving students a choice between one of the two itineraries. The idea was to spend the 2 hours theory sessions to PBL tutoring and the problem's hours to explain theory subjects and exercises, giving students their theory and problem exercises at the beginning of the course, thus providing the students who chose the more classic itinerary with more autonomy in their studies. All students had to do the practices, some to pass the subject (classic itinerary) and the ones who chose the

ABP had to do it in order to learn the techniques needed for their projects. The success and satisfaction derived from the students that chose the PBL itinerary is the main cause that the number of students applying for this itinerary had increased steadily in each subsequent year.

In PBL, the project is the foundation of learning. Each project involves some learning objectives that the teacher defines expecting students to find them and work them out.

Projects' statements are short (few lines), and the expectation is that students will take a professional role (they are asked or are 'hired' to develop an application) and have large freedom to make decisions on the objectives, using expressions such as "the display is as realistic as possible" or "the most realistic movements" so that they themselves are able to determine the limits.

The experience of implementing the PBL methodology for the period 2004-2009 (Martí et a. 2006, Martí et al. 2009) has been positive, and there has been some high quality work done but we have been thinking on how to improve it further. From this thoughts we have reached the following conclusions:

1. We dedicated all the monitoring students' sessions to make sure that they were progressing in their projects, without any other activity aimed at promoting learning. We did not do so in order to give them more freedom or to promote initiative, however we observed that it could have been interesting to propose some activity.
2. Each working group came every 2 weeks to have a face-to-face session, meaning that we had no way to know anything of their work during the intermediate week.
3. We did not have a clear definition of the skills to evaluate nor how to do it properly (evaluation criteria) during the tutored sessions.

The aim of this paper is to describe the progress made in each of the previous issues: For the first, definition of project deliverables issued at monitoring sessions, for the second, the use of OpenMeetings to organize online ABP groups meeting to allow continuous follow-up and for the last to improve the evaluation criteria to better evaluate student skills. To better understand these developments in the first place we will explain our organization in PBL.

3 Our PBL Approach

Students self-organise in groups of 4 or 5 people and take some responsibility in case problems arise within the group. Each group chooses their own weekly attendance schedule (G1 and G2) and meet with the teacher every 15 days.

In the first session the teacher purposes 3 projects to the students and they have to choose one. The goal of each project is to create a graphical application that should be useful in a specific field to display graphical information and to be able to analyze it numerically if possible. Examples include graphical simulation applications (traffic lights crossroads and cars, aircraft's departure and arrival at airports, car or planes' driving simulators, Formula 1 races, planets and satellites representations of the solar system, car-wash tunnels) graphical representation of mathematical functions (fractals, 2D, 3D, mesh deformations), games (billiards, 2D tetris, chess) or articulated representations (cranes, amusement park's rides, virtual characters). Students have the opportunity to present their own projects, that teacher can accept if they have similar learning objectives.

Figure 1 shows snapshots of the work of student's solutions to 2 projects proposed by teacher. The image on the left corresponds to a 3D display of the solar system where the learning objective is to model the scene (sun, planets and satellites), the realistic visualization in 3D with lighting effects and finally the definition of the trajectory of each element. Besides one group incorporated a software library that was able to calculate the exact position of each planet in real time.

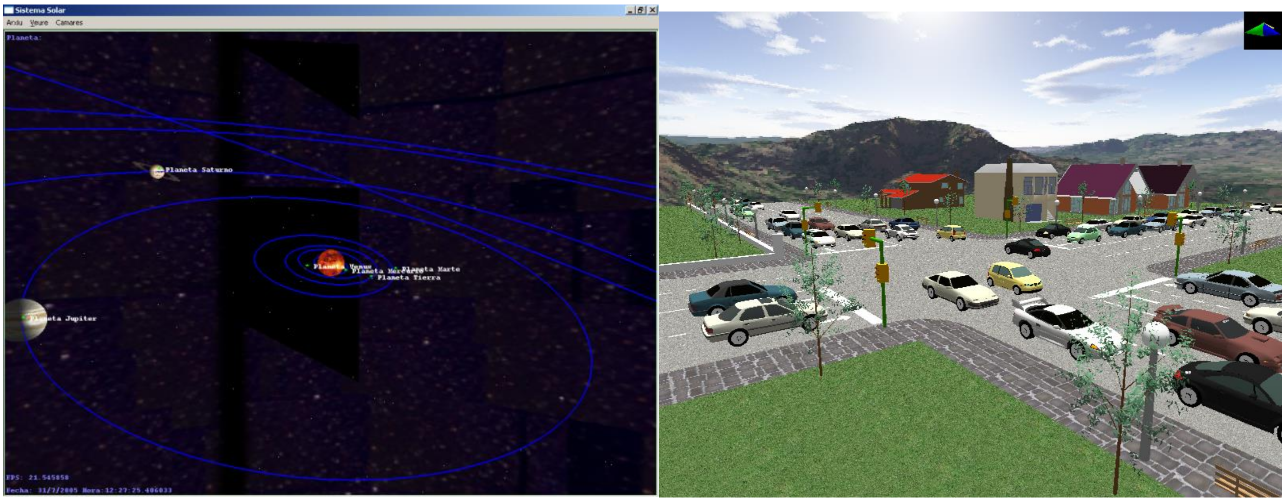

Figure 1: Examples of PBL projects done for the subject. Solar system visualization and junction's simulation.

The solar system project's statement was:

“The IEEE (Instituto de Estudios Espaciales de Catalonia) request you to create a graphic visualization tool that can display the position of the major planets and satellites of the solar system and their movements with the highest degree of realism.”

Figure 1 right corresponds to a project in which we asked for a junction simulator with streets, lanes and traffic lights; here the most important learning objectives were the modeling of the junction (houses, streets, cars, etc.), the visualization of the street in the most realistic possible manner, with different cameras (some of them inside the car), as well as the movement of cars at the intersection and the traffic lights' time management plus the position of car relative to each other.

The statement for the junction project is:

“The Traffic Service requests you to implement a graphical application that allows the simulation of a real situation in a junction with traffic lights, with the option to configure the timing of the red, yellow and green lights and the arrival of cars to the junction. The aim is to represent the scene as realistic as possible at a graphic level. The objective of this tool is to verify that the traffic light's time is correct with relation to the cars in order to avoid traffic jams.”

Furthermore, for this project you need to use queuing theory (external issue to the contents of computer graphics subject), a branch of statistic in which real times of cars arrivals are calculated together with the timing of the traffic lights (red, yellow and green) taken from averages values defined initially by the user. The goal of this simulation is to check that given average values of the times, the junction traffic can withstand the traffic or if it will collapse.

As mentioned, each project includes some learning objectives that the students must achieve. In the first meeting the students decide which project they want to make and analyze what they know, what they do not know and what they need to learn in order to achieve success in their work. In recent years students have been proposing projects (usually 3D video games) that the teacher first assess to check if they achieve the course's learning objectives. Whenever possible, this proposal are accepted in order to boost the students' motivation and involvement in the project. From the first meeting (and including all others) a detailed minute of the discussion is written that includes the discussion, agreements and tasks assigned to each member of the group for the next session.

Every fortnight the group has a two-hour meeting with the tutor. Usually each tutor attends about 5 groups per session in which the group moves the discussion of the project along and asses the work done. The tutor keep track of the group behavior, both individual students and the whole group, and tries to orient them to find solutions and answers without influencing the work or the objectives, providing that the learning objectives are still sound.

To promote learning, in one of the tutored sessions they dynamic of jigsaw classroom is done, ie one member of each group meets on a 'group of experts' and they are provided with an article related to the topic of computer graphics to be read, understand and discuss. Subsequently, each student summarizes what is understood in the article and discuss if what they have learned may be useful for their project. In a jigsaw session 5 or 6 experts meet and once the activity is done, they share with their own group colleagues what has been learned. This activity provides new ideas to the project and is well regarded by students.

During the semester, in two specific periods students are asked to deliver concrete objectives, what we called 'controls'. There, the groups define a few clear objectives they want to achieve (types of graphical applications, functionality, etc), tasks to be done and who is responsible for them and the timing of completing these tasks using a Gant chart. The first control is required at 3 or 4 weeks from the start of the project, the second at 4 weeks previous of the final presentation. In the first control, ambition of goals is assessed and requested, in the second we expect the tasks already done and we advise realism regarding the timing for the remained objectives still to be done, in order that they are achieved in time for the final presentation. The delivery of these documents is done using Moodle Cerbero's platform (Cerbero 2015).

The oral presentation and defense of the project is done in the last meeting of the semester is a session open to all the students of the school.

We can classify the improvements achieved in recent years in three areas: deliverables, online tutorials and evaluation.

3.1 Deliverables

Once the groups are formed and the projects are selected, students must submit the following:

- **Meeting minutes:** At the end of a group meeting (with or without a teacher), students must write a minute that show the developments of the discussion and project decisions. This minute is to be delivered through Moodle.
- **Jigsaw session:** A two-hour jigsaw session of the subject's topic is done at the third week with the aim to provide ideas and tools. After the session each students receives a copy and how this can be useful for their projects.
- **Control:** In two specific weeks (the third and the tenth of a total of thirteen), students as a group must submit a control. In this deliverable students must give specific details such as the exact nature of the work, application's features, functions, task, who is responsible for what and the specific deadline for each task. This is a clear definition of the project. Ambition in the objectives is required in the first delivery; in the second one, closest to the final deadline, they are asked to be realistic.
- **Co and self-evaluation:** After delivering the control, students answer a survey to evaluate their group colleagues and as a self-assessment.

- **Monitoring report:** After delivering each control, the teacher sends the groups a project's monitoring report through Cerbero, which allows students to know the teachers' evaluation of their work until then.
- **Oral presentation and project delivery:** In the last session, one student per group presents the project in 15 minutes to three teachers, two of them outsiders from the subject; the presentation must have a similar format to that of a thesis. Each group must deliver the following documents; written report, oral presentation's slides and computer application.

After the delivery of each control, the teacher sent the groups a monitoring report using Cerbero, this allow students to know how the teacher is assessing their work and what do they need to adjust or change before the final delivery. This report has the structure of a survey questionnaire.

From the first meeting we emphasize the importance of clear communication in the discussion's minutes and agreements; we also request that the students take responsibility roles for different aspects of the project: modeling, animation, visualization, etc. Each student is responsible for one part of the project and also should collaborate with others as a group member

3.2 Online tutorials and virtual meetings

From teacher's meetings we agreed to use an online tool to communicate with students that enable us to:

- Perform online teacher-student tutorials.
- To have online teacher-students virtual meetings that allows the teacher the use of video or images.
- Facilitar a los alumnos que puedan hacer reuniones on-line si no podían coincidir en un determinado lugar y espacio.
- Allow students the opportunity to have online meetings if they were not able to meet in person.

The minimum online interactions that should be done are:

- **Image**, the participant should be able see each other using a webcam.
- **Sound**, they should be able to talk to each other using a microphone.
- **Slides,** the ability to share graphic information.
- **Handwrite,** to be able to write on the board to clarify some concept.

We believe that these interactions are perfectly acceptable to use in any desktop computer with a webcam and a microphone at an affordable cost. The same can be used in tablets, considering that Moodle 2.4 allows you to configure the server to mobiles and touch tablets. In the case of handwrite interaction, we agree that it is going to be used primarily by the teacher, so that only he or she should have a digitizing tablet with their accompanying pen to use. Also, it is possible to hand write on tablets.

The free for use tools and open source code that we have considered are:

a) OpenSims (OpenSims 2015)
b) OpenMeetings (OpenMeetings 2015)

Table 1 shows a comparison between both environments, using the following criteria:

- **Images**: whether you can transmit images by webcam
- **Sound**: whether is possible to transmit sound.
- **Slides**: whether is possible to send and display slides.

- **Handwrite**: whether is possible to hand write.
- **Users**: Defining users. Whether they have to belong to the environments or can be taken from Moodle.
- **Environment**: 2D or 3D.
- **Requirements**: whether there is the need to install any type of program on the user's computer, teacher's or students'.

Table 1: Comparative between OpenSims and OpenMeetings environments.

Environments	Image	Sound	Slides	Drawings	Users	2D/3D	Requerimientos
OpenSims	Comp. Graphics	YES	NO	NO	Propios	3D	Instalar visor
OpenMeetings	2.5	YES	YES	YES	Moodle	2D	NO

For this first experience we decided to use the *OpenMeetings* environment for its better compatibility with Moodle and its lower computational cost. For this setting two parameters are defined:

1) **Moderator mode:** who moderates the session. There are 3 options:
   - The teacher moderates and the students wait for him or her. Ideal mode for tutoring appointments (Fig. 2).
   - The first user to access moderates and everybody else waits for the moderator to given them their turn.
   - Everybody moderates.

The last 2 options can be used in group meetings by the students with or without a teacher. The teacher can observe the session to check online how does the group work.

2) **Recording:** Recording the session is allowed. A menu option has to be selected at the beginning of the session. This generates .avi files or .fly that the teacher can download in local mode. This is a very useful option if we want to see or define participation forums where you can obtain qualitative and quantitative indicators of student participation.

For our teaching field in PBL, during the 2012-2013 academic period we have updated the document manager Cerberus (Cerberus 2015), incorporating the OpenMeetings tool (OpenMeetings 2015) for the following activities:

- **Teacher's virtual tutorials:** during tutorial times, the teacher opens the OpenMeetings so any students can connect in order to have his or her questions answered (Fig. 2).
- **PBL Meeting Rooms:** For each ABP an OpenMeetings session (Fig. 3) has been opened for the students to do online work sessions in case they are not able to meet in person or during the week where attendance is not compulsory.

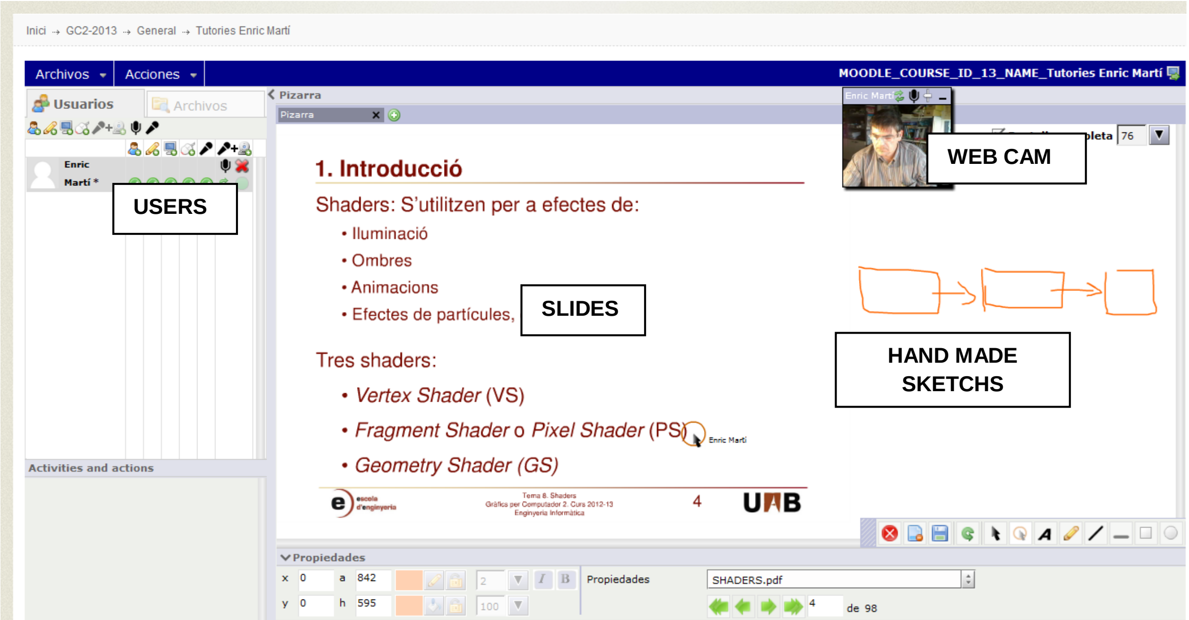

Figure 2: Screenshot of online tutorization using OpenMeetings.

During the 2012-2013 academic year, three groups have used the tool in a few sessions. We believe that the failure to provide sufficient information for the operation and the work involved in the project have created some difficulties with its use among the students. The use of tutorial has also not being high (about 10 or 12 tutorials in the semester), but in this case we value its usefulness for the students that did not need to commute to the school but wanted to ask questions to their teachers. During tutorials, voice and the subject's slides have been used often to answer queries.

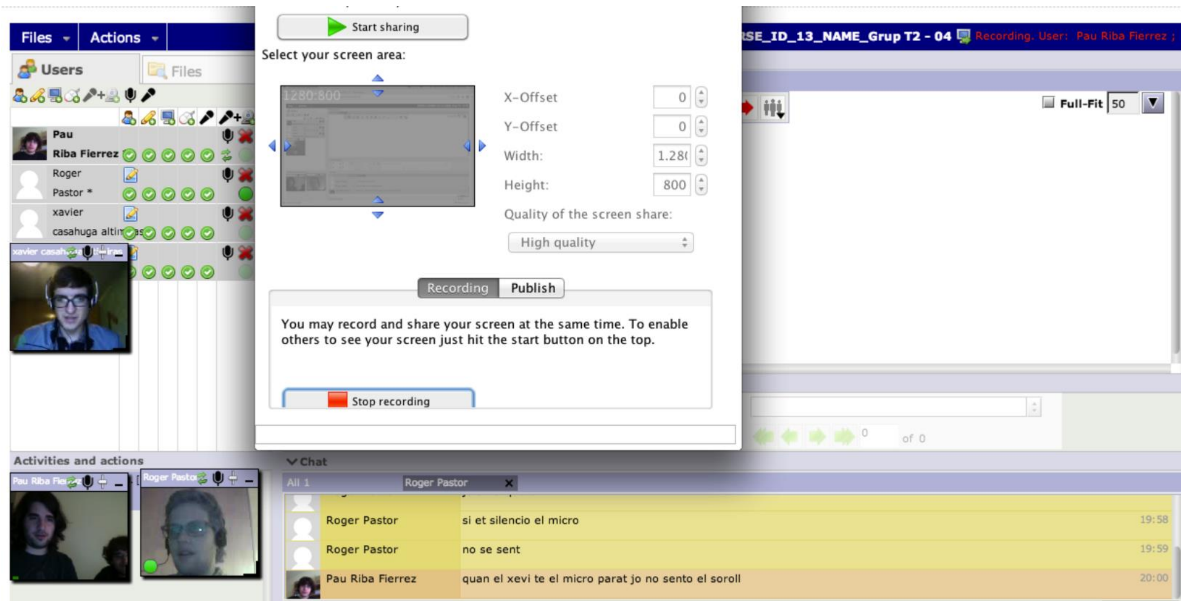

Figure 3: Screenshot of a PBL Meeting Room of a PBL working group.

3.3 Subject's evaluation

For the evaluation we chose two groups in indicators. A set of group indicators which grade is the same for all members of the group and a set of individual indicator for each person. These indicators are:

- **Group evaluation (7 points):** The indicators are the same for all members of the group. They are:

- **Group work (4 points):** The members of the tribunal who attend the oral presentation assess the complexity and innovation of the work, functionality, user interface and the quality of the application according to the current software standard. The have a report template to check.
- **Presentation deliverables (2 points):** We evaluate organization, clarity and presentation of the meeting's minutes.
- **Meeting minutes (1 point):** Clarity, presentation and consistency of the records and controls delivered.
- **Merits (0.5 points up to 1 point):** This assesses whether the work has been referenced by other groups or has been rated among the top three by peers in the oral presentation.

- **Individual evaluation (3 points):** This are individual marks for each member of the group obtained during the attendance classes (a total of 5-6). They are evaluated by the teacher based on:
  - **Attendance and punctuality (1 point):** Arrival and departure to the sessions on time.
  - **Attitude (1 point):** Active participation in classes' discussions, students show a passive or active behavior.
  - **Leadership (1 point):** Students' opinion valued by colleagues, whether others turn to him or her with queries.
  - **Merits (0.5 up to 1 point):** Whether he or she did the oral presentation and or the student stands out among his or her peers.

We intent to evaluate few skills with many indicators in order to be confident with our assessment. Initially, the students are not told the evaluations' criteria beyond knowing that there is a group evaluation of 60% and an individual evaluation of 40%, as to not bias their attitude to work exclusively to achieve a certain mark. We are working to make rubrics suitable for evaluation.

4 Results

We believe that with these actions we have achieved a better leadership and supervision of students' work throughout the project and also we have seen an increase in the quality of their work. Surveys have shown that students value positively activities such as the jigsaw classroom or deliveries even thought they have to make effort, particularly in the drafting of the minutes. When the students receive the details on how they are marked, the complains are fewer given that the criteria are clear and not easily open to debate. The argument that the students or groups who make more of an effort obtains better marks is irrefutable.

Regarding the use of online tools, they have been used very little, according to the experience gathered during the first semester of the academic year 2012-2013, we believe that this was due to the workload. According to the surveys done, students use other platforms, such as Skipe, to communicate, which are not well adapted to the teaching environment.

Table 2: Evolution of students enrolled. Amount of enrolled students in the subject (#Students), students who choose PBL (#PBL) and percentage of the total enrollment (%PBL).

Year	# Students	# PBL	% PBL

2004-05	148	60	40,54
2005-06	155	95	61,29
2006-07	65	25	38,46
2007-08	76	34	44,73
2008-09	81	51	62,96
2009-10	68	46	67,64
2010-11	67	50	74,62
2011-12	58	48	82,75
2012-13	55	47	85,45

The result of our experience is shown in two tables. Table 2 shows the evolution of the students enrolled and those who chose the PBL itinerary. In the academic year 2006-2007 the subject had fewer students due to the subject being moved from being optional for the third year to being optional for students in the year four or five. From 2009-2010 the Engineering degree of 5 years is replaced with the 4 years degree, bringing the number of enrolled students down due to the progressive closing of the degree, until the year 2012-2013 which was the last year with a significant number of students. Despite all that, it can be seen that the percentage of students who chose the PBL itinerary has been growing since 2007-2008, specially taking into account that this is an optional course, which reaffirm the idea that the PBL method do attract students interest. Most of students that began in the computer graphics subject would know the PBL experience by means of references of old students. Talking with students to know their opinion, these that have chosen PBL itinerary were very interested in the subject and to work in a computer graphics project was an attractive proposal. Asking people that have chosen classical itinerary, a lot of them are interested in the subject, but they were working and they couldn't spend time the time required for the PBL itinerary .

At the end of the course we conducted an electronic survey for the students to rate their experience with PBL. The survey has 8 questions answered using either a numerical rate, comments or both:

1. Difficulty of the proposed project (numerical mark and comments).
2. Team work capabilities (numerical mark and comments).
3. Teacher tutorization work (numerical mark and comments).
4. Self-evaluation: to what extend you have participated and contributed to the team work (comments).
5. How good your group mates have been (comments).
6. How do you rate PBL for the subject learning (numerical mark and comments).
7. Positive and negative aspects of PBL (comments).
8. Overall assessment (numerical mark).

The results in table 3 are of questions 3, 6 and 8. The ratings are from 0 (deficient) to 10 (excellent). We can see that the overall assessment of the students to the use of this methodology and the global assessment score is above 8 (medium-high) in all the years. In the final year of the course (2013-2014) we explain the decrease in the valuation of the methodology as the result of the urge to finish their studies on the students' part, given that the degree was closing after those students graduated. From interviewing students we gathered that it was a very exhausting experience given the amount of time they had to allocate to their projects, even so, they appreciate to have certain freedom in developing the project and also they valued it very highly because of the obtained results and their learning of computer graphic techniques. Some of their answers about the PBL experience are:

- "I think I have learned a lot during the Project and I have faced problems that I would never approached without the teacher's help."
- "The fact of developing a project with freedom of action allows a higher degree of learning tan simply memorizing concepts that actually do not matter in practice, as many other subjects do. We have not had any problems with the teacher, who has always solved any doubts, either personally at tutoring sessions or by email. "
- "The subject is one of the most satisfactories due to the team work carried out."
- "Negative points: You can not stop working any week cause the workload is continuous. Positive points: freedom for learning."

Table 3: Polls students of the subject. Rating tutoring students made by the teacher, methodology and overall assessment of the subject (all grades of 10) and in the last column the number of students who answered the poll (# samples).

Year	Teacher tutoring	Methodology	Overall assessment	# samples
2004-05	7,6	8,0	8,2	46
2005-06	8,06	8,1	8,35	63
2006-07	8,3	8,35	8,6	20
2007-08	8,04	8,28	8,8	25
2008-09	7,17	8,3	8,44	40
2009-10	8,13	8,41	8,55	29
2010-11	8,08	8,36	8,48	38
2011-12	8,22	8,34	8,44	25
2012-13	8,96	7,92	8,42	34

Viewing the results and talking with students to know their opinion, we claim that PBL students are satisfied with the work carried out in the PBL methodology. This satisfaction, in a more subjective way, shows the growing demand for these students in that we (the subject teachers) direct their final year project. With this, we believe that PBL improve positive learning skills in students.

5 Conclusions and discussion

In this paper we presented the 9 year experience of implementing the PBL methodology in the Computer Graphics' subject in the Informatics Engineering degree; a method that we have seen evolve and improve firstly by using it properly while improving the assessment and finally by using online distance communication applications, such as OpenMeetings, in order to be able to monitor students groups meetings outside of the classroom, that are essential to the students in order to keep their project moving forward. In this section we show some quantitative results and some discussion points started either by faculty or students. The use of online tools allows us to keep direct contact with students outside the classroom also help them to keep their meetings going even in the cases where they are in different locations. Targeted activities such as jigsaw session or deliverables represent additional work that help students to better organize the complexity of the project. The students shown some difficulties drawing up the minutes and in voicing the ideas discussed in meetings. In the future we need to address this issue.

One topic of discussion among faculty was that the current evaluation system is centered in a numerical mark which does not duly show in the students file the competencies and skills worked by using PBL, which, by the way, are specified in the subject's teaching guide. We believe that the subject's evaluation system must be adapted to the changes in teaching methods, incorporating the assessment of competencies and skills in the students' files.

Another topic of discussion already mentioned is the disclosure to the students of the evaluation criteria beyond the basics of group and individual assessments. In our case we do not disclose these details to avoid the calculation resulting in a lack of spontaneity and to foster the development of skills in a more natural way, since in many cases in the professional world the evaluation criteria are not that thoroughly specified either. An argument in favor to full disclosure is to give the students the clear criteria so they can know exactly how are they going to be evaluated.

Our future work will focus on doing several statistical tests to detect any differences among students opinion. Also in cooperation with members of the UAB Didactics Department a methodology for assessing the impact of PBL on student learning will be designed to support our opinion with more scientific evidence.

Our assessment is highly positive, which encourage us to continue trying to improve and adapt it to the changing students' profiles. We offer our templates to the community and we are open to discussion with the objective to share and improve our experience in PBL.

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Achievements in interdisciplinary engineering education at Universidad Nacional de Colombia: Showing six years of experiences

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Abstract

Since 2009 the Faculty of Engineering of the Universidad Nacional Colombia has created a course for the realization of projects, in an interdisciplinary environment, in order to encourage team learning. To do their projects, students of different engineering programs are joining in a single course. Since this course was open, more than 500 projects have been conducted. Even though projects have been made with an academic approach, most of them have been real life problems.

More than 200 students enrolled the course to undertake the projects. Projects are obtained from a public call. Then, a group of six students of three different programs were put together. After that a teacher guides them taking the role of manager. Students should develop the project with such scope, which can be developed in four months. So it defined objectives, cost, schedule, outcomes and results together and do it in the semester-long course. They meet twice a week, in a meeting of their six members, as a committee type and the other in a plenary with the other students of the course.

An analysis based on the observation done to the students of the course by a group of 22 teachers and collected in the management reports has allowed the development of this document. The main skill gained has been developing the skills for teamwork as do a professional, soft skills and main outcomes for the research and the industry.

Keywords: Project-based learning, curriculum design, interdisciplinary achievement, soft skills, learning effects

1 Introduction

Technological development has forced to change the way professionals must perform their work. The categories have grown and so as the jobs that need management knowledge, abstract reasoning and personal services. According to the National Research Council - NRC of the National Academy of Sciences of the United States, skills that are not automatically obtained, such as adaptive solutions to problems, critical thinking, complex decisions, ethical reasoning and innovation are required (Koenig, 2011). Within the areas of development, it has been proposed to study three categories: Cognitive Skills to solve unconventional problems, critical analysis and systems thinking; interpersonal skills such as complex communication, social relationships, teamwork, cultural sensitivity, tolerance and personal skills such as self-management, time management, adaptability and executive functions.

In Europe, the ET2020 fixed a strategic policy in 2009 about training and education until 2020 (ET-2020, 2009). Among the skills to implement there is the one to improve the level and quality of education as well as creativity and innovation, including entrepreneurship at all levels of education and training. The feedback made by the European Union in 2013 on the conclusions of the research on education and training (ET-2020, 2013) requested to strengthen the education strategy for Europe 2020 taking into account to “Rethinking education”; furthermore they also recommended to introduce measures of transversal development and skills from the early stages of education through to higher stages using innovative, student-centered models.

In Latin America, perhaps the problem is bigger. A major evidence that education needs a structural change are the PISA tests (Programme for International Student Assessment) and TIMSS (English Trends in International Mathematics and Science Study). By the results reported, student does not have the basic knowledge for their age or the skills to cope with everyday problems (Bassi, Busso, Urzúa, & Vargas, 2012). In regards to the last three decades, there is a disconnection or disengagement between the skills required by the market and those Latin American schools continue to form, confirming the results of the general study by Litzinger on which students do not have the methodologies aligned with the with professional expertise (Litzinger et al., 2011).

Professional performance studies were also conducted in Colombia. Since 2005 the Ministry of Education has conducted surveys among graduates of higher education. After confronting the content of different careers the results in 2013 showed that most graduates are performing work related activities to their studies, and they have also acquired skills related to teamwork and ethics but they require to develop skills with the use of information technology, work under pressure, identifying symbols to communicate and ways on how to use research and technological development in their activities (MEM, 2013). In contrast, in the departments of human resources, 19.9% of applicants are rejected for a job due to the lack of soft skills such as ease of communication, teamwork, responsibility, punctuality and the ability to adapt to change (Servicio de Empleo, 2014)

Project Based Learning (PBL) is a methodology that manages to obtain a high level of professional performance in all fields of engineering as argued by several authors. It increases teamwork capacity, it greatly improves their thinking skills and increases their creativity (Zhou, Kolmos, & Nielsen, 2012).

In the review done by Thomas (Thomas, 2000) on the research on PBL he defines it as a set of complex tasks based on questions to challenging problems and whom are engaged by students in topics related to design, decision-making and research activities which gives these students the opportunity to work with relative autonomy over a period of time to complete a product or realistic presentation.

The PBL curriculum requires students to focus on applying knowledge and skills. This curriculum is a supplement to traditional teaching. Bradley-Levine (Bradley-Levine & Mosier, 2014) defines this process as an organization around an open question. It is a guideline that teachers use to connect current and relevant issues and problems with the academy. So, during the development process, students formulate new questions and apply their knowledge to the products they develop.

With the needs identified at the Universidad Nacional de Colombia and included in the curriculum reform of 2007 in order to strengthen skills such as teamwork, to be analytic, to gather information, to communicate and self-learning the Faculty of Engineering created the Interdisciplinary Workshop Projects (Spanish name is: Taller de Proyectos Interdisciplinarios -TPI) course, which has been offered since the first semester of 2009 separately for each department of the Faculty and collectively from the second semester of the same year (Duarte, Orjuela, Rodríguez, Salazar, & Soto, 2011). Since then and until 2014 there have been conducted nearly 50 projects with an average of 250 students per semester.

According to PBL models of Savin-Baden (Savin-Baden, 2007) the model of PBL from the National University of Colombia operates as a combination of modes II and III. In this classification, the model II or "Problem-based learning for professional action", brings real professional problems with pragmatic solutions to the academic scenario and the model III, "Problem-based learning for interdisciplinary understanding" applying PBL in an interdisciplinary environment.

2 Background

With the results obtained from some surveys from graduates and from some government studies it was proposed to the Board of the Faculty of Engineering the implementation of the Interdisciplinary Workshop Projects course. Initially a group of experts was convened on issues related to projects and business. Additionally, responsible professors for small groups of students were also gathered (Duarte et al., 2011). These students should develop projects taken from a bank of real proposals. At the same time, these proposals would be made by teachers and students of the course or by research groups. Students should develop the project using engineering tools as well as social, economic and environmental techniques, while teachers would be there as facilitators of the process and the outcome.

During the development of the course, students would perform oral presentations, would prepare drafts for written reports, state of progress and the final result. For this, groups of six students from different careers would be formed.

The course is of 64 hours in the classroom and 80 hours outside the classroom and spread over two sessions of two hours per week. One session is intended for the teams to submit progress the teacher or to meet with each other. The other, is a magisterial session for all the students in the course, where an oral presentation of an expert on issues related to the development, implementation and project experience would be held.

From the beginning, the course would have two major milestones, first the selection of the project with the allocation of the work teams; and the second presentation of the proposal. After the first milestone the project in charge of the students would begin and begins the real development of the project.

3 Methodology

The motivation for this research is to show the process and the methodology of an interdisciplinary learning at the Universidad Nacional de Colombia, on both students and teachers of engineering. For its implementation it was necessary to do an observed outcome analysis throughout the course reports. Furthermore, the reports are a collection of important aspects about the comments of teachers and students during the course progress. The course has 22 teachers by semester and there is an average of 300 students.

4 Course Methodology

The Faculty of Engineering at the National University offers nine engineering programs: Agricultural, Electrical, Electronics, Mechanical, Mechatronics, Chemical, Systems, industrial and Civil. In the first six programs, the course of Interdisciplinary Workshop Projects (TPI) is mandatory and it is taken by students from seventh to tenth semester, but the vast majority of students belong to ninth semester. In the last two programs, Industrial and Civil this course is optional.

Currently Interdisciplinary Workshop Projects begins with a call for projects, allocation of projects, group assignment, conducting and evaluating projects, accompanied by two poster sessions and two sessions of short presentations.

4.1 Call for Project ideas

Two weeks before starting the course in the semester, a public convening takes place to the entire university community and to some engineering associations in order to register an idea about any project they want to start or that they are developing.

Project ideas are written widely and do not require a formal project formulation. It is open to students, teachers, and professionals in any area and in general anyone who is interested and that has finds out about the existence of the call. Given the diversity of people who can apply, it is expected that the language that expresses the idea is unclear or not in technical engineering terms. To achieve the purpose of training, these ideas are not edited and if for some reason, someone postulates ideas of projects with an incorrect grammatical structure, it will not be corrected in order to meet the training objectives.

4.2 Establishment of working groups

In the early Interdisciplinary Workshop Projects, projects were awarded following certain parameters: But were selected mainly from the course coordinator randomly, meeting the interdisciplinary requirements of different careers and groups of up to six students; always trying to link students related to the topic of the project. The following criteria were used after doing some modifications in the way students were set up in groups:

- Projects should have minimum 6 students of three different careers.
- The students of the course, prior to initiation and during the stage of the call can suggest one or more projects. But it does not guarantee that the project will be selected.
- The course lecturers can propose projects and they are responsible of the group in case the project is selected.
- Students can choose any project idea of the call and they must respect that no more than two students can register from the same career.

To assign projects a session registration is made for a period of two hours. The ideas are printed in a format which is afterwards is pasted to a wall. Students read the ideas and select the one that interests them. Through this way, the ideas for the project to be developed in the course are completed. During this registration session of the project ideas, proponents and students can promote their project, so through this way the number of students required is completed and therefore guarantee the implementation of the project in the course.

4.3 Role and teacher recruitment

Since the course began TPI, teachers act as "managers" of a project. They may be experts in the field of project or not. However should have the ability to lead and organize projects. Otherwise, each teacher will be responsible for two groups of six students and therefore will be in charge of two projects.

4.4 Students roll

As mentioned before, students must act as professionals in the project. The workgroup made up of students of different careers is an interdisciplinary team and is responsible for the formulation and for completing the project within a period of 15 weeks. They have to formulate and finish the project with the objectives, scope, schedule and deliverables.

4.5 Lecturers

During the course and in the weeks, which there are no specific programming, keynote speeches for two hours are performed and all students from TPI should assist. These talks are intended to address some common issues to project development, show cases of success and failure of business, deal with strategic issues for the presentation of projects and teach some topics related to documentation, reading and writing. Also, these talks help maintain the unity of the entire course, as an entity of the Faculty of Engineering.

4.6 Assignments

The students have to demonstrate their results with four public presentations. The first one is a poster, the second one is an advance of the presentation and the third one is a poster with the final results and finally, a mini congress is performed to present the completed results. This are evaluated each time by three juries already selected and they constitute a 45% of the final grade.

Furthermore, each professor evaluates their own group and focuses in the project tasks along with the team work. From here the rest is taken from the evaluation, in other words the remaining 55%.

5 Results and discussions

A list of 337 records for the last two years of TPI was consolidated (Rodríguez, 2013, 2014). This information contains details about the number of students, teachers and individuals. (external entities, companies or entrepreneurs) who were part by providing some ideas to the project. In this list, there are 1125 students who participated in the courses of TPI during this period distributed as follows: 278 and 232 in the two semesters of 2013, 301 and 314 in the semesters of 2014.

Figure 1 shows the percentage in the participation of students from the National University of Colombia, the teacher and the private individuals in the call for project ideas. It is also shows how many of each of the projects were conducted during the years 2013 to 2014. From the individuals (noted as "particular" in the figure) is taken into account public and private entities, companies, entrepreneurs or individuals different from students and teachers.

When TIP began, there were few projects proposed by students. This grew and up to the moment the number of proposals by students has increased and it has equaled the teachers, showing a growing interest and motivation to the course. In the last two years, approximately 40% were from projects performed from student's proposals as shown in figure 1.

But at the beginning this did not happen. During the development of the course it was observed an increasing participation of the students in the formulation of projects in the course. Students in the last two years have presented between 30 and 35 projects by semester. Each year it is being performed a mayor quantity of projects from students. Projects that were initially awarded to students vary from a 28% to a 56% in the first course in 2014 duplicating the percentages. In the last year, students select the projects and it is them who prefer to choose from their own (Rodríguez, 2014)

Likewise, although individuals propose 33% of the projects for TPI, only 18% are done. The quantity of the projects proposed and performed by the teachers they all keep a good balance and few are discarded.

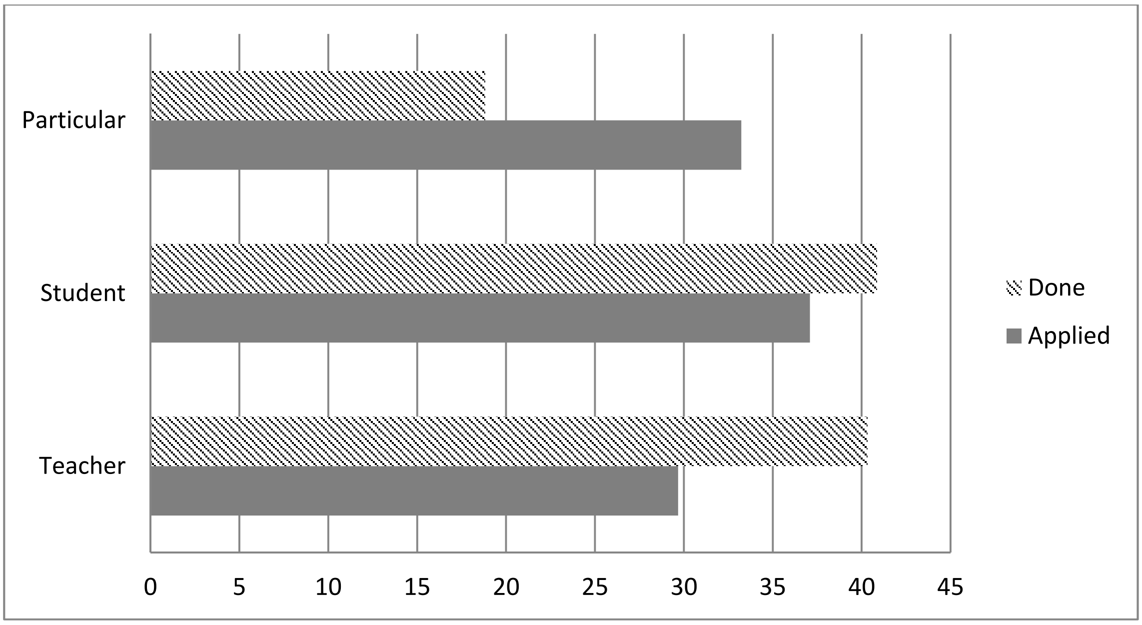

Figure 1 Percentage share of students, teachers and particulars in the call and conduct of TPI projects. Source (Rodríguez, 2013, 2014).

Figure 2. Shows the proposal of the projects carried out by each one of the engineering careers of the Universidad Nacional, compared with the quantity in percentage of the projects that were accomplished. It also shows the demand of the disciplines in the engineering careers to each one of the ideas formulated in accordance with the considerations of who proposes the idea. Finally, it also shows how the ideas where carried out in the TPI course according to the students participation.

The amount of requested projects, in the areas of agriculture and civil (each one with the values between 4% and 6%) are very low due to the few amount of students in these areas. Keeping in mind that in these careers it exist a low amount of students, a balance still remains proportional with the students of the course.

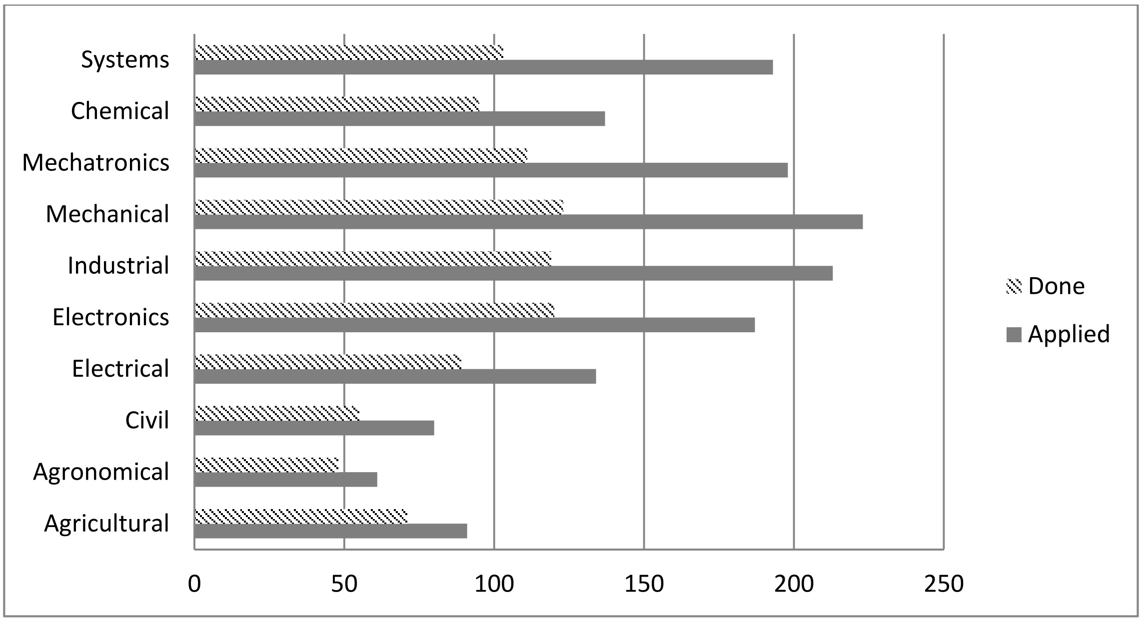

Figure 2 Proposal and carried out projects according to disciplines, in percentage. Source (Rodríguez, 2013, 2014).

Figure 3 shows the projects by typology according to the call for project ideas and finally shows the projects done by the students of the TPI course for the years 2013 and 2014. The projects presented to the course have a different approach, which it has been described as a typology.

There is a strong trend to implement development projects of product and innovation (43.6%). Social and investigation topics maintain a similar level (close to 14%) and academic projects (8%) are the least requested. The amount of academic and investigation projects obey to the fact that teachers hope to support activities of investigation and academic with activities of TPI and win in the accomplishment with interdisciplinary contributions (Rodríguez, 2014)

Another important aspect, as shown in figure 3, is that student demand careers that have more impact on the development of devices: Electronics, Systems, Industrial, Mechanical and Mechatronics, exposes TPI as an appropriate place to develop and establish exercises related to the PBL models topic, which are built in the future should emphasize in the areas of product design strategies and take in the application business and community PBL demands (Kolmos, 2010). This issue is a global behavior in the millennials (Howe & Strauss, 2007; Much, Wagener, Breitkreutz, & Hellenbrand, 2014; Telefónica, 2014). Students of TPI, are motivated to select and participate in projects with a high degree of innovation and development, too. Very few studies on issues related to academic or research purposes. This trend is not only marked in the number of proposals but those performed. This marks the aims of the course, to emulate professional activities and improve social abilities.

While it is true that many of the talks have focused on product development and design, as shown in figure 3, the projects proposed and selected largely deal with innovation issues, product development and work activities with communities; professional activities and the improvement of social skills.

Many of the proposed projects as for example, the machine construction and automatic systems, ships, rural studies of energy, obviously cannot be developed in four months. But many of the projects have continued in time and benefited the development of products, companies, project ideas and research as shown by documents (Duarte et al., 2011; Rodríguez, 2013, 2014).

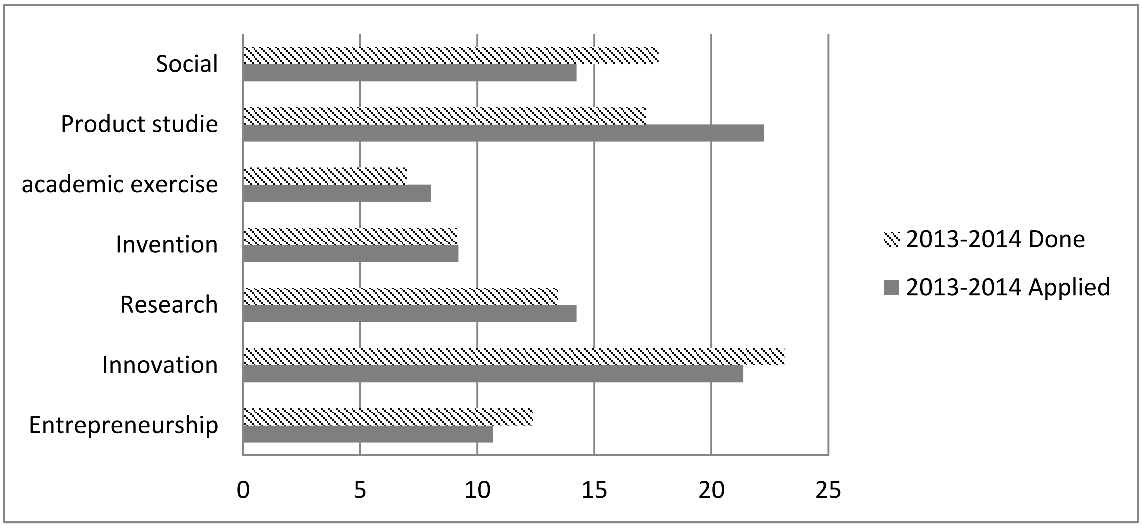

Figure 3 Proposal and carried out projects by type, in percentage. Source (Rodríguez, 2013, 2014)

The selection scheme, from the poorly formulated problem can emulate the reality of work in the academia. Professional essentially do not select the company by the product they make, regardless of the reputation of the company, but they do it based on the needs of the enterprises staff (Larraz, 2014). But when they begin their work, they must participate in the development of a process or product in a coordinated manner in interdisciplinary and multidisciplinary teams of the companies. In TPI, students take the idea and mature it according to the conditions of the equipment, which in this case would be the company development of communication and teamwork as evidenced (Rodríguez, 2014).

A survey conducted in 2013 (Nieto et al., 2013) showed that this course develops skills of teamwork, interdisciplinary, oral and written communication. The same study also indicated that during the development of the course little expertise of each discipline is applied.

There have been proposals of companies that today are in the process of consolidation and industrial processes have been established within and outside the University who are already working, but unfortunately there are few reports. Also, some of the students at TPI, after completing their project in the semester students have developed relationships with the Colombian government entities to finance projects such as the case of the Chamber of Commerce of Bogotá (CCB, 2014) and in the future it is expected that there are a number consolidated important companies in this area.

Despite the achievements, there are still many aspects to improve in the course. One of the weaknesses of the strengths course TPI is the education and training of teachers and mentors of the course. For the first half of 2015 some pedagogical training meetings will be held and are rethinking assessment schemes. They also are consolidating some processes in the progress to open this course to other faculties and the inclusion model for the first semester with one year of training in engineering introduction to the use of PBL models.

Problems have been identified in the student's evaluation. They should precisely know what is to be evaluated in each one of the project submission and they should also know how they will be evaluated. At the moment the evaluations are being done by a group of three juries that examine the results and achievements but that do not have unified their different points of views.

Likewise, in the student's proposals there could exist repeated projects from previous semesters or from other courses. At the begging this was seen as something favorable because the students could implement their personal projects and take them from other courses accompanying the process with more students in this course in an interdisciplinary way. This led to take results from predecessors projects and adapt them, spoiling the learning process (Rodríguez, 2014).

To determine the effectiveness in the professional field some surveys have been done between the students and graduates. Positive results are expected from these, according to what it is observed in reference to the acquisition of soft abilities. This will be the key in the methodology generalization from the Problem Based Learning in the engineering curriculum from the Universidad Nacional de Colombia

6 Conclusion

The Workshop of Interdisciplinary Projects or in spanish, “Taller de Proyectos Interdisciplinarios (TPI)” is the first course that has been created with the PBL methodology for students from the majority of engineering careers at the Universidad Nacional de Colombia. Despite there exists a traditional curriculum in engineering; TPI has been incorporated during six years.

The TPI course is a great opportunity that students have in order to present their projects, work in different engineering's and for information exchange.

In the Project proposal, which has a four months term, students, teachers and particulars participated. Never the less the students projects are the ones that are being done in a bigger proportion.

The experience during the development of the workshop of interdisciplinary projects has shown that the students prefer to propose and to develop projects with a high content in technology. But in order for the students to develop different types of abilities more diverse projects are being developed.

TPI is a course that continues making changes to be better and even though the current structure works, changes must be done to enhance the evaluation methods and also to understand the behavior and effectiveness of the method and the professional practice.

In the future it is hoped to present the results of the professional evaluation as well as the modifications in the evaluation method. Furthermore, with the obtain results it is hoped to pave the way to study the possibility to incorporate PBL in the engineering curriculum in a systematic way.

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Professional Competency Development in a PBL Curriculum

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Abstract

Substantial dialogue exists regarding the needs of the engineering profession and the changes in engineering education necessary to meet them. Important to this change is an increased emphasis on the professional competencies as identified by the Washington Accord and the ABET professional skills for engineering graduates and how to educate for them. ABET is the national accrediting body for engineering education programs in the United States. This paper will explore the potential for a project based learning engineering curriculum model to meet this need. It will summarize a newly developed upper-division undergraduate project-based learning (PBL) engineering program in the U.S. engineering educational system and its approach to professional competency development. Based on the ABET intent, students graduate with integrated technical/professional knowledge and competencies. The program does not have formal courses; instead learning activities are organized and indexed in industry projects where they are solving complex and ill-structured industry problems. The program started in January 2010 and has 75 graduates to date and has earned ABET-EAC accreditation.

A mixed-methods research approach will address the research question: "What is the professional development trajectory of students in the new project based learning (PBL) curriculum?" Quantitative method includes the development of an instrument to measure student growth in professional competencies. Qualitative measures include an interview protocol to understand which components of the PBL model affected the student professional development trajectory. The paper will provide initial results and analysis for the quantitative study, which indicated a positive impact on student attainment of the professional competencies in the PBL curriculum as compared to students in a traditional curriculum.

Keywords: professional competency, professional skills, PBL, assessment

1 Introduction

Two recently commissioned reports from UNESCO [Beanland and Hadgraft, 2011 & 2013] identify that engineering education has not responded in a significant enough fashion to the rapid expansion of knowledge over the past 50 years that has changed the way engineers perform their role of providing solution for their societies' need for change. The lack of response has resulted in both an undersupply of engineering graduates around the world and in "engineering graduates (who) are deficient in the capabilities ... required of engineers."

The engineering education community around the world is engaged in dialogue regarding the needs of the engineering profession, what should be the nature, context, and curriculum for undergraduate education, and the engineering education transformation process to meet these needs (Beanland and Hadgraft, 2013; Sheppard, et. al, 2009; National Academy of Engineering, 2005; National Science Board, 2007; National Research Council, 2004). Within the international community, a landmark point in this dialogue commenced in 1989 with professional organizations and institutions from Australia, Canada, Ireland, New Zealand, United Kingdom, and the U.S. forming what would become the Washington Accord. The Accord was later joined by several countries from around the world (Beanland and Hadgraft, 2013). It sought to establish standards for professional competencies and graduate attributes for engineering students graduating from an accredited institution. In 1996, ABET introduced a new set of engineering accreditation criteria, ABET Engineering Criteria 2000. Of greatest significance towards changing engineering education was the General Criterion 3 Student outcomes, generally known as the ABET Criteria. Programs had to define student outcomes for the attainment of the professional skill and competency aspects of engineering.

Despite these efforts, Sheppard's, et. al., 2009 *Educating Engineers: Designing for the Future of the Field* identified that the curricular design in the engineering education system still had not changed much in regards to meeting the professional development needs of the profession. It was still heavily biased towards analysis to the detriment of professional skills development and other areas of engineering, despite students and employers, alike, expecting a higher degree of synergy between the classroom and what is needed in field (Passow, 2012).

In response to this dialogue, a Midwestern community college and university collaborated to develop a two-year, upper-division, 100% PBL model of engineering education (Ulseth, et. al., 2011). It began in January 2010 as an adaptation of the Aalborg PBL model (Johnson and Ulseth, 2014). The program has 75 graduates to date and has earned ABET-EAC accreditation. A program focus is the student attainment of professional competencies.

2 Professional Development in Engineering Education

A pair of 2005 studies by Shuman (2005) and Loui (2005) focused on the ineffectiveness of the traditional lecture format for teaching the ABET professional skills and argued that a modern engineering education focus on active and cooperative learning approaches. The Loui study identified that students primarily learn about professionalism from relatives and co-workers who are engineers and rarely from their technical courses, and proposed that engineering education should have a focus of "socializing students to become professional engineers."

A promising professional competencies development approach is a curricular focus on professional identity formation. Ibarra and Barbulescu (2010) identified professional identity as an important factor in the student adaption to the workplace. Sheppard, et. al. (2009) describes professional identity in terms of standards of the professional community, "to serve the public with specialized knowledge and skills through commitment to the field's public purposes and ethical standards." Eliot and Turns (2011) define it as the "personal identification with the duties, responsibilities, and knowledge associated with a professional role," developed through a social process where students are connecting expectations with their own needs, wants, and attitude.

In the curriculum development process, three core curricular themes emerged: first, the social nature of engineering education and the importance of students developing their professional identity as an engineer; second, the importance for embedding the learning in professional practice; and third, the potential a PBL curriculum has to support the first two themes

2.1 Role Acquisition

Thorton and Nardi (1975) proposed that professional role identification is a four-stage developmental process where individuals go from having idealized perceptions of the professional role to a more personalized role aligned with their own values and goals:

1. Anticipatory Stage: Individuals start with a highly idealized understanding of the role of the professional, which is often incomplete. "Social and psychological adjustment" to the professional role is initiated in this beginning stage and is only of value to the extent to which the individual's understanding of the profession is accurate.
2. Formal Stage: Individuals undergo a formal learning experience with the purpose of learning the duties, responsibilities, and knowledge for a professional role. Expectations at this point are generally formal and explicitly stated and focus more on the "behaviors, knowledge, and skills" of the individuals in the role than the actual attitudes held by the individual. Individuals are conforming to the professional role.
3. Informal Stage: Individuals encounter the unofficial or informal expectations associated with the professional role which may align or contradict the formal expectations. Peers and colleagues have the greatest credibility. Expectations are more "implicit and refer to the attitudinal and cognitive features of role performance." This stage is where the individual starts shaping or adjusting the role to fit his individual perspectives and desired outcomes versus the conforming to the role.
4. Personal Stage: Individuals begin internalizing the professional role expectation and attempt to align or adapt it with their values and goals.

It could be argued that this may be too simplistic of a model for the process of professional identity creation; it establishes a framework for creating a more complex curricular model.

2.2 Professional Practice

Passow's (2012) study of ABET competencies identifies the need for utilizing the "context of professional practice". Sheppard, et. al, (2009) also identifies the need for a professional practice "spine" where students experience "practice-like" experiences as a central component to the educational process; enabling students to "move from being passive *viewers* of engineering action to taking their places as active participants or *creators* within the field of engineering." This professional practice develops the student engineering professional identity.

2.3 Project Based Learning

As professional practice is sought in developing the professional identity of engineering students, a curricular model that supports this is necessary. Felder and Brent (2003) identify PBL as an instructional model that can be readily adapted to achieving the professional competency development desired in engineering students. Several other prevalent publications identify the use of PBL as a critical component of transforming engineering education and developing the necessary professional skills and identities of engineering students: Beanland and Hadgraft, in their 2013 UNESCO Report: Engineering Education, Sheppard, et. al. (2009) in Educating Engineering: Designing for the Future of the Field, and Litzinger, et. al. (2011) in Engineering Education and the Development of Expertise.

3 PBL Curricular Design for Professional Competencies

The new PBL curriculum purposefully starts with the four stages of the Thornton and Nardi role acquisition model and embeds them in a four-semester design sequence professional practice spine. It was specifically developed to address the alignment gap between the desired outcomes for engineering graduates and those attained by traditional program graduates (Ulseth, et. al., 2011). The new PBL model starts every semester in the anticipatory stage for each student with a professional development plan to identify where they are in their understanding and abilities of the professional role for an engineer. Based on this faculty-guided self-assessment, each student identifies: their current professional performance abilities; their professional growth goals for the semester; and their planned activities they will participate in for the upcoming semester to achieve their professional development goals.

Each semester students experience the formal and informal stages of role development. The formal stage is centered on the PBL program's weekly professional development seminars, which formalize the expectations for the week's specific professional engineering competency. The first day of the week starts with the "seminar," a session where all students and staff attend a seminar on a relevant professional development topic. On Wednesday, this topic is a structured part of each team's two-hour meeting with their engineering design project mentor. In this meeting, a discussion is conducted on the development of the team's project, but just as importantly, the discussion also focuses on the professional development of the individuals in the team. Every week ends with students reflecting in their journals regarding their development for the week, including their professional development on the topic of the week.

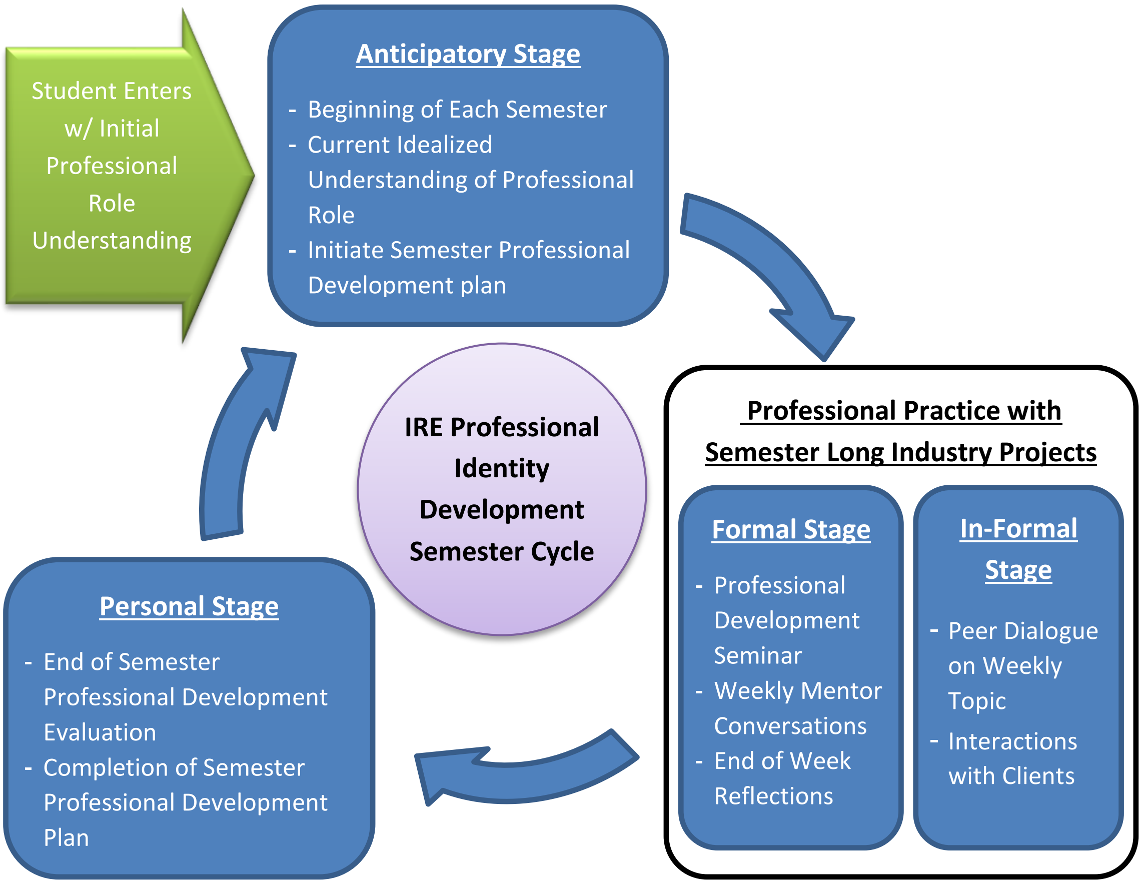
The formal structure and the team structure are both designed to set up the informal stage. As students are adapting the expectations of that week's professional topic to fit their own individual perspectives, their peers have all heard the same message around the professional competency, which guides and provides common language for informal peer conversations. The mid-week meeting with their project mentor facilitates and coaches the adaptation in a professionally supportive atmosphere. The end of the week reflection activity provides the opportunity and expectation for students to identify how they will accept that week's professional topic within their own professional identity.

Vertically integrated teams provide a professionally supportive collegial atmosphere; students in the beginning semesters of the program benefit from peers on their teams who are further along in their professional development; it provides a positive peer perspective on the value of professional competencies. Thorton and Nardi identify these types of interactions as ones in which students place the most value. Students further along in the curriculum also benefit from having to guide the younger students. They must first reflect on their own understanding and experiences before guiding the younger student with a particular professional competency. Interactions with clients and faculty leaders also provide multiple opportunities for students to practice professional skills and get formative, non-graded feedback on how to improve.

The personal stage is an integrated part of the end of semester assessments and grades for each student. Mentors evaluate each student on performance in all the professionalism areas through a performance evaluation similar to what practicing engineers undergo in the professional setting. These experiences culminate in a chapter of the student's individualized personal development plan (PDP) with a summary of the learning activities during the semester, the level of attainment of the goals from the previous semester, and a summary of the feedback the student has gotten during the performance evaluation. These inputs lead to the development of new goals and detailed action plans for the next semester.

The four-stage cycle is repeated each of the four semesters of the upper division program, with required substantial progress each semester towards the desired graduation level professional outcomes. The revisiting of the professional development topics with increasing level of sophistication each semester reflects the intent of the spiral configuration of the Networked Components Model proposed by Sheppard, et. al. (2009). It better reflects what is understood about learning and role acquisition than the more traditional linear "one-time" through from theory to application model. Professional competencies account for three credits out of 15 credits of student work each semester. The model is illustrated in Figure 1.

Figure 1: PBL Professional Development Model



4 Research Methodology

This study looks specifically at how students in the PBL curriculum develop their professional competencies as compared to students in a more traditional program. An explanatory sequential mixed method approach will be used to address the study's research question:

"What is the professional development trajectory of students in the new project based learning (PBL) curriculum?"

The first phase of the study, and the focus of this paper, is an initial quantitative study to understand the effect of the PBL curriculum on the student professional development trajectory. It includes the development of an instrument to assess the growth of the student importance for and performance of professional competencies, followed by collection of data from study participants, and an analysis of the results. A future, second phase, qualitative study will focus on understanding how the PBL curricular aspects affect the student professional development trajectory. The explanatory sequential mixed methods approach will provide for a third interpretation of the study results focused on expanding the understanding of the professional development trajectory in the PBL curriculum.

The quantitative study seeks to identify if a difference exists between PBL and non-PBL students in their self-reported growth of importance and performance in their professional abilities. The study will focus on the following four directional hypotheses:

1) PBL students will have an increase in their self-reported importance for professional skills
2) This importance increase will be greater for PBL students than for non-PBL students
3) PBL students will have an increase in their self-reported performance for professional skills
4) This performance increase will be greater for PBL students than for non-PBL students

Currently there are limited well-established resources for assessing student attainment of professional skills (Shuman, 2005). As part of the quantitative study, two instruments were developed to evaluate the professional growth of students in the PBL model as compared to students studying in a more traditional model. The first focuses on the individual professional abilities and the second focuses on these professional abilities in a team context.

4.1 Instrument Development

4.2.1 Individual Professional Development Instrument

The individual professional development instrument is based on the ABET student outcomes in Criteria 3 itself. The criteria of specific focus in the study are: an ability to function on multi-disciplinary teams (3.d); an understanding of professional and ethical responsibility (3.f); and an ability to communicate effectively (3.g). In the fall of 2012, a group of the PBL students participated in a workshop where they were first trained on the ABET student outcomes and then developed a list of 19 individual professional behavioral expectations that reflected these outcomes in their own language as students. They were used to develop the items in Table 1.

Each expectation is presented in the instrument to participants with the following statement:

"Engineering students are expected to act professionally with one another, with mentors, and with people external to the program. Below is a list of important professional behaviors that engineering students and graduates should follow."

Students are then asked to rate (1 = Low, 5 = High) each expectation item on both:

a) Its importance to your personal and project success & b) Your current level of performance

Table 1: Individual Professional Development Instrument Items

Function on Multi-	Understanding of Professional and	Ability to Communicate

Disciplinary Team (3.d)	Ethical Responsibility (3.f)	Effectively (3.g)
Arrive at all meetings on time Treat all others with respect Meet the needs of your team by completing work on time and of high-quality Give proactive feedback to others Do not take frustrations out on those around you	When told something, record and act upon it Dress and groom appropriately Work hard to create an environment free of harassment and conducive to learning Willingly help others inside and outside of University Meet all deadlines Schedule time to better yourself through reading current events Act ethically in all respects Continually seek to improve yourself Maintain a positive attitude Act safely while completing all tasks	Read memos and respond appropriately Speak professionally, free of vulgarities and with appropriate grammar Pay close attention to your emails and respond to requests in a timely manner

4.2.2. Team Professional Development Instrument

The second instrument is a professional development survey that identifies students' beliefs on the importance of professional development and their current performance level within the context of functioning as a member of a team. This 1-5 Likert-scale instrument is an adaptation of TIDEE professional development work of Davis and Beyerlien (2011). Each expectation is presented in the instrument to participants with the following statement:

"Many engineering projects challenge and stretch the abilities of people involved. This exercise guides you through steps to identify knowledge or skill deficits in your project team and to create a plan for growing your abilities to meet these needs. With instructor feedback and focused effort on your part, you will increase your ability to perform as a professional and become a better independent learner. The first step in planning professional development is to identify abilities needed to be successful. The twelve abilities listed throughout the survey are a good place to begin."

They are asked to rate each ability (and associated behaviors listed) (1 = Low, 5 = High) for:

a) Its importance to your personal and project success & b) Your current level of performance

Professional Ability Expectations In a Team Setting

- **Analyzing information** Applying analysis methods/tools to understand & explain conditions
- **Solving problems** Formulating, selecting, and implementing actions for optimal outcomes
- **Designing solutions** Producing creative, practical products that bring value to varied stakeholders
- **Researching questions** Investigating, processing, interpreting information to answer important questions
- **Communicating** Receiving, processing, sharing information to achieve desired impact

- **Collaborating** Working with a team to achieve collective & individual goals
- **Relating inclusively** Valuing and sustaining a supportive environment for all knowledge & perspectives
- **Leading others** Developing shared vision & plans; empowering to achieve individual & mutual goals
- **Practicing self-growth** Planning, self-assessing, & achieving goals for personal development
- **Being a high achiever** Delivering consistently high quality work & results on time
- **Adapting to change** Being aware, responding proactively to social, global, & technological change
- **Serving professionally** Serving with integrity, responsibility & sensitivity to individual & societal norms

4.2 Experiment

The study began with both instruments being administered to students entering the PBL upper-division program, as juniors, for the fall of 2013 and the fall of 2014. This group is identified at the PBL pre-treatment group. The instruments were also administered to 2013 and 2014 graduates of the program. These graduates are the PBL post-treatment group.

At the same time, a comparison, non-PBL pre-treatment group was identified and is comprised of junior year students entering a traditional upper-division engineering programs in the upper Midwest Region of the U.S. The instruments were also administered to 2013 and 2014 graduates of these programs. These graduates are the non-PBL post-treatment group.

Both instruments were adapted to a web format utilizing Survey Monkey (Sue & Ritter, 2012). Results from the instrument were downloaded into a spreadsheet for data analysis. For each data set, averages and standard deviations were calculated. A Z-score > 2 for statistical significance was sought for to identify growth from prior to upper-division experience as compared to after upper-division experience. Table 2 details the number of students completing the instrument.

Table 2: Number (n) of Students Completing Both Instruments.

	Comparison Group		PBL Group	
	pre-nonPBL	post-nonPBL	pre-PBL	post-PBL
Number of students (n)	87	43	46	30

5 Results

Results, summarized in Table 3, indicate that students who experienced the PBL curriculum indicate growth in self-reported performance for both parts of the instrument with an increase of 0.3 and 0.4 respectively. The current results indicate no significant growth for non-PBL students in performance overall for these 30 professional abilities. The results for both PBL and non-PBL students indicate no growth in the importance for professional abilities.

Table 3 Composite Pre-Post Professional Responsibility Growths

		PBL Group Mean Scores				Non-PBL Group Mean Scores			
		Pre	Post	Growth	Z-score	Pre	Post	Growth	Z-score
Individual Professional Responsibility	*Performance*	**4.0**	**4.3**	**0.3**	**2.7**	4.1	4.2	0.1	1.0
	Importance	4.7	4.7	0.0	-0.1	4.6	4.6	0.0	-0.3
Team Professional Responsibility	*Performance*	**3.6**	**4**	**0.4**	**4.9**	3.7	3.9	0.2	0.6
	Importance	4.6	4.6	0.0	1.0	4.6	4.6	0.0	-0.1

The results were also analysed at the individual item level. The PBL students showed significant growth in 15 of the 30 instrument items and the non-PBL students showed significant growth in only one instrument item, as displayed in Table 4.

Table 4 Individual Instrument Items of Growth

PBL Group Growth Items	**Pre-Score Mean**	**Post-Score Mean**	**Growth**	**Z-Score**
Importance: Pay Close Attention to Email & Timely Response	4.70	4.93	0.23	2.69
Importance: Act Safely	4.67	4.90	0.23	2.13
Importance: Researching questions	4.39	4.77	0.38	2.87
Performance: Pay Atten. to Email & Timely Response	3.96	4.47	0.51	2.90
Performance: Act Safely	4.24	4.60	0.36	2.32
Performance: Meet Needs of Team	4.04	4.37	0.32	2.04
Performance: Willingly help others in & out of Eng. Env.	4.22	4.70	0.48	3.06
Performance: When Told Som., Record & Act Upon It	3.76	4.17	0.41	2.17
Performance: Analysing information	3.38	3.97	0.59	4.04
Performance: Solving problems	3.39	3.97	0.58	3.06
Performance: Researching questions	3.45	4.00	0.55	2.83
Performance: Communicating	3.59	4.23	0.64	3.65
Performance: Relating inclusively	3.66	4.17	0.51	3.39
Performance: Leading Others	3.55	3.93	0.38	2.22

<u>Performance</u>: Practicing Self-Growth	3.41	3.90	0.49	3.03
Non - PBL Group Growth Items				
<u>Performance</u>: Read Memos and Respond Appropriately	3.87	4.16	0.29	2.15

6 Discussion

From the current quantitative analysis, there is statistically significant evidence to indicate support for hypotheses three and four that engineering students subjected to the PBL curriculum do indicate a self-reported growth in the professional ability performance. This growth is greater in comparison to the students in the non-PBL control group; which showed no overall statistically significant growth in performance. Both the Individual Professional Development Instrument and the Team Professional Development Instrument support this initial finding. Given the similarity of the results from both instrument, the use of only one instrument will be explored as the study continues.

The current evidence does not appear to support hypotheses one and two. The students in the PBL curriculum group and the non-PBL curriculum group did not show statistically significant growth in the overall importance for professional abilities. These results give some indication that the student importance for the professional skills was established prior to the start of upper division and does not appear to change over the two-year time frame regardless of the curriculum mode. One potential reason is the instrument does not have the capability to detect the growth in the way it is currently structured. Another potential is that there is little room for growth in importance regardless of the curricular model because the importance for the professional competencies is already known and valued by the students from their experiences prior to starting their upper division programs.

7 Conclusion and Future Works

The results do indicate that the growth in the ability for students' performance of professional competencies increases for students who experience the PBL curriculum as compared to the non-growth for students experiencing the traditional engineering curriculum. This provides an initial indication that a PBL curriculum incorporating the described "professional development model" has the potential to provide the called for change in engineering education and meeting the professional competency need of the engineering profession.

Although the quantitative data shows promising results, it does leave a couple aspects of the trajectory to be explained further. The first aspect is why the students in the PBL group do not show the expected growth in importance for professional competency proposed in hypotheses one and two. The quantitative study also gives little insight to a second aspect of understanding how the curriculum affects the student professional performance development trajectory.

A future, second phase, qualitative study of the PBL student professional development trajectory will focus on explaining these two aspects further. It will be administered to a subset of participants and the results will be analysed to further explain the results of the quantitative study. The first aspect is to provide some understanding of why students in the PBL curriculum did not identify growth in the their importance for professional competencies; growth in importance for professional competencies was an expected outcome of the students in the PBL curriculum. The second aspect of the qualitative study is to further explain the growth seen in the self-reported performance of professional competencies. It goes deeper into the research question, “What is the professional development trajectory of students in the new project based learning (PBL) curriculum?” to identify how the curricular elements affected the student trajectory.

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Designing Activity Led Learning to Promote the Development of Professional Judgement Capacity.

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Abstract

Providing learning environments in which students can exercise and improve their understanding of the judgements they make should enable them to produce consistently better solutions to problems in professional practice. This paper proposes that Activity Led Learning (ALL) environments can be constructed to compel learners to exercise judgement in complex realistic project scenarios in order to promote the development of judgement as a part of the progression from student to new professional entrant. A phenomenological study was made of a cohort of first year BEng Aerospace students throughout a project of ten weeks duration. The purpose of the study was to observe and examine the learners' experience of exercising judgement in an ALL environment in order to determine whether the learning environment can be constructed to promote the development of judgement capacity. In the project the students were randomly divided into small teams of five to six and tasked to investigate and deduce the cause of an air crash. In the phenomenological study, the students were observed, and written accounts of their dialogues and activities were made and analysed. It was found that the students exercised a range of complex rational and heuristic judgments to develop their conclusions. The findings suggest that the duration of a project and the way in which the information is presented, have an observable impact upon the way learners define a potential problem space and in consequence the types of judgement that they can exercise.

Keywords: engineering projects, activity led learning, judgement

1. Background

1.1 Literature

The faculty of judgement has been considered to be of fundamental importance in human cognition, it is also one of the most complex of reasoning processes. Kant according to Hanna (2013) placed judgement above all other cognitive functions, whilst more recently Lipman (2003) considered judgement to be a mental accomplishment of immense complexity and Down et al (1999) cite Hager (1998) who argued that the development of the 'key competencies' is linked to the capacity to form sound judgements. The importance of judgement is also implicit in the argument put forward by Trevelyan (2009) who described engineering practice as the development and predictable delivery of predictable products and services from human performance and interactions that are essentially intrinsically unpredictable. Hager (1999) further hypothesized that making better judgements is an ideal objective of workplace learning and consequently development can be represented by the capacity to make appropriate judgements.

Kahneman & Tversky (1982) modelled rational and heuristic human judgement and the effects of evolved cognitive bias to explain the tendency to potentially serious errors in judgement. Lipman (2003) proposed that improving reasoning cannot be assumed to enable individuals to exercise better judgement and that it could be more effective to educate the individual learner to be reasonable and sceptical of the judgements they make. To make sense of the unpredictable it would seem, requires that the faculty of judgement is exercised in a particular way. The need to develop judgement capacity in learners is however, largely understated as a pedagogic objective and is assumed to be implicit within current educational practice (Igarashi et al 2014)

1.2 Activity Led Learning

Activity Led Learning (ALL) at Coventry University is defined as "a self-directed process in which the individual learner, or team of learners, seek and apply relevant knowledge, skilful practices, understanding and resources (personal and physical) relevant to the activity [being undertaken]" Wilson-Medhurst et al (2008:2). ALL is an evolution of earlier work on problem based learning (PBL) by Savin-Baden (2000) who refers to its initial development at McMaster University by Barrows & Tamblyn (1980) and their claim that learning through the examination and solving of problems is more effective than memorising knowledge for developing a usable body of knowledge. In ALL the learning experience is based on an activity with the learners at the centre of a community of inquiry that is facilitated by the tutor rather than focussed on subject content which is summarised and handed over to the learners as passive participants. The problem and activity are placed before knowledge and the learner is placed in a challenging learning environment to make connections between what they experience through action and knowledge.

1.3 Student Project Outline

The case study presented in this paper is one of six similar studies from a larger programme of research into the development of judgement capacity through ALL at Coventry University. The other research studies were on undergraduate programmes in mechanical & automotive, ethical hacking, aerospace, civil engineering architecture & built environment and a group of apprentices in precision production engineering. The students were given the task of determining the cause of an air crash. During the first four weeks of the project, the students were given diverse information about the aircraft in a series of short tutorials and online documents. The information provided included its service history, the flight information immediately prior to the crash, air worthiness directive and aircraft maintenance reports, meteorological and air traffic control reports, the cockpit voice recorder and flight recorder data and statements from eyewitnesses who saw the incident. Any additional information the learner considered relevant was provided only on request, providing further opportunities for disjuncture and the recognition of the absence of relevant information. During the project the students had access to a flight simulator and use of the following tools; Group Mahara Page, Group Forum, MATLAB, Google Drive and Presentation Software PowerPoint, Prezie, PowToon and Moodle for referencing. For assessment the students presented their findings in a 10 minute Presentation (maximum 10 slides) taking the role of the Air Accidents Investigation Branch (AAIB). The structure of the presentation was prescribed and had to include a title page, content list, introduction, research & data collection, data extraction method, findings, analysis, conclusion. The students had to demonstrate their evolution of the solution and reasoning up to a final decision as to why the aircraft crashed.

2. Methodology

2.1 Phenomenology

A phenomenological methodology was used in the collection of data and the analysis. Judgements, particularly in complex contexts are resistant to measurement, however we can know a priori that given any propositions, individuals must exercise judgements to intend a state of affairs (Sokolowski 2000) and those judgements must precede action. Actions constitute the 'residues' of judgement and by observing and recording those actions and analysing them for meaning it can be inferred that judgements of a particular type have been made. By rejecting the assumptions that normally constitute observations of human behaviour, phenomenological research methods are effective at understanding perception and experience from the perspective of the research subject (Lester 1999). Interpreting the phenomenology of the learner experience enables understanding of that experience in its context to inform educational practice and pedagogic theory.

2.2 Observation and Recording

Eighty one opportunistic observations were made of the activities of seventy four students working both individually and in groups during their tutorial sessions over a period of ten weeks. Additional observations of group activity were undertaken by prior agreement with project teams. Twelve students gave, on request, a brief reflective précis of their views on their group's work and three semi-structured interviews were recorded with selected volunteers. The observations and reported experiences were manually recorded and included information on group structure, equipment and in particular the dialogues and actions of the learners as they worked. The transcripts of those actions, dialogues and situations were analysed for meaning to determine what judgements could be potentially attributed to them.

2.3 Data Extraction and Analysis methodology

The method of analysis of the transcripts uses 2 propositions in the categorisation of judgement. The first is the taxonomy of judgment proposed by Lipman (2003) which is comprised of ‘culminating judgements’ and 'mediating judgements', including judgements of; identity, difference, similarity, composition, inference, relevance, causality, membership, analogy, appropriateness, value, hypothesis, counterfactual, practical, factual, reference, measurement, translation, instrumentality (means end adjustment), division. Secondly, Kahneman (2011) hypothesised that human cognition exercises judgments in two distinct modes that he refers to as 'system 1' and 'system 2' thinking. The former is fast and heuristic and the latter slow and rational. Because 'system 2' rationality requires mental and psychological effort and time, humans tend to rely extensively on 'system 1' which rapidly develops plausible solutions that 'system 2' sanctions. 'System 1' reasoning is much better than random choice or mere guesswork but is subject to evolutionary cognitive biases that can cause erroneous judgements and result in unpredictable outcomes. In addition, the heuristic judgements of intention attribution and coherence (plausibility), both of which are particular cases of factuality, were salient in the analysis and included in the categorisation of judgements. The broader research of which this study is a part, seeks to understand the learner's experience of making judgement during ALL. Three related areas of specific interest emerge from the study namely, problem space definition, the effects of the problem space construction on judgement and the effects of information absence on culminating judgement.

The following extracts are presented as illustrative of the nature of the evidence collected and to illustrate the method of analysis and extraction of the learners' experiences of exercising judgements from the observation records.

1st Participant Group, First Observation Record, 15/10/2013;

The students' first tutorial activity, and they are working through the flight log searching on acronyms, vocabulary and failure mode codes. They are looking for repetitions and frequency of events as indicative of likely causes. Beginning by focussing on the flight log information indicates an initial heuristic judgment of relevance. This bounded rationality can reduce the potential problem space to manageable proportions and produce a causal hypothesis in a short time if it is correct. The log search indicates that a range of judgments were being made i.e. identity, membership, difference and composition, culminating with judgments of relevance and hypotheticality. The proposition to consider events with higher frequencies may result in a form of the logical fallacy of representativeness, viz that an event has salient features with the process it is associated with doesn't necessarily increase its probability.

1st Participant Group, Fourth Observation Record, 07/11/2013 Week 6;

The group hold an extra tutorial meeting. Four team members were present, two actively engaged in the debate and using laptops, the other two much more passive. The discourse below summarises the first segment of a discussion lasting over an hour. The analysis of the dialogue is italicised and interleaved

> "The rate of turn indicates an evasive action took place."

Judgement of causality by inference including judgements of measurement and relevance.

> "There are massive changes in X! I don't think this is a fuel loss!"

Judgement of causality by judgement of value and factuality viz there is not enough evidence to support fuel loss proposition.

> "The incident angle goes from 97.5 to 4.6 in about a second, so a fuel leak is looking very plausible."

Judgement of causality by judgement of measurement and counterfactuality, viz there is enough evidence to support fuel loss proposition.

> "The leak doesn't occur until in flight and this is more than a little leak yeah? Sounds more like the wing has fallen off!"

Judgement of inference by judgement of counterfactuality

In the above discourse the students began by re-iterating an earlier discussion about an evasive manoeuvre and the fuel leak. Their problem space has become populated with a lot of data from the flight recorder and other reports that form propositions on which they exercise a range of judgements, including measurement, value, relevance and composition. There is still a degree of uncertainty about the data and whether it provides sufficient evidence for the conclusion that is emerging and ultimately there are culminating judgments of factuality, counter-factuality and causality. Particularly salient in their intentionality is the dramatic decrease in mass and whether a fuel leak is sufficient evidence and therefore potentially causal.

1st Participant Group Fifth Observation Record, 26/11/2013 ;

This is the last group meeting prior to the presentation of their findings and conclusion. They have established in a flight simulator that the failure of one engine would not make the airplane uncontrollable. They have become increasingly aware that time is now limited.

"The engine is loose and there is a continuing fuel leak, avoiding the harrier jump jet stressed the engine mounts and the engine broke free."

The judgement of causality has become heuristic. There was no evidence an engine was loose but the inclusion of this proposition makes the narrative more coherent.

"If we had a debris field report we could have proven this from the debris field."

A rational judgement of counterfactuality that arises from previous judgements of factuality. They could have asked for a debris field report but didn't action it, possibly due to time limits.

"Is there any evidence the engine was loosely fitted?"

Rational proposition

"J Thinks it might have, the evidence would be in the maintenance report."

A judgement of factuality however the evidence is not there and they have forgotten their previous efforts would have probably found it.

Just prior to their final presentation this group fabricated a narrative about the engine mounting bolts being incorrectly heat treated which resulted in their premature failure under load. No information of this nature was provided. By intending this situation they change the narrative of their thinking to construct a more coherent version of their judgements of causality and thereby justify their proposition that the engine was lost.

3. Results

3.1 Problem Space Definition

For these students, working with air crash data to solve a relatively open-ended project of this type is a new experience. With no prior experience from which to make direct judgements of analogy they have to exercise heuristic judgements of relevance, appropriateness and composition in order to create a definition of the potential problem space. This early stage in problem solving is effectively a rapid exertion of heuristic judgements of the arguments most likely to produce a solution. This occurs despite the learners having no experience to draw on and is performed subconsciously to reduce the problem space to manageable proportions (Newell & Simon 1971). Experts are also known to do this but have memories of similar problems that they can re-activate so that initial problem space definition and their judgements are faster and potentially more astute (Eraut 1994). As more information is presented to the problem space the students exercise further judgements of discrimination, relevance, appropriateness and composition with judgements of hypotheticality to progressively refine the problem space in which various hypotheses are proposed, judged, reintroduced and re-judged. The problem space becomes increasingly complex and reasoning continues through a number of iterations until their judgements have intended a coherent model of the events and proximal phenomena leading up to the crash at which point they can make a culminating judgment of causality.

3.2 Learners' Experience of Exercising Judgements in ALL

The learners consider a diverse range of evidence and the project has both technical and socio-technical domains. Technical data on aircraft position and manoeuvres, air speed, fuel, air traffic control, is made available together with information which is value laden such as eye witness statements, pilot and co-pilot voice recordings, bird flock sightings and weather and visibility reports. The technical data is potentially counterintuitive to the broader socio-technical issues and the disjunctures are compelling. Learners have to exercise judgements about the value and veracity of some of the information in order to define the problem space and make a hypothesis from which they can develop a solution. The phenomenology of the learner's experience reveals that the coherence of intended solutions in the problem space tends to greater rationality in the majority of cases though heuristic judgements persist and have a strong influence on the outcomes. For a smaller number of learners, their judgements are predominantly heuristic throughout the problem space and the solution is considered on the coherence of its narrative.

3.3 The Effect of Problem Space Construction on Judgement

From the information given to the students in the first few tutorials, the aircraft in the investigation is an older series 200 A320, the autopilot had been changed and a fuel leak on the starboard wing had been repaired prior to take off. With the exception of eyewitness statements all the other information presented at this point in time is entirely technical data and reports on this aircraft. With no other information or experience available, the scenario presents as though the cause is a mechanical or system failure. Consequently, the students intended a problem space in which the solution depends on finding a preferably prima facie technical cause premised upon the failure of an engineered component. This initial problem space definition appears rational but is in fact a heuristic judgement of causality and relevance about the nature of the problem space that is influenced by the cognitive bias of base rate neglect and not on the probability of a certain category of evidence. Various incidental factors in the learning environment affect the learner's capacity to intend a problem space accurately and efficiently. By way of example, one student searching through the aircraft maintenance log was convinced the definitive mechanical failure could be found in the log by selecting on the highest frequency of events. The same student's intentionality was reinforced by an intention attribution. He thought that because the tutor had spent some time discussing the document he had implied it must be of significance. Among the teams observed, intention attribution, the 'primus inter pares' effect and persistent absence of other team members impacts severely upon the dynamic of the team and culminating judgements can be driven by team interaction rather than recourse to reasoned argument.

3.4 The Effect of Information Absence on Culminating Judgement

An examination of the data distribution for air crashes between 1950 and 2010 shows on average, 60% of all air crashes were attributed to human error (largely pilot error) and only 20% to purely 'mechanical' failure. (Accident Statistics 2014). This information wasn't given or discovered by the students, its exclusion skewed the potential problem space toward a mechanical systems failure and the inclusion of it early on could be considered crucial in the initial problem space definition. Later the learners acquire information that just after take-off, in poor visibility, the pilot of the airplane has to make an evasive manoeuvre to avoid a military aircraft that has strayed into the airspace. The severity of the manoeuvre is sufficient to cause the failure of the starboard wing structure. The proximal cause therefore is actually a structural failure but the ultimate cause is human error. While the students include the evasion of other aircraft in their construct of the problem they do not specifically refer to any human error in their analysis.

4. Conclusions

Where a project is of sufficient duration to permit enough iterations, the initial heuristic judgements can be progressively overruled by rational judgements providing the learner can exert sufficient cognitive effort within the problem space. In the exertion of judgements the majority of students progressively develop an alternative intentionality of a problem. On the other hand, if time is limited the learner is driven to rely increasingly on fast heuristic judgements. They do not appear to be aware of the increasing tendency to error with judgements of this type. The way in which the project information presents to the problem space affects the potential range of judgements. Information that is undisclosed or not re-activated within memory may as well not exist and the problem space is narrowed by the lack of potential solutions. Heuristic judgements construct the most coherent (elegant) version of events with the information available, the quantity and quality of data becomes irrelevant. When a state of affairs is intended by making a judgement, essentially a choice appears to be made but in fact only one interpretation is intended and any ambiguity goes unnoticed. Heuristic reasoning does not keep an audit trail of all the alternative scenarios that were presented (Khaneman 2011). Earlier propositions are forgotten in order to intend and realise new solutions, the learners continually revisit propositions and re-judge the growing number of variations as if they were new propositions.

These conclusions suggest that a project in ALL should:

1. provide sufficient time for the learner to exert cognitive effort toward making rational judgements.
2. allow the inclusion of a feedback mechanism that increases learner scepticism about heuristic judgements i.e. the necessity to refer to data distribution of similar events and problems.
3. provide the relevant information for the problem space at one time to exercise judgements of causality and hypotheticality and permit the learner to define a problem space by encountering the relevant information and making judgements about the disjunctures that occur during the flow of information.

The findings suggest that Activity Led Learning can be used to create experiential learning environments that exercise the development of judgement capacity particularly if the learning environment is constructed as a series of cognitive disjunctures that flow into each other and enable the learner to build networks of knowledge. This study will lead to recommendations on how ALL should be constructed for the purpose of developing professional judgement capacity in undergraduate learners.

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Assistant professors’ expectations and understandings of PBL group supervision: Three cases of no prior experience in PBL

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Abstract

Alborg University (AAU) is characterized as a PBL university but during the last years, AAU has received an increasing share of new academic staff with no prior experience of PBL. We expect that the new staff, without any intervention, will draw on their prior experience from either giving or receiving supervision at non-PBL universities, when they supervise themselves. Although this will help them along the way, we suspect that this it is not enough. This study focuses on their expectation, understanding and practice. The aim is to create and test various interventions to enhance the situation. Thus, our research question falls in two parts. A question concerning status quo: What kind of challenges, if any, does assistant professors novice to the PBL supervision model experience? And a second: How can we as trainers of trainees enhance their perspective and capability according to these challenges? PBL has a focus on solving clearly stated problems, teamwork, self-directed and student centred learning, exemplary learning and inter-disciplinary problem analysis and problem solving (de Graaff & Kolmos, 2007). Particularly about the AAU model and supervision, the role is in other contexts known as an advisor or facilitator for each semester (Barge, 2010). The type of role can undertake different variations depending on the perspective and practice of the supervisor (Bøgelund, 2013). Each role has different implications for the PBL approach. In order to classify the level of supervision of the four staff members, we apply Dreyfus and Dreyfus’ (1986) model describing five levels of expertise. Also Biggs’ (2003) model of four types of knowledge (declarative, procedural, conditional, functional) is used to describe the type of supervision knowledge our cases demonstrate. As for the design we seek four cases of assistant professors who did not do their own master and PhD training at AAU or another PBL institution. In order to determine a part of the baseline, we use a questionnaire to get background information. This aides our development of the interview guide for a focus group interview. Focus groups are useful when one wants to study how a specific group experiences a situation, like being new to a PBL environment (Albrecht et al., 1993). The cases are not all known to each other in advance, which is useful when we want them to talk about their taken-for-granted assumptions (Morgan, 1998). The study consists of four phases. The two first (the baseline test) are reported through this paper and the presentation of it. Phase one consists of questioning and interviewing the four cases to get an understanding of their perspective on PBL and facilitation of group work. In phase two we observe their group supervision. In phase three we undertake different interventions according to the challenges we uncover in the baseline test. In the fourth and final phase we observe their practice again to see if and what kind of changes the interventions have initiated.

Keywords: PBL implementation, teacher role in PBL, tutoring models

1 Motivation for study

Like any other university, Aalborg University (AAU) employs new assistant professors every year. AAU is, however, different from many other universities since its teaching is organised around the principles of problem and project based learning (PBL), which among other things include students working in groups on projects with academic staff acting as supervisor (Barge, 2010; AAU PBL Academy, 2015). Such type of teaching and supervision would therefore be unfamiliar for academic staff that did not receive their degree at AAU or another PBL university. The Faculty of Engineering and Science (FES) at AAU has since 2010, employed a number of new assistant professors. With some variation from year to year, on average 22% (see Figure 1) of these assistant professors have not previously been employed at AAU. This means that a rather large share of new academic staff have got no prior experience of PBL when they start to work (supervise) at AAU. Some of them might have some experience from other universities that practices PBL, but no PBL-university is completely alike.

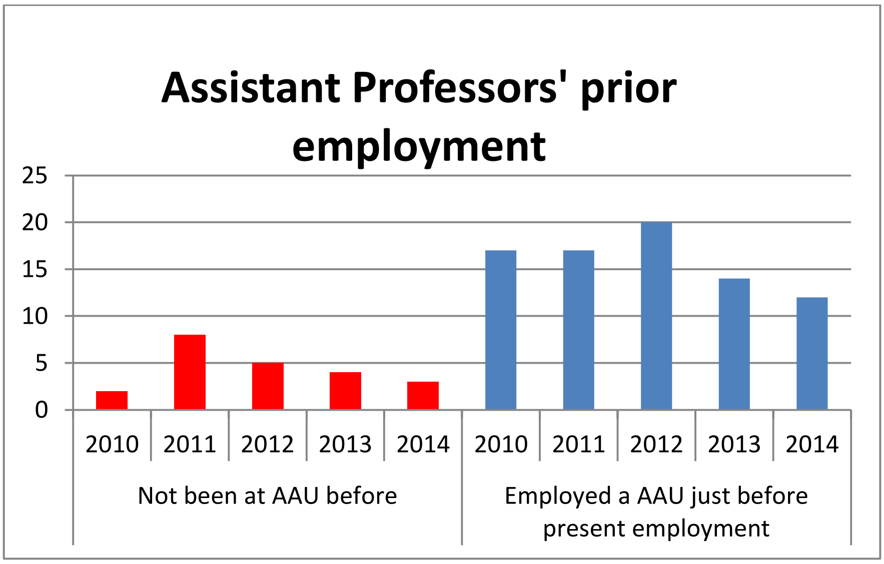

Figure 1: Numbers of Assistant professors from the Faculty of Engineering and Science (FES) and their prior employment with Aalborg University (AAU). NB: Being a PhD student in Denmark is considered being an employee. Source: The Faculty Office for Engineering and Science / Medicine, AAU.

The introduction of new educations and amalgamations and redeployment of higher education and research institutions within the Danish educational sector are among the reasons for the recruitment of new staff from outside the university. Also the increasing share of international PhD students that subsequently find their employment as assistant professors at AAU adds to the picture. There are many advantages for a university in employing others than “home breed” PhDs. One such advantage is gaining new insights of already existing subjects at the university, another is getting insights about new subjects altogether as well as the advantage of expanding the networks. Some challenges might also be expected. We expect that the new staff, without any intervention, will draw on their prior experience from either giving or receiving supervision at non-PBL universities, when they supervise student groups themselves. Previous learning experiences have a powerful impact to socialize supervisors into doing to others what was once done to them (Lee, 2008). Although this will help them along the way, we suspect that this it is not enough in a PBL setting and will create some challenges or quality deficits.

2 Research questions

The current study will address this situation by focusing on the expectations, understandings, and practice of assistant professors with no prior experience of PBL.

The aim will be twofold: To gain knowledge about their expectations, understandings, and practice, and to create and test various interventions to enhance the situation. Thus, our research question falls in two parts. An initiating question concerning status quo: ***What kind of challenges does assistant professors novice to the PBL supervision model experience?*** On the basis of this initial research question we aim to consider how to improve the situation: ***How can we as trainers of trainees enhance their capability according to these challenges?***

The current paper will address only the first question, whereas subsequent papers will address the second research question.

The assistant professorship is the period, where they are new to the university and therefore try out the realities of being university teachers at the same time as they participate in the compulsory teacher training course for university teachers at AAU. In Denmark, it is a requirement to have passed such a course in order to later achieve a tenured position as associate professor. Each university has its own course which usually consists of some general topics on education as well as issues particular for the university itself. Such a teacher training programme creates both the reflective and practical opportunity to engage in dialog with and supervision of the assistant professors. We have therefore studied three assistant professors from FES. Our three assistant professors have all just begun the course and they have not done their Master here while all of them have done their PhD at AAU. In this way, they are almost completely new to PBL, particularly the Aalborg PBL Model.

3 Theoretical framework

3.1 Problem Based Learning

As earlier defined PBL stands for problem and project based learning and it has a focus on solving clearly stated problems, teamwork, self-directed and student centred learning, exemplary learning and inter-disciplinary problem analysis and problem solving (de Graaff & Kolmos, 2007). These teaching and learning processes can be organized in many different ways and different higher education institutions each have their own model (e.g. Neville & Norman, 2007). In particular the AAU PBL Model (Barge, 2010; AAU PBL Academy, 2015) is characterised by six principles. ***1. Problem orientation*** meaning that problems/wonderings appropriate to the study programme serve as the basis for the learning process. The problem can both be theoretical and practical but needs to be authentic. “Problem”, however, does not in itself indicate an unsatisfactory situation, but might just as well be an opportunity for improvement or a (theoretical) puzzlement where consequences are not yet known. ***2. Project organization*** in which the project is a goal oriented process limited in time, usually a semester amounting to half the credits of that semester (15 ECTS). The project stands as both the means through which the students address the problem and the means by which students achieve the articulated educational objectives. ***3. Courses supporting the project*** which are meant to secure that the students are presented to a wide range of theories and methods that might be used in the projects. The courses include a high level of student activity and is organised as a mix of lectures, workshops, laboratory work, seminars, and exercises. The courses usually take up the other half of a semester’s work load (15 ECTS). ***4. Team-based approach***. A majority of students’ problem and project work is conducted in groups of three to eight students. The students manage the project and they support each other in achieving the goals. The collaboration includes knowledge sharing, group decision making, subject based discussions, and feedback to each other. In addition the group might collaborate with external partners such as private companies, public institutions, or other project groups at the university. ***5. Exemplarity*** which means that the learning outcome is transferable to other situations which the students might meet in their professional life. ***6. Responsibility for own learning*** indicating that students have a high degree of freedom to choose the projects. The ability to be able to assess the quality of own work and knowledge is a central theme for PBL. Each group gets assigned a supervisor who facilitates the group. However, it is the group who has the sole responsibility for the collaboration, planning of the project, and its results, including their own learning.

3.2 Supervision

The supervisor's role in particularly the AAU PBL Model is in other contexts known as an advisor or facilitator. Each semester, a supervisor serves as a resource for the group but it is always the students who have the responsibility for the learning and the result (Barge, 2010 & AAU PBL Academy, 2015). At AAU supervisors usually act as facilitators in mainly three different realms:

1) Problem analysis and problem solving
    a. Clearly stated problem, methods and theories relevant to the problem, well-motivated, exemplary, interdisciplinary
2) Teamwork
    a. Communication, roles, sharing of knowledge and conflict management
3) SDL (self directed learning)
    a. Being critical, project management, reflexive learning and evaluation of process

The supervisor at AAU can undertake various roles depending on his perspective and experience. More specifically the roles can vary with the type of knowledge that the supervisor aims for the students to produce. This knowledge is formulated in the study regulations which states specific learning outcomes for all courses and projects, but the supervisor also interprets these in the light of own professionalism. Bøgelund (2015) argues that such roles could concern the role of professional sparring partner, the role of project leader and the role of all-round facilitator. Each role will have different implications for the actual interaction with the students and they can be mixed in a single supervisor.

1) Professional sparring partner
    a. The supervisor will expect the student to be already self-directed and able to co-operate to some extent. It is seemingly not the responsibility of the supervisor to facilitate this. Focus will be on academic issues. Learning the field. Problems of the field are interesting.
2) Project leader
    a. The supervisor will expect the student to be already self-directed within limits set by the supervisor and able to co-operate to some extent. It is not the responsibility of the supervisor to facilitate this. Focus will be on teasing out interesting and profitable knowledge. The supervisor will have a great saying in how the project is framed and organised. Problems of interest to industries and profitable markets are interesting.
3) The all-round facilitator
    a. The classical PBL supervisor, who facilitate all three realms stated above with a point of departure in student needs and abilities and learning goals. Problems found by the students that live up to the ambitions of the study regulations are interesting.

Another model for supervisor roles is described by Kolmos and Holgaard (2007) and Tofteskov (1996). This model describes four types, each with strengths and weaknesses for students in relation to PBL. This model is more focused on the handcraftsmanship of supervision – what good facilitation means and how it is best achieved - and not the type of knowledge the single supervisor wants the students to produce.

1) Process-supervisor
    a. The focus is on the students' learning process and on supporting the progression of students' knowledge even if it means that the students do not achieve the maximum level of knowledge. The view is that the students may learn as much from their mistakes as from what works. The aim is also on having the students reflect over their own and the group's learning process.
2) Product-supervisor
    a. Supervision is much aimed at the project report and the knowledge the students are supposed to learn. The supervisor feels ownership of the report.
3) Control-supervisor
    a. Supervision is like an exam where the supervisor checks each single student's understanding and contribution. It can create fear and distance but the students might also feel properly prepared for the exam.
4) Laissez-faire supervisor
    a. Appear to be more superficial and aims only at supporting the students' own ideas. Its strength lies in that the focus is on motivating the students and letting them set the pace and direction.

3.3 Levels of expertise as a supervisor

Each of the above mentioned seven supervisor roles can be performed at various levels of expertise. Dreyfus and Dreyfus (1986) describe five levels as novice, advanced beginner, competence, proficiency, and expert. In general, experts are more autonomous, flexible, and responsive to the context in their actions, while novices are more guided by rules and models devoid of context. We anticipate that the three assistant professors are all at the level of novices or advanced beginners, but it is essential for our study to explore the exact nature of their level and understanding of the role of the supervisor. Therefore, to describe what kinds of knowledge our cases are able to demonstrate, we use Biggs' (2003) model of four types of knowledge (declarative, procedural, conditional, functional).

1) Declarative:
    a. Knowledge acquired by reading and listening
    b. This knowledge is seen in the person's ability to declare it (back)
2) Procedural:
    a. Skills, i.e. knowing what to do and in which order, in given circumstances
    b. This knowledge is seen through observing how a person acts in given circumstances
3) Conditional:
    a. Includes declarative and procedural knowledge. Conditional means knowing when and why to do which types of actions
    b. This knowledge is seen through a mix of observation and interview of a person in given circumstances
4) Functional:
    a. Includes declarative, procedural, and conditional knowledge. A sophisticated level of know-how, akin to phronesis and professional mastering

b. This knowledge is seen through a mix of observation and interview of a person in a wide range of circumstances, including circumstances of a complex nature.

In order to get knowledge of what level the three assistant professors are at, we therefore need to both interview and observe them.

4 Study design and methods

As mentioned earlier, this paper is part of a wider study; and this wider study is made up of four phases. The four phases are depicted below. The initial question is addressed through the first two phases, whereas the second research question is addressed through the last two phases. In order to give the context for the results reported through this paper we will briefly go through all phases in the following.

Phase 1: Interview

Phase 2: Observation

Baseline test

Phase 3: Intervention

Phase 4: Observation of change + interview

Phase one consists of interviewing the three assistant professors in order to get a prior understanding of their perspective on problem based learning and facilitation of group work. In phase two we will observe the way the three assistant professors carry out group supervision. This will be done after the paper deadline, but before the conference and thereby be part of our presentation. Phase one and two result in data by which we will be able to create a baseline consisting of the understanding and approach of the three assistant professors. In phase three we will undertake different interventions according to the challenges we uncover in the baseline test. This could be done either in a workshop or a more individual tutoring session. In the fourth and final phase we observe their practice again to see if and what kind of changes the interventions have initiated. This phase will also include interviews to determine their level of knowledge.

Both authors act as pedagogical supervisors at the AAU teacher training course and this year we both supervise five assistant professors in 2015. Three of our 10 assistant professors matched our criteria and they all said yes to participate. The three assistant professors are therefore chosen in a mix of convenience and random sampling and for rather practical reasons among our own trainee students. They are from two different fields: Department of Mechanical and Manufacturing Engineering (two participants) and Department of Civil Engineering (one participant). The number of three assistant professors is suitable to be able to get some range of data and at the same time have enough time to get into depth with all three of them. However, this is only suitable for a pilot study such as ours. In future work, it would be beneficial with a larger sample.

For the first two phases we used the methods of document analysis, interviews and observation in order to determine the baseline for our three assistant professors. We began by searching the AAU web page in order to get various facts about their background. Then we invited all three for a focus group interview. Focus groups are particularly useful when one wants to study how a specific group experience a situation, like being new to a PBL environment (Albrecht et al., 1993) and the fact that the three assistant professors are not all known to each other in advance, is useful when we want them to talk about their taken-for-granted assumptions (Morgan, 1998).

The interview guide was informed by our theoretical approach and includes questions about prior supervision experience, pedagogical training for supervisors, own experience being supervised, how they characterize a good supervisor, knowledge of PBL, etc. The guide was emailed to the participants before the interview. Our focus group interview guide can be found in the appendix. The focus group interview was recorded as an audio file and a summary of important impressions and themes to pick up on were written down immediately after the interview by both authors of the paper. Participants were later asked to comment on, and validate quotes, which were central to the discussion (Olsen & Pedersen, 1997). To ensure a level of triangulation in the analysis of the data, we heard a large part of the audio recording together and discussed the interpretation of utterances.

In the following the results of the focus group interview are presented and discussed.

5 Baseline test results

5.1 Background of the three assistant professors

All three assistant professors come from southern or eastern part of Europe and have done their Masters outside of Denmark. However, one (Assistant Professor 1; AP1) did one semester (½ year) at AAU as an Erasmus student and have thus tried out the Aalborg PBL Model. None of them have tried PBL at the university where they did their first degree. All three of them describe the teaching at their Master's educations as quite traditional teaching with lectures in combination with exercises or workshops. They have all tried out minor projects, but not in groups and not "PBL-like". Those projects were always individual, with most of the relevant literature available and they did not receive AAU-type supervision in those projects. Instead they could go and ask the lecturers for academic help if needed; asking e.g. for relevant literature or posing questions of academic nature. AP1 had a little experience with the group work as an Erasmus student, thus getting a little insight into how it is to be a student at AAU. His main experience compared to earlier on in his studies is the length of the projects and how to take proper leadership of that time. In his words: "You have quite much time and how do you handle it?" (AP1).

All of them did their PhD at AAU. AP1 finished his PhD in 2014, AP2 in 2013, and AP3 in 2012. Since finishing their PhD, all of them have been employed at AAU. In this sense, they are not *completely* new to the AAU PBL Model. However, given the fact that they have all just begun the assistant professor teacher training, and the fact that they themselves told us that how to supervise is not something that is generally discussed among the colleagues, we anticipate that they are still so new to the AAU PBL Model that we expect them to have different challenges than students who did their Master at AAU. This is also supported by the comments of the assistant professors. For instance AP2 states the following: "The Danes have an advantage because they tried it out themselves" (63 min). AP1 during the same discussion states that: "You also need to understand how a group works in order to be able to supervise it" (63 min).

5.2 Type of knowledge production wanted

In this section we analyse their understanding of PBL and what type of knowledge production they see themselves facilitating including if they see their role as that of a professional sparring partner, a project leader, or being an all-round facilitator.

They all understand the basics about PBL and are positive towards it, especially the fact that working with problems initiate learning about *how* to *apply* scientific knowledge not just know it. At the same time they recognize that the exemplary approach and deep learning also can lead to gaps in basic knowledge, which they see as a setback of the PBL approach. In the end they believe it is all very much about finding a proper *balance* between the two types of knowledge production – discipline based and problem based knowledge production.

As defined above in the theoretical part of this paper, team work is the second realm of the AAU supervisor role. They all appreciate this part of PBL as a good thing. AP2 also stated the following concerning 'good groups': "The team thing is very good. If you give them a little bit of material, they can just work, especially with these specialities [Master thesis]" (AP2, 18 min). On the other hand the possibility of hiding out in a group and being less motivated due to the fact that you are not responsible as an individual also seems to them to be a challenge of the PBL approach. As AP3 puts it: "You cannot force anyone, if they are lazy, they are lazy." (21 min)

In terms of SDL – the third pillar of the facilitation realms – the three assistant professors are a little hesitant or even without awareness of this realm. Especially the two of them that did not encounter a year as Erasmus students.

All three of them argue to possess a mix of the three supervision roles: a professional sparring partner, a project leader, and an all-round facilitator, but mainly the two first; what you might also refer to as academic and 'industrial pruned' supervision respectively. On own initiative to interfere in the group's planning, collaboration, knowledge sharing and other such skills from the third pillar of the facilitation realms was not considered proper. It is something the students should be able to manage themselves or at least discussion of such issues should be on the students' initiative. Hence it is not the role of the assistant professors to assist in developing "soft PBL competencies", but they are more than willing to make themselves available for questions relating to the discipline and they find that it is their job to interfere here.

However, they also discussed that there might be different ways of being a supervisor: "I am sure that there are different ways of looking upon supervision in the division where I am sitting" (AP1) and AP3 (14 min) states that her environment "probably combine the academic with the industrial approach; most of the projects are with a company. It happened that I had a censor [external examiner] who said it was too industrial". This was followed by AP2 stating: "It's a mix in my environment" and AP1 stating: "A mix, but semester based, more than it is person based – sometimes it is more academic, sometimes more industrial. It depends – on the last semesters it might be more related to the companies, whereas the first semester Master is more academic".

5.3 What is good supervision and how is it achieved at best?

We asked them indirectly about the four supervision types.

Laissez-faire: They only use this approach to a minor extent. AP2 thinks a supervisor should be available and interfere when there are problems, take initiative, not just wait for them to come to him. They all appear to agree with the statement of AP2: "Not loose, controllable loose" (34 min). However, AP3 appeared to be a bit laissez faire as she stated that at this age they are mature so she will only interfere if they come to her with a problem with their collaboration. She would not on own initiative check how the process is.

Product: They all have a rather large focus on the report. They will edit grammar also (AP3), but if there are too many they will ask the students to generally look at the grammar themselves. They are all willing to read drafts of the same chapter several times. AP1 states that "I think it is quite important the reporting phase, … It is the task of the supervisor to help them structure the project" (40 min).

Process-product: Generally they have an understanding of that it is ok when students do not end up having a product that is working as long as they know why it is not working and have learnt a lot. But this also depends on which state they are at in the education, the project and the level of difficulty. It is more acceptable for first year of Master's level than last year.

Control: They did not appear to be much control-supervisors. The general view was that this is towards the end at the exam.

Towards the end of the interview, they were asked to say a few keywords as to how a good supervisor is. They stressed the following: availability, flexible/be able to adapt to different students and situations, be able to read the students. They also stated that besides being available, they should keep the students motivated and the supervisor should be consistent and not change his mind all the time.

5.4 Level of expertise

None of them had experience discussing their supervision with others as earlier touched upon. Only when they experience a problem, do they go and ask a colleague. None of them have observed their colleagues supervise. Therefore they did not have any particular idea of how their "home breed" colleagues who have studied at AAU themselves supervise and how it may be different from their own approach.

All three of them had very little, or no experience, supervising groups. AP1, however, shared an experience with a group of 7-semesters students who came from outside AAU and who were not able at all to work in groups and collaborate. They had to interfere. He told that this was much different from the year before where he had had students who all knew how to work in groups. AP1 also appeared to be more articulate about his views. One might term him as an advanced beginner while AP2 and AP3 were complete novices. In fact AP3 explained that she had no experience supervising groups and that some of the view point she shared was based on things she expected would happen, or expected she would do in certain circumstances.

6 Discussion and conclusion

Given the fact that we only have a small sample of cases, the conclusions are only tentative. Furthermore, the choice of theoretical framework might also have affected the conclusions since other frameworks might have illuminated other factors. Taken this into account, the three assistant professors seem to have declarative knowledge about what PBL is, as they are able to describe and discuss it to some extent. To see whether they have procedural and conditional knowledge we will have to observe them. Functional knowledge will acquire different observations. In terms of supervision, we can only assess declarative knowledge in an interview. Regarding their "start position" in the "handcraftsmanship" of being a supervisor they are not very much control-supervisors but quite a bit process and product. They are laissez-faire when it comes to issues of collaboration and project management, but not in relation to scientific questions. Here they are more product oriented.

All three of the assistant professors emphasized that the main factor for the success of the group was the group itself; the supervisor was not that important. In one way, we can argue that this fits well with the Aalborg PBL Model where the students are the ones with the main responsibility for their own learning. On the other hand, it is also striking that they do not realize the great impact they can have on a group – given that the group understands how to use the supervisor. This is probably an outcome of their background not being focused on issues like problem solving, project management and communication in the AAU sense and it also explains their lack of awareness on these soft PBL skills. It might also have some explanatory power in terms of them being more of an academic or even an industrial supervisor. No matter the reasons why; the area of soft PBL skills is definitely an area worth looking into in terms of training them as supervisors.

Another area of interest in terms of training is the lack of peer supervision. They had an idea that supervision is both individual (each has his own way) and contextual in the sense that it also depends on culture, academic environments and experience and time of the education, but it was not anything that they used proactively as a learning resource. Asked about the supervisory approach of their academic environment they had quite vague ideas about this. Judging from the statements of our three assistant professors this might also be a sign of the "homebred" assistant professors, but at least this group of coming supervisors has a tacit knowledge about group supervision owing to their own experiences. However, both groups of assistant professors benefit from being more explicit about supervision challenges in a peer context.

In the motivation for the study, we argued that we anticipate that the difference in PBL experience of completely new assistant professors compared to "home breed" ones creates particular challenges for the former. To determine if this is the case would require also researching a large group of "home breeds", including researching a lot more new assistant professors in order to do a real comparison. We have not researched this and we argue that it is likely that also home breed assistant professors might feel challenged in the areas mentioned above. The fact that they might be less challenged does not alter the fact that the new assistant professors experience a challenge, and we need to do something about it. What further makes the matter more complicated is that AAU does not have a specific supervisor type that is the "right one". In terms of future work, it is interesting that the areas where they feel they need more knowledge (how a group works, ask questions) is also the areas where they at this point appear more passive. In the future study we will emphasise that they get more understanding of these issues and then it would be interesting to see if they later chance their views on these areas.

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Appendix: Interview guide on expectations and understandings of PBL group supervision

Background facts

- What did you study?
- Where did you study?
- What type of teaching and supervision have you received?
- What type of teaching experience do you have?

Knowledge and attitude towards PBL

- What do you know about PBL? Where do you know it from?
- Why did you take the job at AAU? Because of PBL or despite of PBL? Or none.
- Any thoughts about how it may fit your subject area?
- What are the main differences – if any – between the way you've been supervised and the way you are supposed to supervise here?

Knowledge, experience, and attitudes towards supervision

- Have you supervised before? How, when?
- Are you looking forward to be a supervisor at AAU?
- What is the ideal supervisor like? If such exist
- Is supervision at a PBL university different or much the same as other universities?
- What is the supervisor's role towards the report the students do?

- What is the supervisor's role towards checking the students' individual knowledge during the process versus being a professional sparring partner?
- How active should the supervisor be with the students; should he in some circumstance take over as project leader?
- What role should the supervisor take if the students appear to be going in a wrong direction?
- Should a supervisor be involved in all aspects of the process?
- Give examples of situations where different types of supervision are needed?
- What type of knowledge and skills about supervision at a PBL university do you feel is most important to you at this moment in your career?
- What kind of supervision do you see your colleagues do? What is important to them you think?

Problem Based Learning in the Conceptual Design of Hybrid Electric Vehicles

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Abstract

While traditional lecturing methods are an excellent method for providing fundamental knowledge to students, courses related to engineering capstone design of modern vehicles lack the means to provide students the fast evolving knowledge related to the electronics, controls, mechatronics, and vehicle communication of electric, hybrid electric and fuel cell vehicles. One of the solutions to address this issue is delivering a course using a problem-based inquiry approach. Problem-based learning is a powerful educational method that allows learners to develop problem solving skills while working towards solving a problem. Students actively engaged in the learning process provide superior learning outcomes. This paper presents a problem-based learning methodology applied to an engineering topic, analyses student engagement, compares the effectiveness of a whole-course PBL model with a hybrid-PBL delivery model of the same course, and provides a qualitative analysis of the benefits provided by the PBL approach.

Keywords: Curriculum design, PBL implementation, PBL model and approaches, PBL process and student engagement, Higher education

1 Introduction

Problem-based learning (PBL) is an efficient method that facilitates the development of self-directed learning skills by working in groups through a structured problem solving strategy. Although the method has been criticized by a lower level acquisition of knowledge, published literature has shown that compared to the traditional lecturing approach, the learning outcomes provided by PBL are superior. Studies have shown that students enjoy participating in many forms of active learning strategies and have a stronger understanding of the concepts. Since the initial successful development in the 1070s by the medical educators, PBL has been since adopted by a wide variety of universities due to the reported superiority of PBL trained learners in life-long learning.

The effectiveness of the problem based learning approach is disputed in the published literature. While some authors advocate for the superiority of the traditional teacher-centred approach based on direct guided instruction (Mayer 2004, Kirschner et al, 2006), other suggest that student-centred inquiry based approaches like problem based learning (Barrows & Tamblyn, 1980) (Woods, 1984) (Barrows, 1986) (Biggs, 2003) and teaching approaches with a strong experiential learning content (Kolb, Boyatzis, & Mainemelis, 2011), (Kolb 2015) encourage deep learning and provide superior learning outcomes.

Considered by some authors as “the most significant innovation in education for the profession for many years” (Bond & Feletti, 1999), PBL has its strengths and limitation. On the other hand, today’s explosion in information and technology creates challenges for the traditional intensive lecturing approach. The controversy related to the best teaching and learning approach will probably exist for a long time.

Although the number of courses taught in traditional ways outnumbers by far the number of course taught with non-traditional approaches, an increasing number of faculty members deliver courses using the PBL approach and publish their experience. One of the reasons of this trend is a shifting of the instructor's intentions from "teaching" to "teaching & learning". In the minds of some of these instructors, the question "what should I do to deliver an exceptional lecture" is often substituted by "what should I do to offer the best learning experience".

2 The problem

Universities with automotive programs perform many research activities related to state-of-the-art technologies for modern vehicles. The automotive industry adopts every year new solutions for building electric and hybrid vehicles. The knowledge in this field evolves every year. Preparing graduates for such a fast evolving industry is a difficult task.

The conceptual design of a vehicle requires an amount of information that cannot be taught in a single course using a traditional lecture-intensive approach. To ensure that students learn the rapidly evolving knowledge, they are encouraged to perform many inquiry-based and problem-solving activities. PBL is an approach that allows students to perform these activities. Students involved in a course that delivers engineering concepts through PBL are required to use engineering design and analysis methods that have been taught in previous courses. They are also expected to search, identify and read relevant published research related to the design of modern vehicles, and they are required to browse through automotive magazines to be aware of the current industry trends. This paper presents the implementation of PBL in a fourth-year course related to the conceptual design of electric and hybrid electric vehicles.

3 Curriculum design

In conventional problem-solving learning, students are first taught the knowledge and then are asked to solve a problem. With a fundamentally different approach, PBL allows students to acquire knowledge and gain skills through a sequence of problems, learning materials, inquiries, and other active learning activities facilitated by the course instructor.

The course described in this paper is delivered in a classroom environment to full-time students enrolled in the last semester of an Automotive and Vehicle Technology (AVT) program. To reach this stage of their undergraduate university education students have acquired knowledge related to engineering design and analyses, electronics, controls, mechatronics, management, and gained one year of relevant industrial experience through full-time co-op employment. The Conceptual Design of Electric and Hybrid Vehicles course, initially offered with a hybrid PBL approach, is currently offered using a full-PBL strategy.

The acceptance of a new teaching strategy is an important concern for any instructor. The course described in this paper is the only PBL course offered to the AVT program. The students were informed of the course expectations, the specific knowledge taught in previous courses that is vital for the success of their work, the anticipated amount and type of weekly effort, the expected leadership roles, and the recommended collaboration and group work. Although initially received with hesitation, the students enrolled in the course accepted after two to three weeks PBL as a learning method. The acceptance of the PBL approach constantly increased during the course after the weekly presentations. Many students were proud of their accomplishments, received well the class feedback and suggestions that followed the presentations, and argued with evidence to support their engineering decisions.

The effectiveness of the course curriculum is analysed through the understanding, knowledge, and skills gained in different stages of the course, and through the achievement of the learning outcomes. To be an effective course, the problems that the students are required to explore need to use a combination of previously taught and new knowledge, but also need to be interesting enough to trigger students' willingness to explore modern ideas. For instance, most students excelled in presenting futuristic smart-phone controlled user interfaces between the driver and the vehicle, but showed less interest towards the more traditional problem related to the conceptual design of the vehicle powertrain.

The achievement of the learning outcomes can be analysed through course assessments. The course presented in this paper includes individual presentations, weekly group reports, a final presentation, and a final report. The final presentation is considered by students as the most important assessment because it is a competition between groups. The competition is judged by a panel that includes engineering managers from major automotive related companies, and faculty members whose main research is related to electric and hybrid vehicles. Presenting their designs in front of possible future managers gave students a willingness to show their accomplishments but also created a certain level of fear as they expected to be asked questions by knowledgeable people not related to the course. This combination of fear and willingness to impress was one of the key factors in preparing good conceptual designs. The score cards used for the presentations were based on the expected learning outcomes, and the score given by judges is an important test of achieving the learning outcomes.

4 Methodology

One of the aims of the course is to develop intellectual, effective and social skills. The intellectual skills are developed through the subject-specific academic work. The affective skills are developed through group work, while the social skills are developed through group communication and through individual and group presentations.

Groups or four students were selected by the course instructor in a strict alphabetic order. Used to work with groups based on friendship, some students experienced different emotions when group members of different academic levels had to collaborate. Other groups ended up with more than one student with very strong personalities that lead to animosities. Ultimately, most students managed to control their affective behaviour as they understood that the purpose of imposed group members is to mimic real-life work expectations after graduation.

The academic goal of the course is to develop subject-specific knowledge by preparing several conceptual design of electric or hybrid vehicle used for rental purposes. Groups of students are expected to prepare a report and to present their concepts in front of a panel of judges. Students develop communication skills by competing for the best design approach.

There were 40 students enrolled in the last offering of the course. Five of the 10 groups of four students were required to prepare conceptual design of electric vehicles, while the work of the other five groups of four students was related to hybrid electric vehicles. The conceptual designs are developed through eight problems. A problem, generally analysed for a week, includes group-work in a classroom environment facilitated by the course instructor, inquiry based group work outside the classroom, report writing, and weekly presentations. All 40 students are expected to attend the presentations and to provide feedback.

To develop group management skills, each student acts twice during the length of the course as group manager. He/she is expected to conduct the initial brainstorming exercise, to take notes of the discussions, to facilitate reaching a consensus on the approach that will be developed, to divide the work between the other three group members, to lead the discussions outside the classroom, to assign academic tasks, to collect the partial reports from the group members, to assemble a weekly report, and to present and defend the report in front of the class. On top of developing managerial skills, this approach is also effective in developing social, collaborative, and communication skills.

The problem topics that students are expected to address are provided in the following order: system specifications and performances; market research (two weeks); propulsion system and transmission; electrical electronic and control systems; user control systems; materials, manufacturing and mechanical systems; emissions, environmental control, and sustainability. The major elements that need to be addressed by each problem are presented to the students at the beginning of each week. Although students are expected to cover all these problems, each group is allowed to address each problem in its own way. Modern and innovative approaches are encouraged as, according to the goal of the design, the vehicles supposed to be built with the suggested conceptual designs would be on the market only in 3 to 5 years.

For each problem every group is required to prepare a written report and a PowerPoint presentation. These weekly deliverables are submitted for marking. However, to ensure a fair competition between teams, only the first four problems are presented to the entire class. The academic load of the course is constant through the semester. Every week students are expected to perform group collaboration and submit their work to the group manager that depends on their deliverables. Furthermore, each student acts twice as a manager whose deliverables depend on the work done by the group members. Being twice a group manager and being six times a group member whose work is important for the weekly group deliverables creates a feeling of importance that increases both course attendance and student engagement.

In the PBL approach implemented in this course students learn in multiple ways. The initial weekly group brainstorming sessions address their general knowledge and encourage them to learn the topics and ideas presented by the group members. Students tackle each problem by performing inquiries, reading the knowledge taught in several previous courses, and making connections between the knowledge taught in these courses. One of the academic advantages of any capstone project is connecting the dots – a synthesis that can only be applied towards the end of the academic studies. Furthermore, student also learn through self-reflection after the weekly presentations when the facilitator encourages each group to defend its product but also encourages students to ask questions and provide feedback.

Instead of delivering lectures, the course instructor acts as a facilitator for the brainstorming activities and for the group work conducted in the classroom. The role of the facilitator is to divide the course curriculum into topics that cover separate systems that require the same time to solve, to convert these topics into problems that are both challenging and attractive, to describe the goal of each problem, to provide guidance when students' approaches diverge from the given problem, and to provide feedback and suggestions for improvement after each presentation and after each weekly report. Moreover, the facilitator is expected to motivate students to hope for success, and to provide a challenging but rewarding learning experience.

5 Results

The goal of this study was to compare the effectiveness of two PBL models and to identify the benefits of the PBL approach compared with a traditional lecture-intensive approach.

The curriculum of a PBL course incorporates a range of teaching strategies and active learning activities, and requires a rigorous planning of the problem-based group discussions, presentations, and deliverables. Delivering such a course for the first time using a full-PBL approach is risky. One strategy is to deliver the course in a hybrid mode by combining PBL activities with classical lecture-based course delivery.

The course presented in this paper was first delivered using a hybrid-PLB model. After gaining confidence in the PBL approach the instructor delivered the course using a full-PBL model. A comparison between the two delivery models indicates that the overall course grade for the full-PBL course was with 8% higher. The difference is not significant and therefore it is not possible to assume that the increase in the overall average grade of this course is due only to the use of a full-PBL model. This small difference does not indicate that the full-PBL model is more effective and provides superior results for this course than a hybrid-PBL model.

It is very difficult to assess the effectiveness of the PLB approach using only quantitative means. To address this concern a qualitative comparison between the PBL approach and the traditional course-delivery approach was performed using three sources: comments included in the student evaluations of the PBL course, discussion with the graduates of the AVT program who took 45 courses delivered with a traditional approach and one PBL course, and the feedback provided by industry managers who judged the PBL course. A summary of these comments and remarks indicate that:

- Students considered the PBL approach very effective in synthesizing key knowledge taken from previous courses and from the published literature that was considered relevant by them and not by the course instructor
- Students enjoyed the open-ended approach and the freedom to design and defend modern solutions (i.e. vehicle-to-vehicle and vehicle-to-system communication)
- The graduates appreciated the leadership roles in conduction brainstorming activities and preparing reports and presentations, and compared them with their current duties
- The panel of engineering managers from the automotive-related industry who judged the final designs noticed the innovative ideas developed through the PBL approach

The feedback provided by judges, students, and graduates combined with the level of achievement of the learning outcomes provide encouragement and support in continuing to deliver the course described in this paper using the PLB approach.

6 Conclusion

Due to the rapidly evolving knowledge and approaches related to modern vehicles, it is difficult to deliver a lecture-intensive course related to the conceptual design of electric and hybrid vehicles. Furthermore, it is difficult teach in a course the knowledge required to develop a conceptual design of a vehicle. This paper presents a problem based learning approach that addresses these concerns. It presents an implementation of a course offered in the last semester of a four year automotive program, describes the methodology of delivering a student-centred course, and describes the skills gained by student through the PBL approach.

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A Problem-Based Learning Approach of Teaching Mathematics to Media Technology Students Using a Game Engine

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Abstract

In this article, we present our idea of using a game engine (Unity) to teach Media Technology students mathematics-related concepts. In order to observe how the introduction of a technological tool, namely the game engine, changes the practices in mathematical work, we adopted the anthropological approach in didactics. This theoretical framework defines the "atoms" of mathematical practice and discourse in terms of tasks, techniques, technologies and theories. We present a didactical scenario when Unity is used for introducing the calculation of reflection and refraction vectors and then we use the anthropological approach to present the practices in calculating these vectors with traditional mathematics and constructing them in Unity. Then, we discuss the differences between the two cases, when we argue that Unity can benefit Media Technology students, who use mathematics as a tool. However, the assumptions on the mathematical practice while using Unity will have to be confirmed in actual educational settings.

Keywords: mathematics education, game engine, problem-based learning, the anthropological approach, media technology

1 Introduction

Over the past years, engineering education has been challenged to embed creativity and innovation, in order to produce graduates who can easily adapt to societal changes (Badran, 2007; Jørgensen & Busk Kofoed, 2007; Zhou, 2012). As a result, a number of engineering programs have arisen that transcend the division between technical, scientific and creative disciplines. The teaching of mathematics to students of such disciplines represents a challenge to the education system because these disciplines are typically constructed in specific opposition to technology and science. This paper emerges from our research that explores the teaching of mathematics in such an engineering discipline, namely the Media Technology program at Aalborg University (Triantafyllou & Timcenko, 2013).

Regarding mathematical education in traditional engineering studies, it has been found that engineering students often have difficulties with understanding the mathematical concepts due to their lack of fundamental understanding of difficult concepts or due to their inability to perform deductive reasoning (Morgan, 1990). Moreover, it has been found that the conceptions of mathematical concepts are different for engineering students from those of mathematics students (Maull & Berry, 2000), and that engineering students see mathematics as a tool, and therefore wish to see the application side as part of the course (Bingolbali, Monaghan, & Roper, 2007). In our own research, we have confirmed the aforementioned findings for Media Technology students and we have also found that these students are reluctant to use technology in mathematics, since they believe that it adds to the complexity of such courses (Triantafyllou & Timcenko, 2014).

Inspired by the constructivist aspects of Problem-Based Learning, which Aalborg University applies to all its programs (Barge, 2010), we came up with the idea of substituting traditional mathematics assignments with mini-projects in a game engine (Unity). The main concept of this approach is that students get simple projects in Unity, where mathematics is used for game mechanics and they have to modify or further develop these projects. With this approach, we aimed at changing the mathematical practice of these students, by relating it with tangible objects in a virtual world. We chose Unity, since Media Technology students are familiar with it, and we wanted to avoid the learning effort of employing a new tool. In the following, we present a theoretical framework for analysing and comparing the practices when traditional mathematics and Unity is employed. Then, we present an example of a didactical scenario, where Unity is used for introducing light reflection and refraction to Media Technology students. We conclude that Unity offers new possibilities for such students, who wish to see the application part of mathematics.

2 Background

Using a game engine for mathematical assignments involves students programming for solving these assignments. The idea that programming could be used to develop or enforce mathematical ideas is not new. Based on constructivism, Seymour Papert developed the programming language LOGO, where children can guide a small turtle around the screen. The turtle leaves a trace while moving around, allowing the child to create various geometrical figures (Papert, 1980). His suggestion was that children learn in a particularly efficient way when they are engaged in developing constructs such as beautiful patterns, interactive art, etc. Papert described LOGO as a “mathematical microworld” that allows children to engage in such projects. During the 1980s, there was great enthusiasm and confidence that LOGO and similar programming languages would radically reform mathematics teaching in primary schools. However, the results in mainstream implementation did not entirely live up to the expectations. There are a number of reasons for the disappointing results; for instance, students easily overlook the nuggets of mathematical knowledge, making their work in the microworld non-mathematical (Ainley, Pratt, & Hansen, 2006; Hoyles & Noss, 1992).

The idea that programming could be helpful in mathematics education in the late 1980s was also developed in the context of teaching mathematics at high school and college. Here the geometric and artistically framed LOGO program was less popular. On the contrary, teachers often utilized common programming languages such as BASIC, COMAL and PASCAL to support learning. One of the outspoken hopes was to create a process-oriented approach to abstract mathematics, basing abstract constructions in concrete numerical computations. Ed Dubinsky’s work is probably the clearest description of the learning potential of programming (Breidenbach, Dubinsky, Hawks, & Nichols, 1992). His theoretical framework describes mathematical concept formation as beginning with performing actions on well-understood mathematical objects; these actions can be organized in processes and encapsulated into objects. These objects can be related to one another in schemas. This theoretical framework of mathematical concept formation was applied to improve the development of the process conception of function for university students and uses computers for empowering and enriching the concrete numerical calculations that are the necessary foundation for concept formation.

During the last years, digital games have been applied in many educational fields to enhance learning motivation (Prensky, 2001). Since game environments or engines allow users to customize their gaming experiences by building and expanding game behaviour, games offer new directions in relation to learning mathematics by programming, which have not been extensively explored. El-Nasr and Smith have proposed the use of modifying, or modding, existing games as a means to learn computer science, mathematics, physics, and aesthetic principles (El-Nasr & Smith, 2006). In two exploratory case studies, they presented skills learned by students as a result of modding existing games and they discussed the benefits of learning computer sciences skills, among others 3D graphics and mathematics. However, the literature has yet to discuss if and how programming in games can contribute to meaningful mathematics learning.

3 Theoretical Framework

The tools that we choose to bring to mathematics students do influence the learning of mathematics that becomes likely or possible (Ainley et al., 2006; Guin, Ruthven, & Trouche, 2006). And in that sense bringing programming into mathematics teaching does support certain types of learning. In order to observe these types of learning, we adopt the theoretical frameworks adopted and developed by Artigue (Artigue, 2002), namely the anthropological approach in didactics initiated by Chevallard (Chevallard, 1990), and the theory of instrumentation developed in cognitive ergonomics (Verillon & Rabardel, 1995).

3.1 Then anthropological approach in didactics

The anthropological approach in didactics provides tools to model mathematical and didactical knowledge (Winsløw, 2012). This didactical theory views mathematics as the product of a human activity. Therefore, mathematical productions are framed by the social and cultural contexts where they develop and mathematical objects are entities which arise from the practices of given institutions (Artigue, 2002). These practices, also called "praxeologies", as described by Artigue, have four components: "…a type of task in which the object is embedded; the techniques used to solve this type of task; the "technology", that is to say the discourse which is used in order to both explain and justify these techniques; and the "theory" which provides a structural basis for the technological discourse itself and can be seen as a technology of the technology." (Artigue, 2002) Winsløw mentions that the tasks and the techniques define each other and calls the couple of a task and a technique as a practical block – the minimal entity of practical knowledge. Technologies explain how to apply and distinguish a whole set of techniques. At a higher level of discourse, technologies are developed, explained, related and justified in and by a theory (Winsløw, 2012). For a given set of practical blocks, we can define the theoretical block, which is formed by a technology and a theory. The anthropological approach describes the mathematical activity using the practical and the theoretical discourse. However, when a technique becomes routine in an institution, it tends to lose its connection to the theoretical discourse and becomes a simple, "de-mathematicised" act. Therefore, this approach helps to observe the changes that happen when technological tools are inserted into mathematical learning, since it offers a framework to observe if and how the practical and the conceptual work are interrelated.

3.2 The instrumental approach

The instrumental approach addresses students' use of technology when learning mathematics from the perspective of appropriating digital tools for solving mathematical tasks (Guin et al., 2006). It views computational artifacts as mediating between user and goal (Rabardel & Bourmaud, 2003). It is an important aspect of this conceptualization that humans have goals on various levels, and hence that the goal of smaller actions can feed into larger plans (Nardi, 1996). Furthermore the approach presupposes a continuation and dialectic between design and use, in the sense that a pupil's goal-directed activity is shaped by his use of a tool (this process is often referred to as instrumentation), and simultaneously the goal-directed activity of the pupil reshapes the tool (this process is often referred to as instrumentalization). In students' work with technology the distinction between epistemic mediations and pragmatic mediations operationalize the difference between learning with technology and just using technology to solve tasks (Guin et al., 2006; Rabardel & Bourmaud, 2003). Epistemic mediations relate to goals internal to the user—affecting his or her conception of, overview of, or knowledge about something and pragmatic mediations related to goals outside of the user—making a change in the world. Finally, Rabardel and Bourmaud introduce sensitivity to a broader conception of the orientation of the mediation. Instrumented mediations can be directed towards (a combination of) the objects of an activity (the solution of a task), other subjects (classmates, the teacher), and oneself (as a reflective or heuristic process). Hence the theoretical framework consists of the concepts: instrumental genesis, as consisting of instrumentation and instrumentalization, the concepts epistemic and pragmatic mediations, as well as sensitivity towards the orientation of an instrumented mediation. The orientation of the mediation can be towards oneself, external objects, and other subjects.

4 The didactical scenario - reflection and refraction vectors

In this article, we use a didactical scenario and we examine how praxeologies change from traditional instruction to instruction with the use of Unity. This didactical scenario concerns light reflection and refraction and is taken from the computer graphics rendering course of the fifth semester at the Media Technology bachelor program. We selected the specific scenario because it involves mathematical work that can be visually represented. In this context, Unity (or any game engine) can greatly contribute to user understanding since it offers visualisation and interaction possibilities.

The didactical scenario took place during one lecture. The lecture started with the mathematical reflection vector calculation (Figure 1). The teacher (one of the authors of this article) reminded the students of the fact that according to the law of reflection, the angle of incidence equals the angle of reflection, and she explained the calculation of the projection of one vector to another. Then, students were asked to think how to calculate the reflection vector based on this information. On the whiteboard, the teacher then solved together with student contributions an exercise on calculating the reflection vector, given the coordinates of the vector of the incoming light and the angle of incidence.

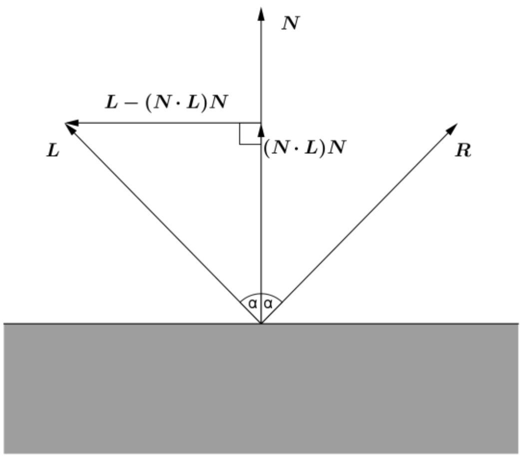

Figure 1: The direction of reflection **R** forms the same angle with the normal vector **N** as the direction **L** pointing toward the incoming light. It is found by subtracting twice the component of **L** that is perpendicular to **N** from **L** itself. (Lengyel, 2012)

Thereafter, the teacher calculation of refraction vector was explained by first introducing Snell's law, which describes the relationship between the angles of incidence and refraction, when referring to light or other waves passing through a boundary between two different isotropic media. Then, she went through the mathematical calculation of the refraction vector (Figure 2), and she discussed the conditions that invalidate the refraction formula and the physical phenomenon observed under these conditions (total internal reflection).

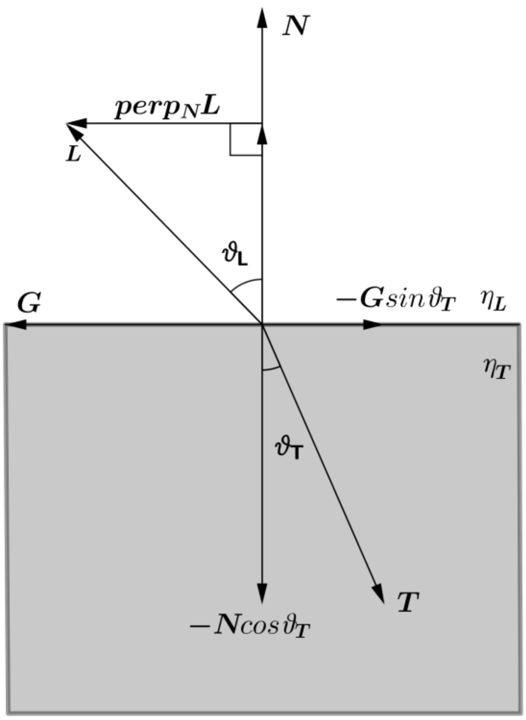

Figure 2: The angle of incidence **L** and the angle of transmission **T** are related by Snell's law. The refraction vector **T** is expressed in terms of its components parallel and perpendicular to the normal vector **N**. (Lengyel, 2012)

After these explanations, students were introduced to their homework, which it was given as a class activity (see Appendix). Students worked in their homework in class, but they could finish it and submit it up to ten days after the lecture. The homework involved using Unity for defining the reflection and refraction vectors, and gave the students the opportunity the formulas, which they were presented in class for changing game mechanics.

5 Calculation of reflection and refraction vectors using traditional mathematics and mathematics in Unity

In this section, we present the calculation of the reflection and the refraction vectors using traditional mathematics (as presented in students textbook) and using Unity. In order to understand the differences in mathematical practice in these two cases, we use the anthropological approach in didactics and describe the calculations in terms of theory, technologies, techniques and tasks involved.

5.1 Calculation of reflection vector

The task at hand here is to calculate the reflection vector **R**, given the direction **L** pointing toward the incoming light (Figure 1). This task has two steps (Table 1): the first is to use the dot product definition in order to calculate the projection of **L** to the normal direction **N** and then express the component of **L** that is perpendicular to the normal direction as the subtraction of two vectors, and the second is to express vector **R** as the subtraction between two other vectors.

For performing the aforementioned task, the techniques of the geometric definition of calculating the dot product and the definition of addition and subtraction of vectors in two dimensions are required. The task and techniques together form the practical block. The theoretical block consists of the technologies and the related theory. The technologies involved are the definition of the length of vectors, the definition of the dot product, the generic definition of addition and subtraction of vectors and the definition of unit vectors. The related theories are the law of reflection and vector spaces.

Table 1: Mathematical calculation of reflection vector

1) We first calculate the component of L that is perpendicular to the normal direction, as the subtraction of vector L and its projection on N (we use capital bold letters for the vectors): $$perp_N\boldsymbol{L} = \boldsymbol{L} - (\boldsymbol{N} \cdot \boldsymbol{L})\boldsymbol{N}$$ 2) The vector R lies at twice the distance from L as does its projection on the normal vector N. We can then express the vector R as: $$\boldsymbol{R} = 2(\boldsymbol{N} \cdot \boldsymbol{L})\boldsymbol{N} - \boldsymbol{L}$$

5.2 Construction of the reflection vector in Unity

When the reflection vector is constructed in Unity, the task is to graphically draw this vector by finding its direction from the reflection formula (Figure 3). In order to perform this task, the following techniques are required: normalization of vectors in Unity, calculation of the dot product of two 3D vectors in Unity, definition of vectors by two points (both in geometry and in Unity), and definition of rays by a point and a direction vector (both in geometry and in Unity).

The theoretical block in this case is very similar to the theoretical block of the mathematical calculation with the only addition of the definition of rays in the set of related technologies.

5.3 Calculation of refraction vector

The task is to calculate the direction of the refraction vector **T**, given the direction **L** pointing toward the incoming light (Figure 2). The angle of incidence **L** and the angle of transmission **T** are related by Snell's law. The task has five steps (Table 2).

The first step is to express the vector **G** in terms of the perpendicular part of vector **L** while the second is to express the refraction vector **T** in terms of its components parallel and perpendicular to the normal vector **N**. The following three steps aim at eliminating the trigonometric numbers in the refraction formula and replacing them with the refraction indices. The techniques to perform these steps include the geometric calculation of the dot product of vectors in 3D space, the addition and subtraction of vectors in 3D space, the decomposition of vectors in parallel and perpendicular components, the normalization of a vector, and using the fundamental trigonometric identity ($sin^2x + cos^2x = 1$) to replace $cosx$ with $sinx$ and vice versa.

The theoretical block contains the relevant technologies and theory. The technologies contain the definition of length of vectors, the definition of the dot product, the definition of addition and subtraction of vectors, the definition of unit vectors, the definition of sine and cosine, the decomposition of vectors in components, and the fundamental trigonometric identity. The theory, which is needed in order to perform the specific task, is the Snell's law, the Pythagoras' theorem, trigonometry and theory of vector spaces.

Table 2: Mathematical calculation of reflection vector

1) We express the vector **G** in terms of the perpendicular part of **L** on **N**:

$$\boldsymbol{G} = \frac{perp_N \boldsymbol{L}}{sin\theta_L} = \frac{\boldsymbol{L} - (\boldsymbol{N} \cdot \boldsymbol{L})\boldsymbol{N}}{sin\theta_L}$$

2) We then express the refraction vector **T** in terms of its components parallel and perpendicular to the normal vector:

$$\boldsymbol{T} = -\boldsymbol{N}cos\theta_T - \boldsymbol{G}sin\theta_T = -\boldsymbol{N}cos\theta_T - \frac{sin\theta_T}{sin\theta_L}[\boldsymbol{L} - (\boldsymbol{N} \cdot \boldsymbol{L})\boldsymbol{N}]$$

3) Using Snell's law, we can replace the quotient of sines with the quotient of refraction indices:

$$\boldsymbol{T} = -\boldsymbol{N}cos\theta_T - \frac{\eta_L}{\eta_T}[\boldsymbol{L} - (\boldsymbol{N} \cdot \boldsymbol{L})\boldsymbol{N}]$$

4) Using the fundamental identity and Snell's law:

$$\boldsymbol{T} = -\boldsymbol{N}\sqrt{1 - \frac{{\eta_L}^2}{{\eta_T}^2}sin^2\theta_L} - \frac{\eta_L}{\eta_T}[\boldsymbol{L} - (\boldsymbol{N} \cdot \boldsymbol{L})\boldsymbol{N}]$$

5) Replacing $sin^2\theta_L$ with $1 - cos^2\theta_L = 1 - (\boldsymbol{N} \cdot \boldsymbol{L})^2$ finally yields:

$$\boldsymbol{T} = \left(\frac{\eta_L}{\eta_T}\boldsymbol{N} \cdot \boldsymbol{L} - \sqrt{1 - \frac{{\eta_L}^2}{{\eta_T}^2}[1 - (\boldsymbol{N} \cdot \boldsymbol{L})^2]}\right)\boldsymbol{N} - \frac{\eta_L}{\eta_T}\boldsymbol{L}$$

5.4 Construction of the refraction vector in Unity

When the refraction vector is constructed in Unity, the task is to graphically draw this vector by finding its direction from the refraction formula (Figure 4). In order to perform this task, the following techniques are required: normalization of vectors in Unity, calculation of the dot product of two 3D vectors in Unity, definition of vectors by two points (both in geometry and in Unity), definition of rays by a point and a direction vector (both in geometry and in Unity) and calculation of the square root of a number.

The theoretical block in this case is very similar to the theoretical block of the mathematical calculation of refraction with the only addition of the definition of rays and the definition of the square root of a number in the set of related technologies.

6 Discussion

In the previous section, we have analysed the tasks, techniques, technologies and theories involved when calculating the reflection and the refraction vector using traditional mathematics and the Unity game engine. From this analysis, we can see that although the theoretical block remains almost the same, the practical knowledge needed for performing the same task using mathematics and Unity differs. Leaving aside the technical implementation aspects, the students have to consider how a mathematical formula is connected with game objects. For example, the direction of the vector **L** in the mathematical model is pointing toward the incoming light, while the ray in Unity representing the incoming light is drawn using a vector with the opposite direction. Therefore, the students have first to create a vector with the opposite direction as L, in order to be able to correctly apply the reflection and refraction formulas in Unity. Moreover, the students can see what these formulas define in the real world (i.e. direction of the reflected/refracted light).

Another aspect that comes up when working in Unity is the specificity of the refraction formula. This formula contains the square root of an expression. When working with this formula with pen and paper, students can easily ignore the fact that the expression under the square root cannot be negative. When this happens in Unity, there is an exception called, and the students can at least see that something is wrong in their program. Realizing that this formula cannot be applied when this happens is important for understanding, since this the condition for total internal reflection to happen. Students can also experiment with different values of the incident angle (since they have the opportunity to manually change the direction of the laser pen in Unity), in order to see for which angles the light is reflected instead of refracted.

Regarding the mathematical concepts involved, the calculation of the reflection and refraction vectors requires a higher level of mathematical discourse. However, we argue that this higher level of mathematical thinking is not necessarily important for Media Technology students. The construction of these vectors in Unity still calls for understanding of the basic related mathematical concepts (e.g. direction of involved vectors, angles, unity vector on a surface), leaving aside the procedure of forming the reflection and refraction formulas. Finally, Unity offers possibilities of interaction with and visualization of game objects, and verification of self-assumptions. Such possibilities can help exploring different conditions and how they affect the game objects and the observed physical phenomena.

Finally, the use of a game engine can support mathematical work where students generate actual objects (in a virtual world), interact with them, change their properties, and observe how different objects interact with each other. This approach in learning stems from a constructivist approach to learning and is well aligned with the PBL approach implemented at Aalborg University, Denmark. Therefore, we believe that it can also be used for other subjects (e.g. image processing, sound computing) for enhancing their PBL character.

7 Conclusion

In this article, we presented our idea of using a game engine (Unity) to teach Media Technology students mathematics-related concepts. In order to observe how the introduction of a technological tool, namely the game engine, changes the practices in mathematical work, we adopted the anthropological approach in didactics. This theoretical framework defines the “atoms” of mathematical practice and discourse in terms of tasks, techniques, technologies and theories (Winsløw, 2012). We presented a didactical scenario when Unity is used for introducing the calculation of reflection and refraction vectors and then we used the anthropological approach to present the practices in calculating these vectors with traditional mathematics and constructing them in Unity. Then, we discussed the differences between the two cases, when we argued that Unity can benefit Media Technology students, who use mathematics as a tool. However, the aforementioned assumptions on the mathematical practice while using Unity will have to be confirmed in actual educational settings. The instrumental approach presented in section 3.2 can be used to verify that this tool is used as intended and results in authentic epistemic mediations. We are currently performing observations and interviews with students at Media Technology in order to verify these assumptions. So far, student reaction to this new approach has been positive and anecdotal feedback shows that the PBL oriented approach is preferable from the traditional way of teaching mathematics.

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Appendix

Class activity on light reflection and refraction: Open the Unity project “Math”, which contains two scenes: the Reflection scene (Figure 3) and the Refraction scene (Figure 4). When in play mode, you can use your arrow keys to rotate the pen in space. Use your mouse scroll keys in order to zoom in and out in the scene and your left mouse key in order to rotate the camera (that means your own view on the scene).

Open the Reflection scene:

1. This scene contains a pen, which emits a beam of light. The beam of light is represented by a red line. In order to draw this line and its reflection on the plane (assume that the plane is a mirror, on which the light reflects), there is a script attached on the pen. Open the script in order to see the code.

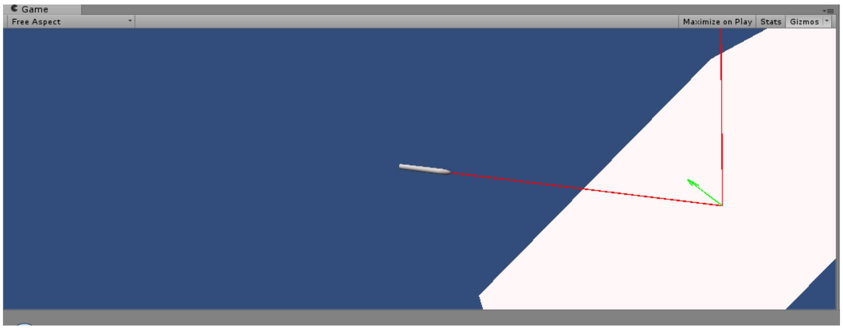

Figure 3: The reflection scene in Unity

2. The code uses the Unity method Reflect(); in order to calculate the direction of the reflected light. Delete this line of code (or make it a comment by adding // at the beginning of the line) and then calculate the direction of the reflected line by using the formula of the reflection:

$$\boldsymbol{R} = 2(\boldsymbol{N} \cdot \boldsymbol{L})\boldsymbol{N} - \boldsymbol{L}$$

3. Suppose (or actually try to do it!) that we substitute the plane with a rough surface (e.g. a terrain with mountains). What adjustments (if any) do you have to do in the code of the pen script for calculating the reflected line?

Open the Refraction scene:

1. This scene contains again a pen, which emits a beam of light. The beam of light is represented by a red line. In order to draw this line and its refraction on the plane (assume that the plane is the interface between two media, e.g. air and water), there is a script attached on the pen. Open the script in order to see the code.

2. Complete the code for drawing the refracted line, by using the formula of the refraction:

$$\boldsymbol{T} = \left(\frac{\eta_L}{\eta_T}\boldsymbol{N} \cdot \boldsymbol{L} - \sqrt{1 - \frac{{\eta_L}^2}{{\eta_T}^2}[1 - (\boldsymbol{N} \cdot \boldsymbol{L})^2]}\right)\boldsymbol{N} - \frac{\eta_L}{\eta_T}\boldsymbol{L}$$

Keep in mind that in some cases total internal reflection can happen instead of refraction!

3. What changes do you have to make in the scene/code if you want to change the materials (e.g. instead of air and water, water and glass)

4. What happens if $\eta_L < \eta_T$?

5. Solve the following exercise by hand and then verify your answer in Unity. In order to check if total internal reflection happens on the critical angle you calculated, print the value of the angle in the console when total internal reflection occurs. Use the command Debug.Log(); for printing.

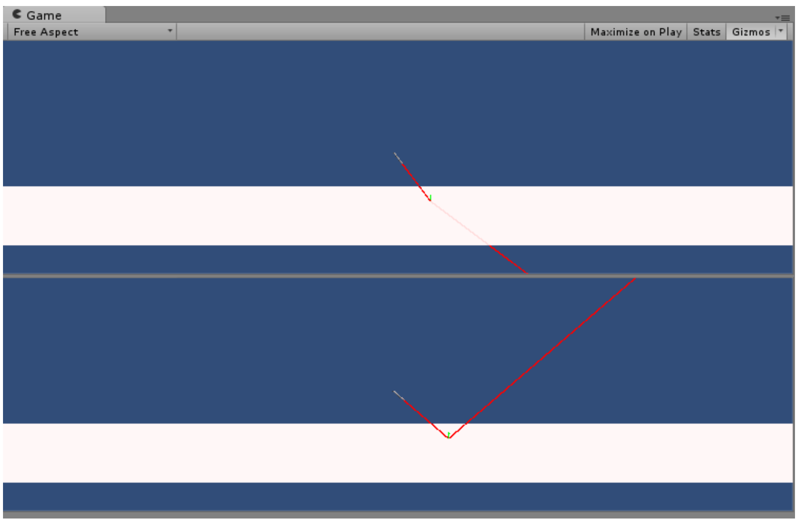

Figure 4: The refraction and the total internal reflection scene in Unity

Exercise:

The critical angel at the interface between two media is the smallest angle of incidence at which total internal reflection occurs. Determine the critical angle for a beam of light traveling upward through water toward the surface where it meets the air. The index of refraction of water is 1.33, and the index of refraction of the air is 1.00.

Tips for Unity programming:

If you want to see the details for one method or command in Unity, highlight the word you are searching for and then press Ctlr and ‘ in windows or Cmd and ‘ in mac. A browser window should open with details from the Unity API.

It is better to run your project having “Maximize on play” deactivated. This way you can observe better what happens in the scene.

PBL in PETOE

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Abstract

PBL is a kind of teaching form and teaching model which accords with the training regularity in engineering ability and the formation logic of comprehensive quality. PETOE required all universities participating in the plan to implement the various methods of PBL with efforts. The innovation of teaching models is regarded by PETOE as the crucial elements in order to achieve the objectives of cultivating outstanding engineers. Targeting at the PETOE participant universities, after presenting the function mechanisms of PBL specific to the cultivation of outstanding engineering talents, the paper focuses on analyzing the achievements of obtained value acquired from the promoting PBL and the universal problems still existing during the implementing PBL since PETOE started five years ago. It is followed by analyzing how teachers can transform from traditional teaching model to the teaching of PBL and offering operable advice and suggestions aimed at solving the problems and further implementation of PBL.

Keywords：PBL；PETOE；learning method；teaching model；teacher；engineering education

1 Background

“The Plan for Educating and Training Outstanding Engineers (PETOE)” initiated by the Ministry of Education of China is one of the only two significant reform projects in the domain of higher education on the “National Outline for Medium and Long-term Education Reform and Development (2010-2020)”. The two main objectives of PETOE are as follows: one is to educate and train a galaxy of high-quality engineering and technical talents of various types, who possess strong creative abilities and are adaptive enough to the development requisites of the economic society facing the industrial circles, the whole world and the future as well so as to strengthen China’s core competitiveness and comprehensive national power. The other objective is to accelerate the reform and innovation of engineering education, to improve the quality of talent training comprehensively in China’s engineering education, to promote China to move from a large to a power nation in the domain of engineering education.(MoE, 2010) PETOE is participated by 208 colleges and universities, including Tsinghua University, Zhejiang University, Shanghai JiaoTong University, and so on by covering 30 provinces and municipalities throughout China. It includes undergraduate, master’s and doctoral levels with 1257 undergraduate majors, 514 postgraduate majors and more than 240,000 students are involved in the project.

Problem/Project Based Learning (PBL) is a kind of teaching form which accords with the training regularity in engineering ability and the formation logic of comprehensive quality. Originated from the realistic problems, cases and projects, PBL achieves the objectives of the course by carrying out different teaching activities such as probing into and solving problems, discussing and analyzing cases, participating in and accomplishing projects as well. PBL is a system of learning methods, and its main forms include problem-based learning, case-based learning and project-based learning (Lin, 2012). Therefore, those universities which are participating in the project are required by PETOE to implement the various methods of PBL with efforts, such as problem-based learning, case-based learning and project-based learning. The innovation of teaching models is regarded by PETOE as the crucial elements in order to achieve the objectives of cultivating outstanding engineers.

Targeting at the PETOE participant universities(PAs), after presenting the function mechanisms of PBL specific to the cultivation of outstanding engineering talents, the paper focuses on analyzing the achievements of obtained value acquired from the process of promoting PBL and the universal problems still existing during the process of implementing PBL since PETOE started five years ago. It is followed by analyzing how teachers can transform from traditional teaching model to the teaching of PBL and offering operable advice and suggestions aimed at solving the problems and further implementation of PBL. As the principal designer of PETOE, the author has been conducting a lot of work in supporting the Ministry of Education (MoE) by implementing PETOE, including promoting PBL in PETOE PUs vigorously. The paper is based on the author's relevant works.

2 The function mechanism of PBL(Lin, 2012)

The functions of PBL can be concluded to the following four aspects: a) the acquisition, application and innovation of knowledge; b) the cultivation and improvement of engineering capacity; c) the development and improvement of social competence; d) the cultivation and promotion of comprehensive quality. Only if it is sufficiently recognized and understood how these functions are generated during the process of implementing PBL, they can be fully played.

2.1 The Acquisition, Application and Innovation of Knowledge

PBL regards knowledge learning as a subject study so as to lead students to conduct analysis and exploration of the subject. Though the knowledge students going to study and acquire is well-developed or even has become classic theory, figuring out the origin and development of the knowledge, however, is a kind of research for students. This kind of research not only makes students to gain the knowledge, but also enables them to apply and innovate the knowledge.

For the need of learning, students must attain subject knowledge by themselves. In order to conduct problem inquiry, case study and project research, students have to teach themselves the knowledge beyond the content of their courses, including related theories, methods, techniques and their applications. This kind of self-study ability is gradually cultivated by their self exploration, teachers' guidance and classmates’ cooperation. Therefore, not only students’ ability in knowledge acquisition but also their self-study ability is nurtured during this process.

PBL well supports the application of knowledge. Students learn knowledge in the way of research. Through studying the conditions, adaptability and limitation of subject knowledge, students can master the knowledge inveterately, which enables them to well apply the knowledge into their problem inquiry, case study and project research. In this way, students not only develop application capacity, but also lay the groundwork for their analytical and problem-solving skills

PBL leads to knowledge innovation. Based on questioning and critical thinking, students can point out the possible problems of the knowledge and the possibility of further developing the knowledge under different circumstances, and then explore and construct novel knowledge through scientific and rational reasoning and strict logical analysis.

2.2 The Cultivation and Improvement of Engineering Capacity

PBL takes the specific problems and real cases from engineering practice, and the designs and R&D projects from industries and enterprises as carriers which carry the content of engineering teaching. This can cultivate and improve students’ engineering capacity in their process of dealing with problems, analyzing cases and researching projects.

Through dealing with the problems, cases and projects, students will unconsciously achieve concepts, general knowledge and principals of engineering, learn thinking and analyzing various engineering issues in the way of engineering thinking and acquire the methods and skills of analyzing and processing engineering data and summarizing and concluding engineering problems. Therefore, students’ engineering qualities can be cultivated and improved during the process of PBL.

PBL is problem-driven, so students have to face practical problems at the very start of their learning. In order to solve a problem finally, they must learn to find out the root, analyze the characteristics and research the nature of the problem in an overall and systematic perspective, they should also look for the method and way to solve the problem using innovative and critical thinking. Consequently, PBL not only trains and improves students’ ability of systematic and innovative thinking but also the ability of finding, analyzing and solving problems.

The research objects of the problems, cases and projects are production and operation systems, industrial products, engineering projects and engineering technology. The objects involve many aspects, mainly including the design, operation and maintenance of production system, upgrading of original products, development and design of new products, and modification and innovation of engineering technology. As a result, PBL can effectively train students’ skill of design and maintenance of production system, development and design of new products, development and integration of engineering projects, and modification and innovation of engineering technology.

2.3 The Development and Promotion of Social Competence

The teaching organization forms and methods of PBL cultivate and promote the social competence of students. The PBL considers the cooperation between students, the interaction between teachers and students and the activities hold by students to accomplish study tasks as kinds of work and social environment. Therefore， the social competence of students can be effectively trained and cultivated. In summary, there are three main aspects that can be cultivated and promoted through PBL: the capability of interpersonal communication, the capability of organization management and the capability of team cooperation.

In the aspect of the interpersonal communication, when allocating tasks, inter-cooperating, expressing ideas and discussing questions, students must learn to be good at expressing their own ideas, accepting other people’s suggestions, integrating different views, coordinating relationships among different aspects and showing respects and appreciation to others, so as to seek common points while reserving difference and accomplish study tasks together. All these will promote the capabilities of communication, interaction and coordination.

In the aspect of organization management, students all participate in the rotation for different management and leadership roles and take responsibility for associated matters. These matters include the decomposition of group study subject, arrangement of group study schedule, carrying out the cooperation research among classmates, the organization of group discussion and the organizational preparation of class discussion. In these ways, the capability of organization management of students can be thoroughly practiced.

In the aspect of the team cooperation, no matter in the group or in the class, students need to be fully aware of the importance of teamwork in the development of modern society and recognize the individual role and status in the team. Students should learn to deal with the relationship between division and cooperation, individual and collective and part and whole; develop their own global consciousness and collective ideas; learn to well deal with the conflicts among classmates; learn to give a full play to the superiority of every classmate, motivate every student’s enthusiasm, so as to achieve team objectives. In sum, the capabilities of team cooperation of students are developed.

2.4 The Cultivation and Improvement of Comprehensive Quality

PBL plays a key role in cultivation and improvement of comprehensive quality of students. At present, the majority of teachers in most universities believe that teachers are just responsible for “teaching knowledge” while the department of student administration should be responsible for “educating students”. But, in fact, in the process of PBL, teachers can achieve the result of “education” during the “teaching” process by their words and deeds as well as teaching organization. In other words, PBL process can play as a platform on which teachers “act”, “set examples” and “guide students” to promote the cultivation and improvement of students’ comprehensive quality.

Modern engineering problems always involve environment protection, ecological balance, the harmony and sustainable development of society, public security and health, national and social interests etc. In the process of PBL, teachers should emphasize students to pay attention to and handle well above factors during the study of engineering problem, cases and projects in order to cultivate the necessary social responsibility of engineers whom students will become in the future.

Teachers' earnest and responsible attitude toward engineering problems, their conscientious spirit of teaching, and their constant pursuit of excellence in teaching quality will be in favour of the cultivation of students' engineering professional ethics, the attitude to strive for excellence and their dedication. Meanwhile, teachers' treating students on an equal footing, giving them selfless help and guidance, encouraging students for their achievement, and being tolerant of their shortcomings and dissenting opinions will also help students learn how to get along with other people, how to improve their own quality, how to be tolerant and how to cultivate a sound personality.

3 Achievements

PUs all posse a preferable innovation foundation in engineering education, taking up 20% universities owning engineering majors in China. They have conducting tremendously in implementing PBL in accordance with the requirements of PETOE.

(1) Utilizing various forms of PBL mode. PBL is a system of learning methods and its main forms include problem-based learning, case-based learning and project-based learning. Meanwhile, various styles of PBL could be formed on the basis of this system. For example, Tianjin University explored the classroom teaching method actively which integrates “thinking, cognizing, speaking and acting” on the basis of interaction between teachers and students in some elementary courses. Furthermore, they attempted to use various teaching models and methods such as CDIO, PBL, PSLG and case-based teaching for reference in specialized courses. Dalian University of Technology implemented teaching model innovation of teaching in large-scale class while implementing discussing in small-size class and carrying out research-based and autonomous classroom teaching. They endeavored to put various teaching methods into practice, such as the method of discussion, situation-based teaching and case-based teaching through the teaching models of “problem-discussion”, “reading-debate”, “experience accumulation” and so on. Beijing Jiaotong University adopted a series of teaching methods with the combination of diversified forms, such as classroom teaching, group project, independent project, experiment, design and manufacture, on the basis of the thought of teaching instruction guided by solving engineering problems..

(2) Implementing comprehensive reform and facility construction centred on PBL. The implementation of PBL is not only the issues of classroom teaching, but also the innovation of correlated curriculum and teaching organization form, the emphasis on the combined educating and training from students and the reformation of examination and evaluation modes, the appropriate teaching environment for carrying out PBL and so on. Tongji University is one of the typical examples in these respects, by carrying out the

teaching modes of elicitation method, inquiry-based method, discussion method, participation method and small-size class through the innovation of training modes and evaluation modes. They advocated to improve the students' comprehensive abilities and personality cultivation through the combined training by designing, comprehensive and innovative projects besides the single form of knowledge transformation and try to achieve the purpose of the diversification of students' performance evaluation modes. Meanwhile, they initiated the plan of the construction of classroom suitable for discussion to construct about 160 classrooms which are well functioned and convenient enough for teaching and interacting between teachers and students to meet the needs of the innovation of teaching modes, training modes and evaluation modes.

(3) Adopting various kinds of examination and evaluation modes so as to support PBL. The examination modes of academic records relates to the effect of PBL directly, simply because it not only guides the students' contribution to their study from the aspects of time and energy but also influences the objectivity and fairness of the evaluation of students' academic records. In general, the methods such as increasing the times of assessment at regular intervals, adopting multiple assessing modes, increasing the proportion of the weight of assessment grades at ordinary times are of great benefits for the implementing of PBL. For example, Tianjin University adopted the mode of combined evaluation in the aspect of examination and increased the proportion of the weight of assessment grades at ordinary times and assessment phases. The transformation of the appraisal mode from academic grades to learning effectiveness guided the students' bias from examination result to learning process, which enhanced the students' learning initiative, learning ability, research ability and engineering practice ability. Ningbo University of Technology played the guiding function of examination in the teaching and adopted the examination methods, such as oral debate, lecture and answer, actual operation, ability test, online examination, thesis design, in accordance with the characteristics of the course, the features of the major and the actual situation of the students who are concerned.

(4) PBL driven by the achievements and products of the students. One of the important functional mechanisms of PBL is to cultivate and promote the engineering ability of students, instead of memorizing the simple facts and information. For this reason, the appraisal of the learning effectiveness of the students by comprehensive learning achievement or the design of the accomplished products or projects can not only assess the ability of finding problems, analyzing problems and solving problems but also can motivate the learning enjoyment of students. For example, Beijing University of Technology carried out the reforms such as teaching driven by production, teaching process tested by learning results, the improvement of the students' level by scientific research. When giving the practical courses, the teachers are required to guide the students to accomplish a relatively integrated digital media product (including cartoons, digital media mutual software, video games and so on), to examine the learning achievement of students and the teaching level of teachers. Meanwhile, the encouragement of the students to submit the learning achievements in classroom and the final graduation projects to participate in the concerned digital media contests enhanced the students' learning initiatives to a certain degree.

(5) The implementation of teaching with engineering projects or production issues as carriers. The problems, cases and projects adopted in the process of implementing PBL will affect the effect of PBL to a large extent, so they should achieve the purpose of utilizing what are taught in the class and training the students' abilities to solve practical engineering problems as well. The common problem existing in the teaching mode of PBL is that the problems, the cases or even the projects were often fabricated by the teachers and lack of engineering background, which definitely affected the effectiveness of PBL to some extent. Consequently, we should attach importance to choosing appropriate materials for PBL. For example, The instruction enterprise courses of the Fuzhou University aimed at the practical usage of engineering The teaching modes, such as the courses of lectures, explanation on spot with combination with production practice and teaching based on cases derived from the problems of production were adopted and also the students had the opportunity to involve in the tutors' research projects so as to receive the training of research methods and exploration abilities comprehensively.

(6) Practicing on the spot while conducting the graduation project. Graduation project is a combined training for students from the aspects of knowledge, ability and quality, which can be regarded as a special form of PBL and therefore, it plays a crucial role during the process of educating and training engineering talents. However, the common problems, such as the replacement of project design by paper, imaginary subject, study separated from reality in classroom made the important teaching process become a mere formality. In order to solve all the above mentioned problems, PETOE required all PUs to conduct the graduation project on the spot. The requirements are as follows: a) the subjects should be derived from engineering practice. b) the project design should be accomplished in enterprises. c) the project design should be guided by supervisor from enterprises. Generally speaking, the majority of PUs carried out the requirements preferably. The benefits are that on one hand the students can solve some problems for the enterprises to a certain extent by receiving the recognition from the enterprises and on the other hand this form of practice is also beneficial for the students to be close to engineering practice and increase their quality of employment.

4 Existing problems

Although PBL has relatively a long research and practice history and also has got positive guidance and strong support from the government, especially from the education sectors, the implementation of PBL still exists different kinds of problems, because of the long period of effect of exam-oriented education, the inherent role definition between teachers and students and the inertial acceptance of passive teaching models. As far as the PETOE PUs are concerned, although tremendous progress has been made in implementing PBL the following problems are still existing in some universities by analyzing from the perspectives of the essential characteristics, main forms and the functional mechanisms of PBL.

(1) The cognition of the nature of PBL is not thorough enough and the classroom teaching with discussion and interaction is regarded as PBL simply; that is to say, the simple addition of some discussion and interaction to the original classroom teaching is regarded as PBL.

(2) The teachers who dominate the PBL lack of engineering practice experience and do not possess the abilities to solve the engineering problems, cases and projects, so the effective implementing of PBL is rather difficult.

(3) The problems and the cases used in PBL are not derived from engineering practice or enterprise realities and they are separated from reality in classroom or just imagined by teachers, which are considered useless to the cultivation and development of the students' engineering abilities.

(4) Necessary cooperation is absent among the teachers who adopt the teaching mode of PBL, and they usually work on their own; and as a result, the function of PBL cannot be played to the full.

(5) The PUs lack of policies and measures to stimulate the teachers to carry out PBL. For instance, there are no definite requirements on teaching methods of PBL or no preferences from the aspects of performance salary for the teachers who have carried out PBL.

5 Analyzing from the aspects of teachers

As far as the teachers are concerned, it is almost impossible for them to transform from traditional teaching model to the teaching of PBL immediately; on the contrary, it is a long-term process of exploration, improvement and perfection gradually.

First and foremost, the teachers should attach importance to changing their own role, that is to say, they should change the teaching idea from teacher-centred to student-centred and transform the students from learning passively surrounding teachers to learning on their own initiatives under the teachers' guidance.

Secondly, the teachers should have sufficient teaching preparation. Organizing the teaching content, planning teaching progress and arranging classroom teaching should be centred on the problems, cases and projects from engineering practice.

Thirdly, the teachers should organize the teaching activities flexibly, that is to say, they should apply versatile approaches and measures to classroom teaching. The aim is to inspire the students' enthusiasm, initiative and creativity on one hand and to response to various accidental teaching occasions so as to ensure the classroom teaching running smoothly on the other hand.

Last but not least, favorable extracurricular communications are required between teachers and students. The teachers should communicate with the students and give guidance to them directed at the issues during the process of autonomous learning and collaborative learning and provide requisite help as well.

In fact, it is almost impossible for the teachers to accomplish all the above mentioned tasks only by one round of teaching attempt in PBL through just one course in curriculum. Genuine PBL requires the teachers to devote a lot of time and energy to their job in order to explore constantly, to accumulate and enrich experience through the repeated teaching practice of PBL, thereby to bring the function of PBL into full play and to realize the instructional objectives of course teaching.

6 Measures and Suggestions

Aimed at the above-mentioned problems and based on the analysis from the perspective of teachers, we propose that the PETOE PUs should conduct as follows while carrying out PBL.

(1) The education and teaching philosophy should be changed from "classroom, teachers and textbooks-centred" to "students, learning, students-centred". The traditional education and teaching philosophy attached importance to the function of course teaching, emphasized the teachers' authority and regarded the content of textbooks as the absolute requirement for teachers' classroom teaching and students' course evaluation. These are inconsistent with the education thought and the teaching philosophy advocated and transmitted by PBL. Modern education and teaching philosophy emphasize "the student-oriented" principle, which is to prepare, organize and carry out the teaching centred on students, to attach importance to students' learning outcome in the process of teaching and learning, to design the teaching content to satisfy the students' aspiration and interest and career development. All these are just what PBL stresses and emphasizes; consequently, transformation of education and teaching philosophy is the crucial prerequisite during the process of implementing PBL.

(2) The research of PBL should be conducted so that the teachers should fully realize the vital importance of PBL during the process of cultivating and training engineering talents. Owing to the four functions of PBL discussed in Section 2, PBL has become a preferable learning mode in global educational world nowadays no matter it is in elementary, secondary education or in higher education, in scientific education or in specialized education. As a result, the study of PBL is undoubtedly significant for the teachers to implement PBL effectively.

(3) Comparably abundant engineering practice should be required as the necessary requirement for the teachers to adopt the teaching mode of PBL. In order to cultivate the students' innovative thinking and innovation ability, PBL encourages students to come up with their respective analysis thought, handling suggestion and solution critically aimed at the problems, cases and projects prepared by the teachers. The various kinds of questions asked by students may be originated from the engineering practice, realistic society or personal absent minded thinking; however, they are frequently complicated and unable to answer with ease. Therefore, the teachers are required not only to answer the students' various unanticipated questions confidently, but also to assist the students to train and advance engineering abilities easily by virtue of their comparatively abundant engineering practice and experience.

(4) The problems, cases and projects used in PBL should be selected, compiled and designed elaborately from engineering practice and enterprise realities. There are two requirements as to choosing the problems, cases and projects employed in a course to carry out PBL. The first one is that the teachers can organize the students to carry out and accomplish the teaching of the main course content surrounded by problems exploration, cases discussion and projects participation. The second one is that the problems, cases and projects can form the logical relationship from simplicity to complexity in nature and from singleness to synthesis in multiplicity, which are in favor of the students' abilities and qualities' cultivation

and development gradually. There are a large amount of real-life materials from engineering practice and enterprise realities which can be used in PBL; therefore, it is not difficult to find out, compile and design the problems, cases and projects which can meet the needs of the above-mentioned two requirements.

(5) The initiative of the students should be motivated to increase efficiency of PBL so as to liberate the teachers from the simple duplication of effort. There is a bias understanding of PBL about carrying out PBL and it is considered that the teachers and students will spend a large amount of time and this kind of false idea might derive from the lack of understanding in carrying out PBL effectively. As a matter of fact, PBL is a kind of active learning for students and they should carry out in-class and after-class learning, by take advantage of all feasible educational and instructional resources. PBL is a kind of creative work for teachers and they should assign the learning tasks which can be accomplished by students independently or by group collaboration to students on one hand, and concentrate on organizing and carrying out innovative teaching by means of flipped classroom and blended learning aimed at the conditions of the students and the teaching progress on the other hand so as to improve the classroom teaching efficiency of PBL.

(6) The cooperation between teachers should be encouraged and intensified. On one hand, the cooperation between teachers can compensate the deficiency in engineering knowledge, abilities and experience of single teacher, such as the cooperation between full-time teachers on campus and the part-time teachers in enterprises can have complementary advantages in carrying out the PBL of a same course in curriculum. On the other hand, the PBL based on projects can be accomplished frequently by the participation of several teachers or teaching teams when turning into the learning stage of specialized courses. Cooperative teaching or teaching courses by several teachers jointly should be a normality of the innovation of curriculum system and teaching methods in colleges and universities and this practice should be advocated and encouraged in the PETOE PUs.

(7) The policies and measures should be formulated to stimulate the teachers to utmost their best in exploring teaching methods of PBL. The phenomenon of valuing research while neglecting teaching is still universal currently; therefore, on one hand, the PETOE PUs should present explicit requirements concerning teaching methods of PBL on the teachers who undertake the teaching tasks of training outstanding engineers, especially the teachers teaching specialized courses during the process of assessing and evaluating teachers. On the other hand, they should formulate definite preferred measures in performance salaries to affirm the teachers' devotion of time and energy to implementing PBL and to stimulate them to update and improve the teaching level and effect by adopting the teaching mode of PBL.

(8) The influence of the information technology and digital resources to PBL should be attached great importance. Nowadays the information technology develop so rapidly that the teachers are required to take the impact, influence and the acceleration on teaching methods and learning modes by information technology and digital resources into consideration thoroughly. First of all, the teachers can take full advantage of the multimedia's demonstration function to demonstrate the derivation backgrounds,

objective environments and complicated relations of the engineering problems, cases and projects derived from engineering practice abundantly to acquire best teaching efficiency. Secondly, the teachers can construct all kinds of complex, even hazardous engineering model by means of modelling and simulation technology to comprehend and grasp the natures and characteristics of engineering problems in order to find out, analyze, discuss and solve all kinds of complicated engineering problems better. Thirdly, abundant online teaching resources provide wide space for the students to acquire knowledge autonomously and reduce their dependence on teachers. Last but not least, mobile communication technologies provide the students with convenience to learning autonomously whenever and wherever possible. So the teachers are demanded to extend the classroom teaching to instructing students to learn after class, to strengthen the extracurricular communication with students through full advantage of internet means and to instruct, assist and reply various kinds of questions proposed by students timely.

7 Conclusion

With the help of PETOE, as a requirement of implementing the plan, PBL is in favor of not only realizing the objective of training outstanding engineers but also implementing PBL effectively and thoroughly. Although implementing PBL is the teachers' incumbent responsibilities and the key to success lies in teachers in essence, the implementation of PBL by the national project of the Chinese government, PBL is definitely to bring more immediate and effective implementing effect in the domain of China's engineering education. The effect will present evident demonstration and guiding function and will influence the teaching of other fields in China's higher education and provide lessons and experience for China's basic education as well.

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Rethinking and Redesigning an Image Processing Course from a Problem-Based Learning Perspective

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Abstract

Our experience at the Media Technology department, Aalborg University Copenhagen has shown that learning core concepts and techniques in image processing is a challenge for undergraduate students. One possible cause for this is the gap between understanding the mathematical formalism of such concepts and being able to use them for solving real-world problems. The Problem-Based Learning (PBL) pedagogy is an approach, which favours learning by applying knowledge to solve such problems. However, formulating an appropriate project for image processing courses presents challenges on how to appropriately present relevant concepts and techniques to students. This article presents our redesign of an image processing course at the Media Technology department, which focused on relevant concept and technique presentation and design projects and employed a game engine (Unity) in order to present such concepts and techniques. In a Unity environment, we developed visualizations of core concepts and basic image processing techniques. Unity was also used by students for developing projects (games) as assignments. The first offering of this new course format has been an intense learning experience for the instructional team. Media Technology students have welcomed the idea of using for image processing a tool they already use for other courses. Moreover, the visualizations and design projects in Unity have proved to increase student understanding compared to previous semesters, where other programming libraries were used. Since these preliminary results were very positive, we are planning to conduct a large scale quantitative study on the use of Unity and student understanding of image processing concepts during next year.

Keywords: image processing, game engine, problem-based learning, design projects, visualizations

1 Introduction

A thorough understanding of signal processing is paramount in many engineering courses, such as communications, sound or image processing. Various educational researchers and engineering educators have investigated ways to make such courses easy to understand. However, the abstract and complex mathematical concepts involved in signal processing and the disconnection of these concepts from real world continue to pose a challenge in conceptually understanding signal analysis (Fayyaz, Streveler, Iqbal, & Kamran, 2015). Fayyaz et. al proposed that difficulties in conceptually learning signal processing arise from insufficient understanding of the following concepts: (1) the difference between continuous and discrete domains, (2) discrete frequency, (3) units of Fourier series and Fourier transforms, (4) periodic/aperiodic or finite/infinite duration signals, (5) sampling, (6) aliasing and folding, (7) abstract mathematical concepts, and (8) advanced mathematical thinking ability. They have also identified the following possible explanations for these learning hurdles: phenomenological primitives, ontological miscategorization of discrete and continuous domain signals, and the lack of ability among students for advanced mathematical thinking.

Our experience in the Media Technology department of Aalborg University, Denmark confirms the aforementioned findings. Our teaching experience has shown that learning core concepts and techniques in image processing is a challenge for undergraduate students. As literature has discussed and our experience has shown a cause for this is the gap between understanding the mathematical formalism of such concepts and being able to use them for solving real-world problems. In order to alleviate such learning hurdles for students, we introduced a new course design for the image processing course at Media Technology.

This article presents our redesign of the image processing course at the Media Technology department, which focused on relevant concept and technique presentation and design projects. This novel course format was offered during the autumn 2014 term at the Aalborg University Copenhagen, Denmark. During this term, we used a game engine (Unity) in order to present course concepts and techniques (Reng, 2012). In a Unity environment, we developed visualizations of core concepts (e.g. image representation in pixels) and basic image processing techniques. Our hypothesis was that by using Unity to implement various image processing techniques (e.g. point processing, neighbourhood processing, histograms, blob detection, etc), students could grasp more easily fundamental concepts (such as colour spaces, filters, object detection etc), since the students work on a familiar and popular environment which is not difficult to use it (compared to a programming library) and is also connected to game development which attracts a lot of students' attention. Unity was also used by students for developing projects (games) as assignments. We got inspiration for introducing this learning approach by the Problem-Based Learning (PBL) pedagogy, which is applied to all programs at Aalborg University. In the following, we mention the core charecteristics of PBL and then present the new course design. We conclude this article by discussing our experiences with this new learning approach and proposing actions for future work.

2 Related research

Our search in the SCOPUS database revealed no articles describing the introduction of a game environment or engine to image or signal processing undergraduate courses. By using the keywords "game AND image processing course" and "Unity AND image processing course", we got 38 and 5 results respectively, but none of them was relevant. We have also used the keywords "Unity AND image processing", which returned 308 results but they did not refer to the educational field, while the keywords "game engine AND image processing" revealed 94 results but they were from the game architecture field. By omitting the image processing part, we have found a few approaches where game environments have been employed for software engineering or computer science courses and some other related approaches, which have applied other PBL-inspired learning methods in signal processing. In the following, we present research from those fields.

Albu and Malakuti investigated a hybrid instructional format that combined traditional lectures with a PBL-based component (Albu & Malakuti, 2009). Their approach aimed at providing a framework for solving multimedia-related digital signal processing problems, where students were encouraged to formulate their own problems. The PBL component was added to the lecture-centric course and custom-designed software was introduced for system design and analysis. The authors observed student-formulated problems in approximately 15% of the total number of handed-in projects. Interesting applications included image segmentation via edge detection, creating audio effects via digital filtering, and segmentation of piano sounds based on harmony analysis. However, some students expressed the desire to receive a more structured project assignment formulated in closed-form and the authors mentioned improvements that have to be made to the software they introduced in terms of stability, flexibility, and efficiency for the implementation of user-formulated filters.

Arévalo et al. describes introduced a PBL approach in a computer vision course (Arévalo et al., 2011). This approach focused on the practical block of the subject and consisted of collaboratively developing a software application to solve a central computer vision problem: detecting and classifying objects in images. The aim of their initiative was twofold: getting the student to assimilate and put the acquired knowledge into practice (specific skills); and to develop generic skills such as planning and conducting their learning, performing individual and group works, coordination, etc. Arévalo et al. evaluated this collaborative PBL approach according to the degree of students' satisfaction and the students' academic outcomes. They evaluated the produced material (final reports, forum contributions, etc.) and students' self-assessments and the results indicated a high degree of satisfaction and involvement of students, better academic outcomes (compared to previous years) and solutions to the problem, in some cases, really creative.

In the field of employing game environments to promote student participation, enable variation in how lectures are taught, and improve student interest in higher education, Wang and Wu used a game development framework as a learning aid in a software engineering course (Wang & Wu, 2009). In their article, they described a case study where a game development framework (XNA) was applied to make students learn software architecture by developing a computer game. They provided a model for how game development frameworks can be integrated with a software engineering or computer science course and they described important requirements to consider when choosing a game development framework for a course. In their approach, they made some extensions to the existing game development framework to let the students focus more on software architectural issues than the technical implementation issues. The responses from the students were overall very positive compared also to previous years. Students felt they learned a lot from the game project and they liked the practical approach of the project. However, there were some students who felt that there was lack of XNA and technical support during the project and that there was too much focus on XNA, and games and too little on software architecture.

In our approach, we got inspired by the working with real-world artifacts approach of PBL and we combined it with the introduction of a game environment (Unity). In this sense, our approach is novel, especially because it is applied in an image processing course. In the following section, we describe the main characteristics of PBL, which build the theoretical framework of our approach.

3 Problem-Based Learning

PBL is a student-centered pedagogy in which students learn through the experience of problem solving (Kolmos, Krogh, & Fink, 2004). Learning begins with a problem to be solved, posed in such a way that students need to gain new knowledge before they can solve the problem, and thereby learning both thinking strategies and domain knowledge. The goals of PBL are to help the students develop flexible knowledge, effective problem solving skills, self-directed learning, effective collaboration skills and intrinsic motivation (Hmelo-Silver, 2004).

PBL may also support group work (Kolmos, 1996). Working in groups, students identify what they already know, what they need to know, and how and where to access new information that may lead to resolution of the problem. This procedure enhances content knowledge while simultaneously fosters the development of communication, problem-solving, critical thinking, collaboration, and self-directed learning skills. PBL may position students in a simulated real world working and professional context, which involves policy, process, and ethical problems that will need to be understood and resolved to some outcome. By working through a combination of learning strategies to discover the nature of a problem, understanding the constraints and options to its resolution, defining the input variables, and understanding the viewpoints involved, students learn to negotiate the complex sociological nature of the problem and how competing resolutions may inform decision-making.

Additionally, PBL represents a paradigm shift from traditional classroom/lecture teaching. The role of the instructor in PBL (known as the tutor) is to facilitate learning by supporting, guiding, and monitoring the learning process. The tutor must build students' confidence to take on the problem, and encourage the students, while also stretching their understanding. Therefore, the role of the teacher is to guide and challenge the learning process rather than strictly provide knowledge.

PBL was first introduced in the medical school program at McMaster University in Hamilton, Ontario, Canada in the late 1960s (Neville, 2008). Since then various universities and other educational institutes have adopted PBL as a model of teaching and learning. Since its establishment in 1974, Aalborg University, Denmark bases all its university programs on PBL, also referred to as “PBL - The Aalborg model” (Barge, 2010). The PBL - Aalborg Model has become both nationally and internationally recognized and a trademark for Aalborg University. Through research in PBL, Aalborg University continues to develop and adapt the PBL-model as a learning model for students as well as teaching staff, and ensures that the model responds well to the demands and changes posed by the surrounding society and changes in the education area.

The PBL – Aalborg Model shapes the institution’s program curricula. The program curriculum at Medialogy is mapped onto academic terms (semesters) according to an appropriate progression with regard to depth and breadth of content as well as sophistication of project work. Each program consists of an appropriate balance of courses, which accompany the students’ project work. In each semester, a theme is selected to serve as the context, in which central theme related courses and semester projects address the learning objectives. Within the theme and the overall learning objectives, problems and project proposals are to be chosen. Apart from their semester projects, students have often to work on projects for their semester courses.

4 The new course design

The most common approaches for running Image Processing (IP) courses is by using a specific IP library (e.g. Matlab Image Processing Tollbox, OpenCV, OpenFrameworks, etc). Such tools are very powerful for conducting research and developing IP applications, but our observations during IP courses and student performance on IP have shown that Media Technology students find it difficult to understand and use the IP concepts. Moreover, student evaluation of the IP course has shown that a pure programming platform (e.g. Matlab, OpenCV, etc) is not very attractive for such students. Therefore, we decided to redesign the Introduction in IP course for Media Technology students.

Taking into account the aforementioned observations, we identified two challenges. On one hand, how to better communicate the IP concepts, and on the other hand how to motivate students to start experimenting with these concepts. We decided to resolve these challenges by employing the PBL context of our university and our background and previous experience in game engineering. Therefore, we introduced the use of a game engine (Unity) as a means for efficient visualization of the IP concepts, and at the same time as a platform for game, development where the IP concepts are used.

The syllabus of the Introduction in IP course contains the following topics:

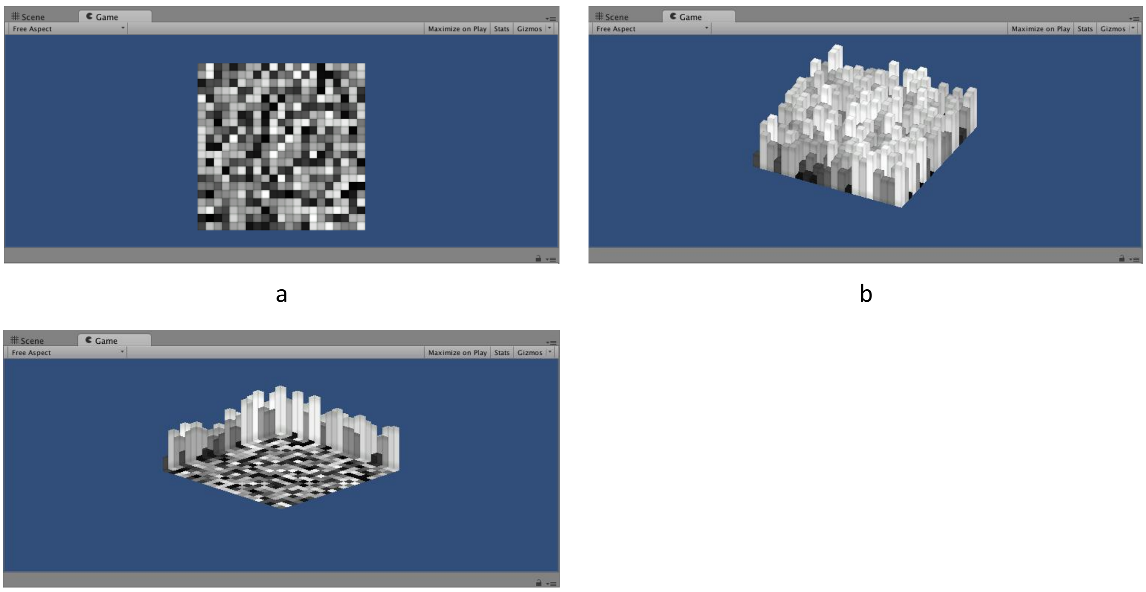
- Introduction to IP / imaging
- Image acquisition
- Color spaces
- Point processing / pixel operations
- Neighborhood operations / Filtering
- Morphological operations
- Color detection/tracking
- Blob analysis
- Segmentation in video and Geometric transformations
- Frequency analysis of images

In the new course design, we used Unity based visualizations for introducing abstract mathematical concepts used in IP. Moreover, students were given the possibility for their design projects to create games within Unity, where they can use IP concepts.

In the following, we present the set of basic illustrations and exercises that we used to support this new approach of teaching IP and their connection with the PBL pedagogy.

Grayscale pixel representation

In this visualization, a Unity scene is created, where the pixels are represented as 3D bars, and their grayscale value (0-255) is used to define the height of the bars in the z-axis. By creating this scene, the students can use the top point of view where the scene is shown as a 2D grayscale image (Figure 1a). Then by simply rotating it, the students can see it from a different point of view (Figure 1b and 1c), where they can see the height of the bars, which correspond to their grayscale values.



a b c

Figure 1: Grayscale pixel representation

In this exercise, we aimed at creating a connection between the grayscale values of the pixels in an image with the histogram of the image. The bars representing the values relate to the bars in a histogram and this connection creates a real-world representation of an abstract concept as the grayscale value of a pixel.

Color representation

This is an exercise, where the students were asked to create a cube in Unity and try to paint it in different colors by using different values for the variables red, green and blue (Figure 2).

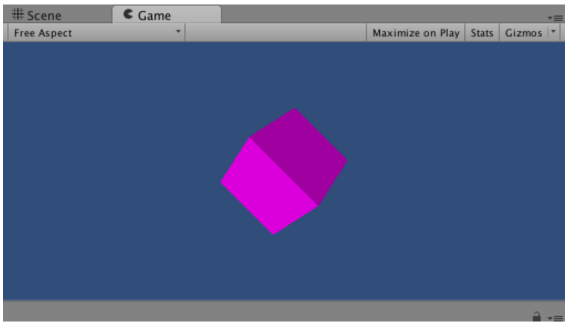


Figure 2: Coloring a cube

For this exercise, students are required to use the RGB (red, green, blue) values in order to change the color of the cube and by doing so, they are experimenting with this color space. *Point processing*

This is an exercise where the students were asked to attach a texture to a Unity game object (e.g. cube) and then do some point processing operation on this texture, like change contrast or brightness, produce inverted images, etc (Figure 3).

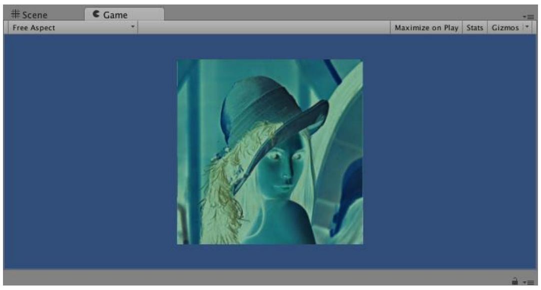


Figure 3: Inverting an image

Point processing: Thresholding

Like in the previous exercise, the students were asked to do some thresholding to a 2D texture (Figure 4).

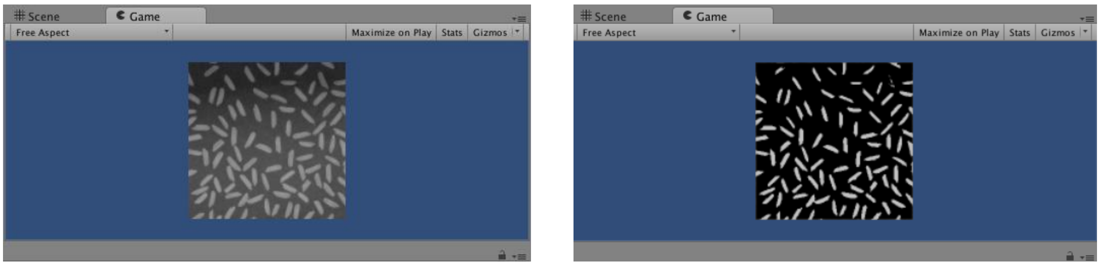


Figure 4: Thresholding an image

Neighborhood processing

In such exercises, the students were asked to apply neighborhood processing operators such as mean filters, rank filters or edge detectors (Figure 5).

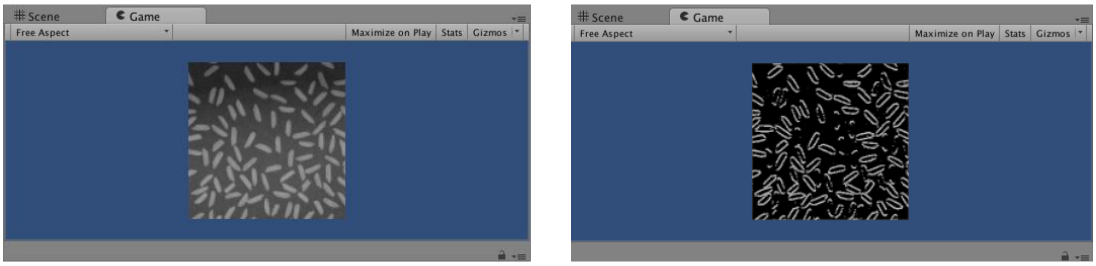


Figure 5: Edge detection (Prewitt kernel)

Morphological operators

In these exercises, the students were asked to apply erosion, dilation, closing and opening in a 2D texture (Figure 6).

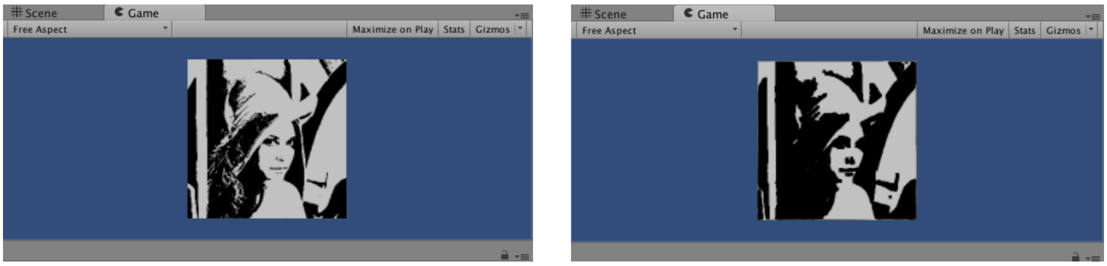


Figure 6: 5x5 erosion

In all the aforementioned exercises, students engaged with game objects that are similar to real world ones and they used a tool, which they have used in other fields of their study. The introduction of real world problems and the interconnection between different courses are two of the main characteristics of PBL.

In combination with these basic exercises, we used group work, which is also aligned with the Aalborg PBL model. We asked the students to work in groups in order to implement in Unity the following small (and more advanced) games, which use IP concepts.

Project 1: Illustrate the grassfire algorithm for BLOB detection by showing all the steps of the blob detection pixel by pixel for the sequential and recursive methods. This illustration is using an island (as an image) and some grass regions (as the BLOBS) that need to be burnt according to the grassfire algorithm.

Project 2: Create a game quiz where different point processing operations are selected (e.g. thresholding, inversion, gray level mapping, brightness, contrast) and the game player should find out which one has been applied to the texture

Project 3: Create a game where the player should use a specific series of operations (point and neighborhood) in order to find out a hidden message within the texture.

Project 4: Create an application where different edge detectors are applied to illustrate the different results.

5 Discussion

The introduction of Unity for visualizing abstract IP concepts has been proved to be beneficial for student understanding. The results (pass/fail) on student performance showed that there was a 12% improvement compared to the last year (59% passed last year, while 71% passed this year). Moreover, students showed better understanding during class discussions and in their design projects. We have also gathered student feedback during lectures, and it was very positive. Students reported that using a tool they already knew allowed them to focus on the comprehension of the new concepts. Furthermore, they mentioned that applying IP in a field they are aware with (game development) increased their motivation to work and their sense of meaningful learning.

Regarding design projects in Unity, the student feedback was also very positive. Students showed enthusiasm on the idea of creating games for an IP course and felt that it contributed to their learning. We believe that these design projects contributed also to introduce a PBL aspect to our course. This approach of letting students build real life objects and artefacts and interact with them is in line with the core aspects of PBL. We have experienced that students were able to submit high quality projects and approached the problem solution in various ways. However, we noticed that they needed much more assistance while conducting group work. This assistance was provided by the teaching assistants assigned to this IP course.

6 Conclusion

The first offering of this new course format has been an intense learning experience for the instructional team. Media Technology students have welcomed the idea of using for IP a tool they already use for other courses. Moreover, the visualizations and design projects in Unity have proved to increase student understanding compared to previous semesters, where other programming libraries were used. Since these preliminary results were very positive, we are planning to conduct a large scale quantitative study on the use of Unity and student understanding of IP concepts during next year.

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Active Learning for Freshmen Students in a Software Engineering Education

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Abstract

During the academic year 2012/2013, a reform in IT engineering program concerning the adoption of active pedagogy for teaching was approved. In this article, we are going to detail the fundamentals of this pedagogical approach, how to apply it in a classroom and how learners can benefit from it by enhancing their capacity in acquiring knowledge and improve their soft skills.

As we all know, the Procedural programming is a fundamental module in IT engineering program as the learner has to put into practice the basic concepts of algorithms and what he/she have acquired in fundamentals of procedural programming at the end of this module.

In the traditional pedagogical approach, we use exercises with mathematical examples to introduce algorithms. These examples might be interesting and efficient for learners to understand mathematics principle but they are also monotonous. During their courses, students are bored, unmotivated and can't understand the relationship between these examples and problems they might face in real life as a programmer. In order to motivate students, we have adopted a methodology that is inspired by the Problem-Based Learning approach (PBL).

This approach is based on forming small groups of students to resolve a "Problem Situation" (Prosit) inspired from a real life situation or containing challenges. The resolution of each Prosit will be made during two sessions. We have also added traditional courses, beside the Prosit resolving session, in order to further reinforce the learner's level. In addition, we have provided a space for our students to interact with each other and with their tutors via our e-learning platform Moodle.

Despite the difficulties, the results were very satisfactory.

Keywords: Problem-Based Learning, Hybrid Pedagogy, freshmen students, Software Engineering, Procedural programming.

1 Introduction

In our country, it is rare for students to work in groups and sometimes difficult to rely on self-study. They are usually used to being guided, thus, dependent. Beside this, students are becoming less motivated by conventional and traditional courses. As the first and main aim of our school is to generate best engineers, it is important and crucial to provide them with best pedagogy and courses. In order to achieve this, we included new educational methodology and tools to remedy aforementioned problems. During the academic year 2012/2013, ESPRIT integrated the active pedagogical approaches for its new students.

As an example of this pedagogy, the course of mathematics applied the Team-Based Learning (TBL) (Louati et al, 2014.). In this article we will describe the active pedagogy adopted in the "Procedural Programming" module. We were inspired by the PBL and added classical education sessions, and a space for exchange on our platform Moodle e-Learning. By using this pedagogy, our goal is to improve the students' acquisition of the module and improve their soft skills.

2 Description of the approach

In our country, it is rare for students to work in groups and sometimes difficult to rely on self-study. They are usually used to being guided, thus, dependent. Beside this, students are becoming less motivated by conventional and traditional courses. As the first and main aim of our school is to generate best engineers, it is important and crucial to provide them with best pedagogy and courses. In order to achieve this, we included new educational methodology and tools to remedy aforementioned problems. During the academic year 2012/2013, ESPRIT integrated the active pedagogical approaches for its new students.

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	9 → 10:30	10:45 → 12:15		14 → 15:30	15:45 → 17:15
Monday	Mathematics	Language		Systems & Networks	
Tuesday	Mathematics	Procedural Programming (Retour, PBL unit #n-1)		Multimédia	
Wednesday	Systems & Networks	Procedural Programming (Aller, PBL unit #n)			
Thursday		Language		Procedural Programming (Coaching)	
Friday	Systems & Networks	Mathematics			
Saturday	Procedural Programming (Restructuring)	Mathematics			

Figure 1: Example timetable

A Prosit is given in the "Aller" session. After six days, in the "Retour" session, students have to present solutions on the Prosit. During the two sessions, learners have to make individual research and meetings to resolve the proposed Prosit.

The "Aller" sessions lasts for 1h30. It is dedicated to the understanding of the Prosit and defines the axes of possible solutions. In those sessions, the tutor gives the Prosit to the teams and begins coaching them about the proposed problem. The tutor mission is to guide learners without giving them solution or hints. The session "Retour" also lasts for 1h30, during which the teams discuss their solutions with their tutors. This latter will not make a correction, but he continues to coach the team to find the accurate solution.

Both sessions are scheduled for two successive days in order to renew the Prosit every week. For example, if the "Retour" session is scheduled for Tuesday, the "Aller" of the new Prosit will be on the following day (Wednesday).

Beside the sessions described in the panel, we have chosen to put a safety net to learners. The purpose of this safety net is to ameliorate learners' knowledge. This safety net is in three forms:

- A session of "restructuration course",

• A session that we call "tutored session",

• A space under our eLearning platform Moodle.

The session "restructuration course" lasts for 1h30. It is provided by another teacher who adopts a traditional methodology. This session will review the objectives of Prosit completed within the week. The process of restructuration is taught based on questions asked by students about various problems encountered during the resolution of Prosit and tutor's feedbacks. We scheduled the session at the end of the week after the "Retour" session.

To better support learners we have added a session called "tutored session." The tutor continues to coach learners on the current Prosit. Learners who still have ambiguity on already treated Prosits can contact the tutor who will give them direct answers.

The e-Learning space we have provided to our students is a space for sharing information among all eight classes including their teachers. This space also offers to students: reference documents, a discussion forum, a forum for learning exercises and multiple choice questions.

3 Description of the module

At the end of the module, the learner can apply the basic concepts of algorithms and knowledge of basic procedural programming. The student can then apply the various stages of development of a simple program:

• Specify a problem: what is given, what is the result.

• Define and implement an algorithm to solve this problem.

Therefore, the module learning outcomes are:

1. Performing the syntax and semantics of the algorithmic language with charts.

2. How to use a C language development environment. The learner should be able to: create a C source file, compile it and run it.

3. Handling variables: define, initialize, capture, view and assign a value.

4. Put into practice the sequence of actions via the control structures: if, if else and switch: if, if else and switch of the C language.

5. Put into practice the three types of repetitive structures: for, while, and do while of the C language.

6. Define and use a one-dimensional array and two-dimensional (matrices).

7. Define and use a chain of characters in C.

8. Knowing and putting into practice the basic algorithms for handling tables and strings: enter, view, search, copy, browse, insert, delete, and concatenate compare.

9. Apply one of the usual sort methods: Sorts spirit, sort and insertion sort by selection.

10. Define a function and use it.

11. Put into practice the different parameter passing modes for functions:

a. By value

b. Passing through address and use of pointers

12. Know and put into practice the principles of modular programming: header (.h) and source (.c)

4 Application of the approach

The module is planned during the first semester of study year. It is spread over 15 weeks. Table 1 contains all the Prosits that were performed weekly and the targeted objectives and assessments.

Table 1: Module organization during the semester

Week	Prosit	Learning Objectives	Assessment
week 1	Prosit0	Initiation	
week 2	Prosit1	Conditional structures	
week 3	Prosit2	Repetitive loops	
week 4	Prosit3	Tables	Oral 1
week 5	Prosit 4	Functions	
week 6	Prosit 4 bis 1	Functions	
week 7	Prosit 4 bis 2	Functions	
week 8		Break	
week 9			Intermediate exam
week 10	---	Back on all Prosits	
week 11	Prosit 5	Functions and Pointers	
week 12	Prosit 5	Functions and Pointers	Oral 2
week 13	Prosit 6	Functions and Matrices	
week 14	Prosit 6	Functions and Matrices	
week 15			Final exam

As indicated in Table1, a Prosit usually lasts a week or more. Each Prosit introduces new objectives with some notions proposed in the previous one. To be more effective, we designed most of the problems unresolved and ill-structured (Barrows, 2002).

In order to encourage the learner checking on his achievements more often, we planned four evaluations throughout the whole semester. We scheduled two types of evaluation:

- Oral
- Practical Test: the Intermediate and final exam are practical.

In the oral, learner randomly selects an exercise to correct on the white board. The teacher discusses with the learner about his solution and asks him some questions. The learner has 15 minutes to think and then 15 minutes to explain his/her solution and answer the questions.

However in practical tests, the learner has a written situation and an evaluation grid. The exam is a problem resembles to a Prosit. The learner conducts his examination on his computer accessing to all documents but in airplane mode. At the end of the exam, the learners leave the classroom and then come back one by one to discuss their solution with a teacher.

At the end of the module, each student will have spent a total of four evaluations: two oral and two practice exams which one is the final exam. The module average is calculated as follows:

$$\text{Average} = \text{Oral1} * 0.1 + \text{Oral2} * 0.1 + \text{Intermediate exam} * 0.3 + \text{Final exam} * 0.5$$

Concerning the space on the e-Learning platform Moodle, we have all the study materials to assure all learning outcomes. We have also added the discussion forums and useful links. The formative MCQ (Multiple Choice Questions) focused on new knowledge that has been acquired and each time they are activated after Prosit “Retour” session and before the restructuration one.

5 Soft Skills

The approach used in this module is not intended to only develop the hard skills of learners but also their soft skills. In the first semester, our school decided that teams will be random. This situation is close to working life where team members don’t select their colleagues. The learner will have to work and play in his team. To succeed in this module, each student must make efforts to improve its soft skills as:

- Communication
- Team spirit
- Autonomy
- Organization

In Tunisia, the educations of the young people aged from 6 to 17 years have mainly traditional courses with occasional assignments. Thus, our students are not used to working in teams and evolve. We also have entered heterogeneous in terms of initial training: some had already algorithmic courses and Pascal programming not. These two points have made teamwork difficult.

For the team to succeed, students must develop a collective intelligence and realize and interdependence. Therefore, learners worked on Prosits that required not yet studied knowledge. This has helped them become more self-reliant, independent of the teacher and interdependence between them.

We noticed that students pose questions to the tutor before they discuss it with his team especially those who have had no programming courses before coming to our school. We asked tutors to apply a simple rule: do no individual discussion and respond only to questions on behalf of the team. So we pushed the team to discuss internally the different points before turning the tutor. Learners who have a good level then explained to the other member’s points "easy" in the Prosit and the team keep only the ambiguities question to the tutor. This has improved communication between members and their team spirit.

This teamwork allowed the students, especially the best, to discover that they can find answers among some members of their team, which improved the interdependence home.

As all modules are taught with an active approach to teaching, students have found themselves forced to manage their schedules to get organized and well done learning.

6 Results

6.1 Method

This study was conducted at the first semester of the academic year 2012/2013. Quantitative measures were applied to answer the research question: “What will the students respond to a PBL based active learning approach?”

A total of 215 first year students enrolled in 7-credit first semester “Procedural programming” course participated in the study. This course is dedicated as a first level course in the software engineer study. On average, study participants were between 19-23 years old and none had ever taken courses with PBL approach.

We asked the students to give us their feedback using a paper survey at the end of the academic year 2012/2013. The survey was anonymous. We received 196 responses from 215 registered students which is 91.16% of participation rate. We used Excel 2007 to analyse the responses.

We also studied the scholar results of the learners in the academic year 2011/2012 and 2012/2013. It should be noted that according to Bigg's model (Bigg’s, 2003), we have changed two lines in three, namely: "the assessment regime" and "teaching and learning activities", and we kept the same learning outcomes for both years.

Finally we will share some testimony from the learners on this experience.

6.2 Scholar results

We compared the scores obtained in this module compared to the previous year. We have kept the same learning outcomes between the two years. In 2011/2012, we had 120 students enrolled in the first year spread over fourth groups of 30 students each. In 2012/2013, we had 215 students in eight groups.

As described in Application of the approach, each learner has spent four exams during the semester and the average will be calculated as follows:

$$\text{Average}_{2012/2013} = \text{Oral1} * 0.1 + \text{Oral2} * 0.1 + \text{Intermediate exam} * 0.3 + \text{Final exam} * 0.5$$

During the 2011/2012, learners had two theoretical tests. The average of a learner in this unit was calculated as follows:

$$\text{Average}_{2011/2012} = \text{Intermediate exam} * 0.4 + \text{Final exam} * 0.6$$

All teachers testified that the 2012/2013 the exams are more difficult than those of the previous year and allowed to make more than the achievement of learning objectives as those of the academic year 2011 / 2012.

Table 2 shows the difference between summarize the progress of the teachings of the module during 2011-2012 and 2012-2013.

Table 2: difference between the progresses of the teachings of the module

	2011-2012	2012-2013
Learning outcomes	Idem	Idem
Number of learners	120	240
Number of groups	4	8
Number of teams	--	6 teams /group
Number of assessments	2	4
Nature assessments	Theoretical	Oral or practical
Formula averaging	Intermediate exam * 0.4 + Final exam * 0.6	Oral1 * 0.1 + Oral2 * 0.1 + Intermediate exam * 0.3 + Final exam * 0.5
Teachers' opinions about the assessments	Do not measure all the learning outcomes of the module.	More difficult than those of the previous year and contributed to ensuring the achievement of learning outcomes.

The evaluation model of change was made in response to a feedback made by teachers who thinks that the theoretical evaluation adopted doesn't allow them to check all the learning outcomes.

In Tunisia, our learners are evaluated with scores between 0 and 20. To validate a module, a student must obtain at least 10. We are interested in the results in two ways:

- Learners who validate the module or not: average bigger or lower then 10,
- Average distribution interval.

Figure 2 shows the effectiveness of the adopted pedagogic approach and the evaluation method followed during the 2012-2013 academic year from that used during the 2011-2012. Indeed, we noticed an improvement compared to the number of learners who validated this module: 55.9% in 2012-2013 versus 50.4% in 2011-2012.

In Figure 3 we looked more deeply into the results to have a clearer idea of the impact of the educational approach. The results show that the approach has helped to double the number of excellent learners for average between 16 and 20 and 1.5 for ratings between 14 and 16. This approach has also reduced the number of learners with an average between 10 and 14 which we consider positive. Indeed, learners who belong to this average class have a lack in the learning outcomes to acquire.

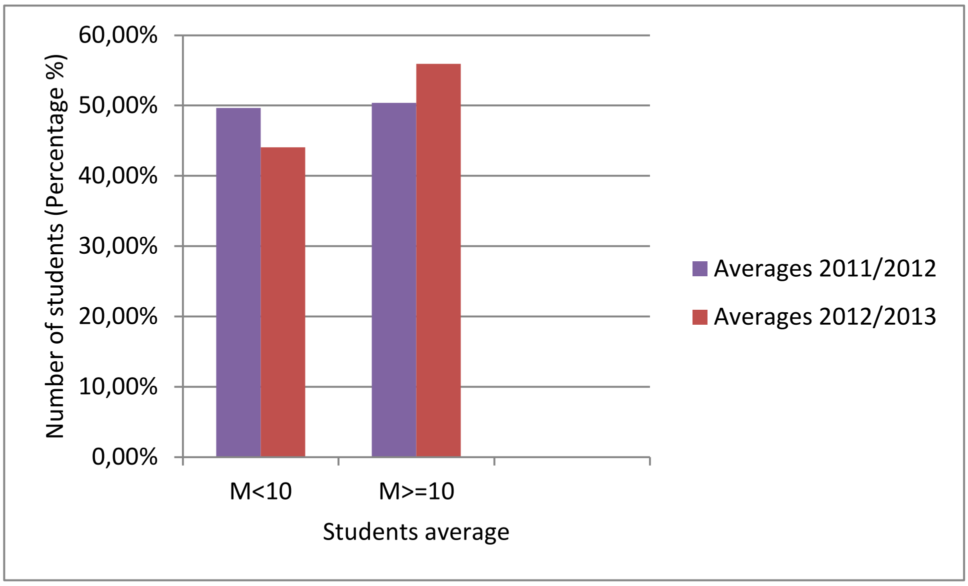

Figure 2: Module average compared to 10

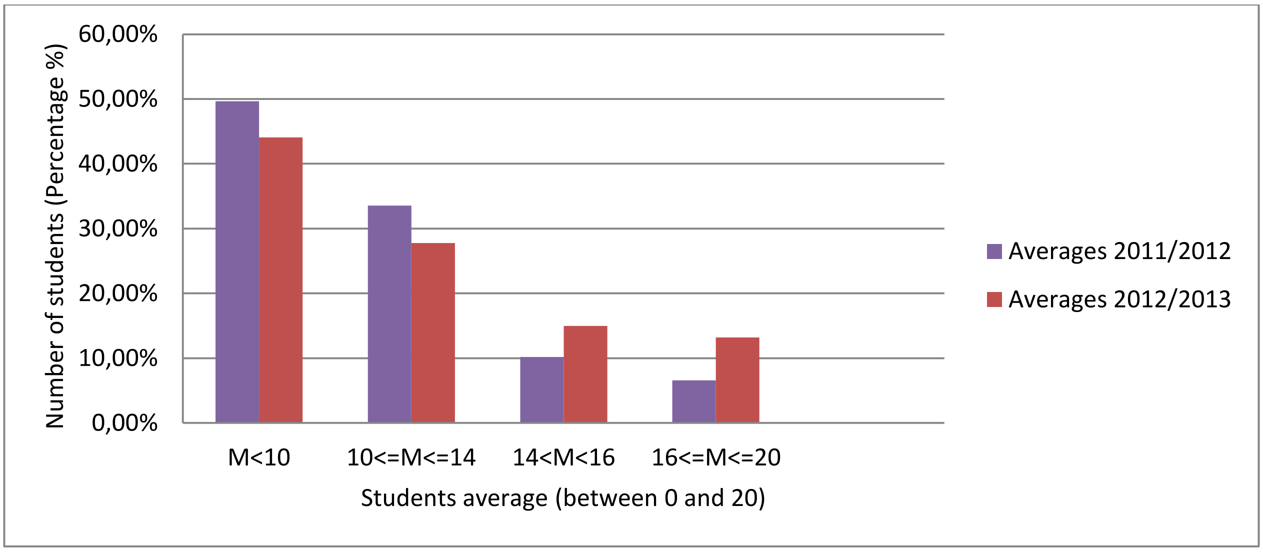

Figure 3: Module average per interval

6.3 Survey results

We asked the students to give us their feedback using a paper survey. The survey was anonymous and conducted at the end of the academic year. We received 196 responses from 215 registered students which is 91.16% of participation rate. The survey was 26 questions long about team work and overall satisfaction. Question with results are listed here in three tables Table 3: Teamwork, Table 4: Contribution of each of the following in your skills and Table 5: Overall Satisfaction.

Table 3: Teamwork

	Totally disagree	Disagree	Neutral / no opinion	Agree	Fully agree
We work better as a team	10,71%	21,43%	12,24%	43,37%	12,24%
Our collaboration within the team was not up to my expectations	10,71%	27,55%	19,90%	30,10%	11,73%
We communicate with each other effectively	6,12%	20,92%	19,39%	38,78%	14,80%
I felt that we are not working as a team, the individual contributions are not balanced	12,04%	24,61%	21,47%	27,23%	14,66%
The role of the leader is essential for the proper performance of the team's work	6,19%	13,40%	22,16%	35,57%	22,68%
All my teammates have contributed to the achievement of the required work	13,33%	20,00%	15,38%	36,92%	14,36%
I feel confident working in teams	5,67%	17,01%	20,62%	39,18%	17,53%
Teamwork was a good experience	7,77%	6,74%	12,95%	38,34%	34,20%
I received useful and constructive comments of my teammates	7,18%	13,33%	17,95%	44,62%	16,92%

Table 4: Contribution of each of the following in your skills

	Very Low	Low	Neutral / no opinion	Important	Very important
The use of problem situations	10,94%	18,23%	25,52%	36,46%	8,85%
Productive work in a team	5,73%	13,54%	16,15%	51,56%	13,02%
Participation in discussing with the team members	4,74%	16,32%	13,16%	39,47%	26,32%
Participation in discussing with other colleagues teams	7,41%	19,05%	22,22%	33,86%	17,46%
Using references recommended by tutors and teachers	12,50%	15,63%	16,67%	36,98%	18,23%
The relevant information retrieval from the Internet	4,19%	9,95%	15,18%	32,98%	37,70%
The analysis and synthesis of information	4,74%	12,11%	24,21%	39,47%	19,47%
Colleagues as teachers	10,42%	16,15%	27,08%	28,65%	17,71%

Table 5: Overall Satisfaction

	Totally disagree	Disagree	Neutral / no opinion	Agree	Fully agree
Learning with PBL was a good experience	19,79%	19,79%	13,02%	29,17%	18,23%
I feel I can improve my ability to work in teams	5,21%	15,10%	19,27%	43,23%	17,19%
I am happy with my contribution in the work of my team	8,33%	11,46%	18,75%	38,02%	23,44%
The quality of supervision was excellent	18,23%	23,96%	24,48%	24,48%	8,85%

Our collaboration within teams could have been better	5,79%	11,05%	18,42%	43,68%	21,05%
Overall I am satisfied with my experience during this semester	7,81%	10,94%	15,63%	44,79%	20,83%
I'll do better next semester	2,63%	1,05%	17,37%	40,53%	38,42%
I want to go back to the classic teaching method	20,00%	20,00%	20,00%	20,00%	20,00%

As we can see in Table 5, ~40% find that learning with PBL was a bad experience and 40% want to go back to the classic pedagogy. Since this survey was conducted after the end of the courses, we can see that there is 44.1% of students didn't validate the course (see Figure 2) which is approximately the same ratio of the students who don't like this approach. In the other hand, we see that 65.62% are satisfied with their experience, 64.73% say the collaboration within teams could have been better, 60.42% say they can improve their ability to work in teams and 78.95% say they will do better next time. Also in Table 3: Teamwork, 72.54% say that teamwork was a good experience. We concluded that it's possible to continue using active learning with these students but we have to find and correct issues.

In the other hand, we find in Table 3 that only 55.61% say that they were working as a team. Also only 36.65% consider that the individual contributions were balanced. 38.27% see that their collaboration within the team was not up to their expectations. We can confirm that working as a team was a challenge for many students and that's why they dislike this approach. We should find some toolbox for learners to collaborate better. To do that, we should consider these answers in Table 3: 27.04% don't communicate with each other effectively, 58.28% agree or fully agree that they need a leader for the proper performance of the team's work and 33.33% find that some teammates didn't contribute to the achievement of the required work.

As we can see in Table 4, students consider that these elements contributed in important or very important way in their skills acquisition: 64.58% Productive work in a team, 65.79% Participation in discussing with the team members, 51.32% Participation in discussing with other colleagues teams and 46.35% Colleagues as teachers. 61.45% say that they have received useful comments from their teammates and 56.71% feel confident working in teams (Table 3). We consider that we have acceptable results for soft skills part and peer to peer learning in this experience.

Finally, only 33.33% was satisfied on the quality of supervision (Table 5). Indeed, our teachers never used this approach and have not received training on supervision.

6.4 Testimonials

We asked the students to give us their feedback and their views on the approach adopted in the module before the final exam. Each group sent his opinion as a poster or a video. Learners were divided between those who are for and those cons. Here some of them:

- APP - What you think? (class 1A3): http://youtu.be/IO6PZyzkyvA (in French, with English subtitles)
- Yes/No video (class 1A4): http://youtu.be/8vuPh-pxmgI (in French, with English subtitles)
- Posters: https://plus.google.com/105371880651878679692/posts/Ryhno8qRJjg (in French, with English comments)

7 Conclusion

In this paper, we presented our implementation of an active learning approach based on PBL in a programming course. The purpose was to ascertain whether our PBL based approach represents a viable alternative to traditional lecture based. During the first semester of the academic year 2012/2013, 215 software engineer students enrolled in first year study at ESPRIT University completed the course of a 15-week semester.

The results of the study showed that overall our active approach motivates more our students and positively influences not only their grades with good assimilation of learning outcomes of the module but also on improving their soft skills.

Due to the positive results, ESPRIT University decided to adopt the active approach in other courses in different level.

While the results are encouraging, we found that many improvements should be made such as in problem situations we give to students or the facilitator work way. Two further experiments were made in this course with the same population (first year students) during the 2013-2014 and 2014-2015 will be described in other papers.

8 References

Biggs. 2003. Aligning Teaching and Assessment to Curriculum Objectives, (Imaginative Curriculum Project, LTSN Generic Centre).

Louati, Bettaieb, Derbel. 2014. *TEAM BASED LEARNING IN MATHEMATICS COURSES.* SEFI.

Lison, Bédard, Côté. 2015. *Être tuteur en apprentissage par problèmes : quels styles d'animation ?.* Ripes.

Barrows, H. S. .2002. *Is it truly possible to have such a thing as dPBL?*. Distance Education, 23(1), 119-122. http://dx.doi.org/10.1080/01587910220124026

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PBL Model for Single Courses of Control Education

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Abstract

This work introduces a Project-Based Learning model for single courses of control system that belong to traditional education curricula. The PBL is applied to facilitate the learning, encourage the development of transversal skills from technical areas, stimulate the use of active learning in engineering programs, and try to give a response to research question how to apply PBL in single courses of engineering that belong to Traditional Education curricula? . The model is conceptualized from two experiences, one experience was developed at Universidad del Valle, Cali, Colombia, and another one was carried out at Universidad Pedagógica y Tecnológica de Colombia UPTC, Sogamoso, Colombia. The PBL model takes into account the culture and customs of each region as well as the facilities of Universities and their policies. The model takes advantage of support resources of traditional education, designs new web-based and local resources to facilitate the PBL application and involves diverse activities around a project aimed to solve a control problem. The model also motivates the development of transversal competences like decision-making, problem solving, self-learning and information management.

Keywords: project-based learning; control education; transversal competences;

1 Introduction

Currently, many researchers around the world work about how to apply and evaluate the Problem- and Project-based learning (PBL). In the engineering education, there are experiences about the curriculum design as those presented in (de Graaff and Kolmos 2007, Du, De Graaff, and Kolmos 2009) that can consider both curricular and organizational transformations of the institutions. There are also experiences oriented to a particular subject, among others are: processing signal (Pardo 2014), computation (Indiramma 2014), industrial electronics and electrical power(Quesada et al. 2013, Hosseinzadeh and Hesamzadeh 2012), FPGA (Kumar, Fernando, and Panicker 2013, Kiray, Demir, and Zhaparov 2013) and control (Shaoqiang and Zhihua 2012); in which, PBL models are centered in a single course, these results are a good option when an organizational change is more difficult to achieve, because it requires to issue new institutional policies or a long time. Usually, these experiences are encouraged by teachers that want to have the advantages of the PBL Education in their courses and whose courses are oriented to develop competencies in a professional area. The work presented herein focuses on a PBL model for single courses of automatic control systems that belong to traditional education curricula.

Control system education demands an educational model that *i)* balances education in mathematics and education in the discipline (theory and practice) (Kheir et al. 1996); *ii)* is according to the needs of industry and the requirements to work in professional fields; *iii)* encourages the development of generic skills (Fernández-Samacá, Ramírez, and Orozco-Gutierrez 2012); *iv)* uses of new technologies and resources based on the web (Dormido 2004); *v)* can be spread to other engineering fields to meet the requirements of new research areas; *vi)* addresses the challenges and solves problems in an interdisciplinary way (Samad and Annaswamy 2011), and *vii)* takes the education of primary and secondary as a stage to motivate its study as well as that of mathematics and science (Murray 2002).

Project-based learning results a good alternative to meet the requirements of control education, because as it is stated in (Kolmos et al. 2008), this promotes deep approaches of learning instead of surface approach, improves active learning, develops criticality of learners, improves self-directed learning capability, increases the consideration of interdisciplinary knowledge and skills, develops management, collaboration and communication skills, develops professional identity and responsibility, and develops and improves the meaningful learning.

The proposed PBL model searches to facilitate the student learning, encourage the development of transversal skills from technical areas and stimulate the use of active learning in engineering programs. This paper presents an experience developed by the Industrial Control Research Group (GICI) of *Universidad del Valle* (UV) and the Processing Signal Research Group of *Universidad Pedagógica y Tecnológica de Colombia* (DSP-UPTC), two Colombian public Universities located, respectively, in Cali and Sogamoso (650 kilometers each other), Colombia.

The PBL model takes into account the culture and customs of each region as well as the facilities of Universities and their policies, (Fernandez-Samacá et al. 2014). Likewise, the model takes advantage of support resources of traditional education and proposes new local and web-based resources and activities around a project aimed to solve a control problem. Regarding to the project, each institution manages its execution. Thus, particular approaches for each program are developed based on the general PBL model; for example, the approach of *Universidad del Valle* (Univalle PBL) stresses on the solution of the problem based on the local context by using industrial prototype plants and devotes mainly in the development of teamwork and communication abilities. On the other hand, the approach of UPTC emphasizes in the case studies by designing homemade prototypes with inexpensive elements and focuses on resourcefulness and creativity. In both cases, the project is developed in stages during two semesters in 16-week periods by student teams that have access to diverse common web- and local-lab resources oriented to the project execution. Therefore, the model considers two dimensions: the 'pedagogical' one that defines the PBL approaches and 'facilities’ that corresponds to the design of learning support resources, (Fernandez-Samacá et al. 2014).

This work is based on previous experiences developed by the GICI group through research projects whose results are presented in (Ramírez et al. 2008) and (Fernández-Samacá, Ramírez, and Orozco-Gutierrez 2012), and aims to answer mainly three questions related to the adoption of PBL in specific areas or courses. The first question is how to apply PBL in single courses of engineering that belong to Traditional Education curricula? The second one is how to provide to students of support resources that allow them to have a PBL environment? Finally, the third question is how to connect the developed PBL environment with the rest of curriculum? The results reported in this paper are focused mainly in to answer the first two ones.

1.1 Methods

In order to solve the research questions, researchers defined a project entitled ‘Project based learning Enviroment for Control Systems’, which was co-funded by the *Departamento Administrativo de Ciencia, Tecnología e Innovación* COLCIENCIAS of the Colombian Government. The main objective of the project is to design a PBL Environment that can be used in different contexts. Therefore, the research project was developed in two public Universities, located in different regions, that have similar programs but with remarkable differences in their industrial and social contexts.

In both Universities, PBL approaches were developed based on the 'PBL alignment model' proposed in (Kolmos, De Graaff, and Du 2009) and diverse local and web-based resources were designed. Thus, the comparison of the contexts is the analytical framework for the collection of data from the two cases. The authors from the two universities collected data by observing academic activities related to the project execution, and by applying a survey focused on knowing the students' impressions about the approaches and designed resources. From the literature review and previous experiences, researchers conceptualized a first version of a PBL model for single courses, which was adjusted from observations of approaches and collected data. The description of this PBL model is the core of this contribution.

2 PBL Model

The PBL model takes into account how to apply the PBL and which resources to use. Both the PBL approach and resources are major challenges, the first one to develop a PBL alternative for specific courses into a traditional curricula and second one to find solutions to needs of a PBL approach according to its philosophy. The dimension of the 'facilities' is strongly tied to the 'pedagogical' one keeping a relationship of reciprocity that is preserved in the design of the whole model, (Fernandez-Samacá et al. 2014). Figure 1 summarizes the PBL model and the relationship between the two dimensions.

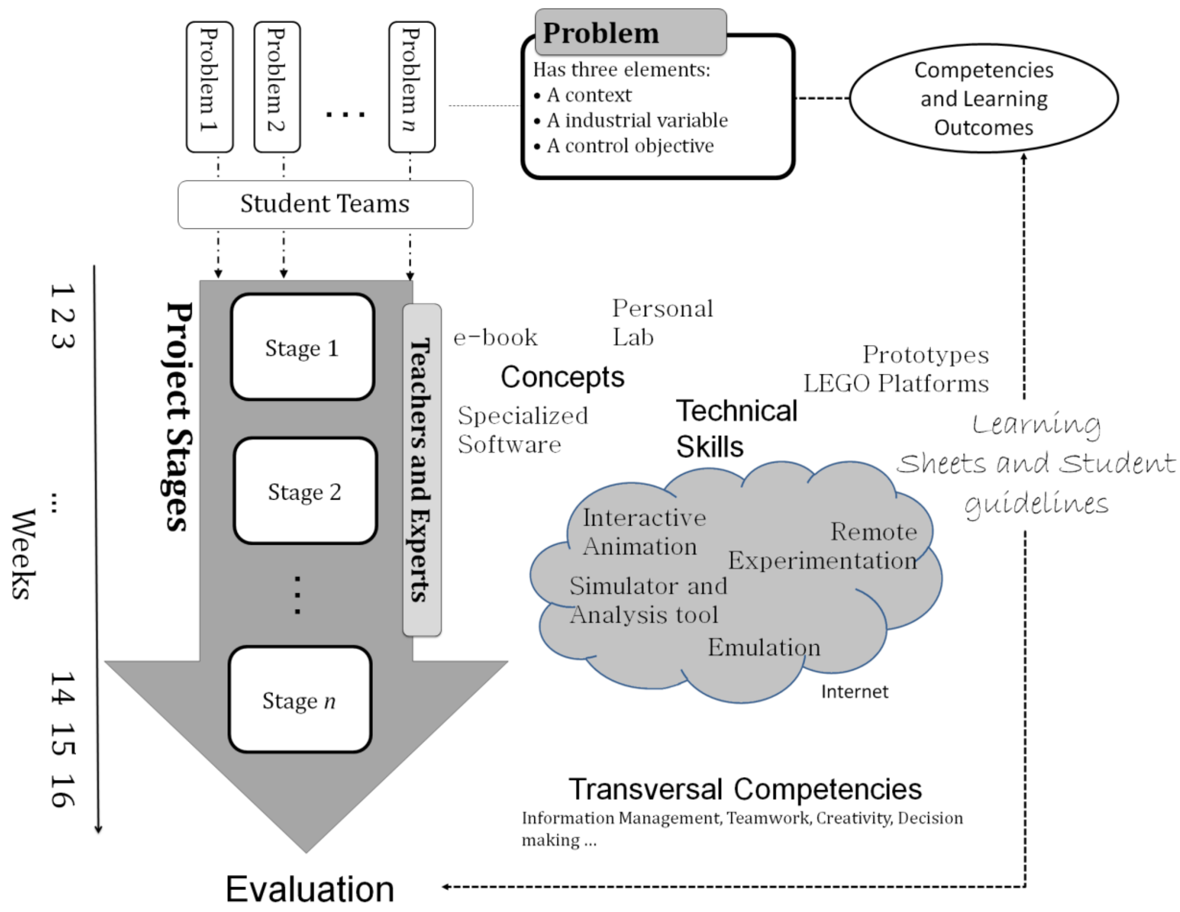


Figure 1: PBL model for curses of Control System, (Fernandez-Samacá et al. 2014)

The objectives of control courses are similar at the both Universities. The courses deal mainly topics like the modelling and analysis of linear control systems, time domain analysis of analogue and discrete systems, frequency analysis, input-output identification, state space models and controller design by using classical control theory. In the design of controllers, the course deals topics like pole location, analysis of the root locus and frequency response, the design of observers and state feedback controllers. These topics are associated to four basic concepts of control discussed in (Kheir et al. 1996); namely, system dynamics, stability, feedback and compensation.

The courses use examples of electrical, gas, fluid, mechanical, thermal and servomechanism systems, among others. The PBL model also takes advantage of contextual topics as sugar cane factories of the Valle del Cauca province, the region in which the Universidad del Valle is located, and underground mining process, one of the local industries of Boyacá province in which UPTC is established. The PBL model considers the development of transversal competencies such as teamwork, self-learning, communication skills, resourcefulness and problem solving as an objective of the courses.

In the both Universities, the PBL model has been applied to the control courses for the Electronics Engineering program. In the UV, the control area has four courses (two theoretical and two lab courses); the first course is Foundations of Linear Control Systems and the second one is known as the Compensation and Analysis of Linear Systems. The theoretical courses have three academic credits (In Colombia, one academic credit = 48 student working hours) and the lab courses have one credit. The program of Electronic Engineering of UPTC has two courses, System Modelling and Control, with three academic credits each one. In both Universities, the courses are developed during two semesters in the third and fourth year of Bachelor (In Colombia, the bachelor is five years long).

2.1 Pedagogical dimension

Table 1 shows a comparison of the PBL approaches based on 'PBL alignment of elements in the curriculum' model proposed in (Kolmos, De Graaff, and Du 2009) that takes into account seven elements to describe a curriculum. The comparison of these approaches was widely discussed in previous contributions as (Fernandez-Samacá et al. 2014). For this reason in this paper, authors emphasize on the elements of the PBL model that orients these approaches.

Table 1: Comparison of PBL approaches. Pedagogical dimension of PBL Model

Elements	UV PBL approach	UPTC PBL approach
1. Objectives	Learning about Modelling, Analysis, Compensation and Control Systems Encouraging the development of transversal competencies	Learning about Modelling, Analysis, Compensation and Control Systems Encouraging the development of transversal competencies
2. Problems, projects and classes	Challenges of context The project organizes academic activities and evaluation Hands-On activities and Interactive animations, e-book	Case Studies The project is performed in parallel with the development of the theory Classical Lectures and Hands-On activities, e-book
3. Progression, size and duration	Project executed in stages Project rotation among teams Two semesters (Learning Outcomes per stage)	Project executed in stages No rotation of projects Two semesters (Learning outcomes per semester)
4. Students learning	Besides those of the control area are: Teamwork, time and information management, self-learning and	Besides those of the control area are: Resourcefulness and creativity, self-learning, teamwork and problem

	problem solving	solving
5. Academic staff	A teacher for the theory and another for labs	A teacher for the theory and a senior student for labs
6. Space and organization	Didactic prototype Local- and web resources and traditional education spaces	Plants built by students Local- and web resources and traditional education spaces
7. Evaluation	Oral presentation and reports Assessment by teachers, peer-assessment and self-assessment	Oral presentation and posters Assessment by teachers

Pedagogical dimension devotes to aspects related to 'how to design academic activities around of the project execution for achieving the learning outcomes'. As it is shown in Figure 1, the pedagogical dimension stresses on the kind of problem; size, duration and following up of the project; student teams, didactic design of classes; the assessment instruments and global evaluation of the course. The challenge is to coordinate all these aspects so students are in a PBL environment despite of the courses belong to a traditional curriculum.

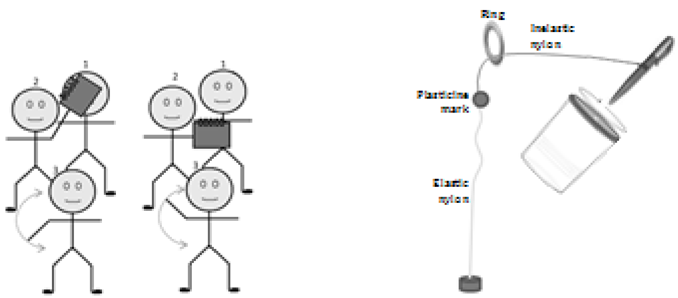
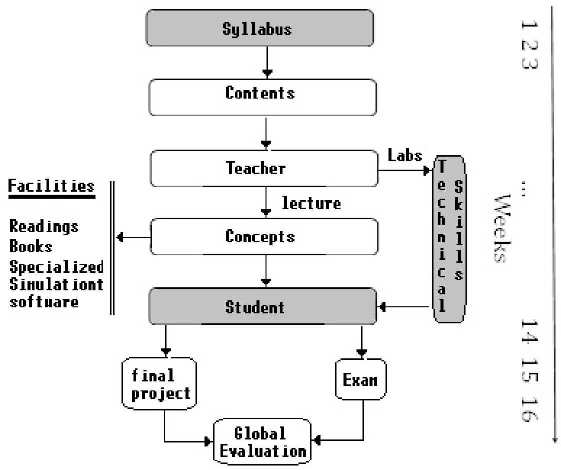
Universidad del Valle	Project Stage: 2	Version: 01 07/05/2013
	Content card: Transfer Function	
Technical competencies summary	Modeling controlled systems (CL5) Modeling control systems, analog and digital, using transfer functions and state variables (CD6)	
Objectives	Get the model and represent a system transfer function	
Contents	Laplace variable "s", transfer function G in continuous time (s), variable 'z', transfer function in discrete time G (z), pulse transfer function, transfer matrices	
Learning Outcomes	Students be able to: Obtain a nonlinear analytical model for open loop systems (RA 2.1). Identify the main non linearities of control systems (RA 2.2). Linearize mathematical models (RA 2.3). Obtain the continuous transfer function (RA 2.4). Obtain the discrete transfer function of the controller (RA 2.5). Obtains the pulse transfer function of the control system (RA 2.6). Gets simplified mathematical models for monitoring (RA 2.7).	
Learning resources	e-book; emulator; remote and personal laboratory	
Hands-On	 Modeling Differential Equations Nyquist-Shannon theorem	
Evaluation	Theoretical exam, written report and oral presentation	

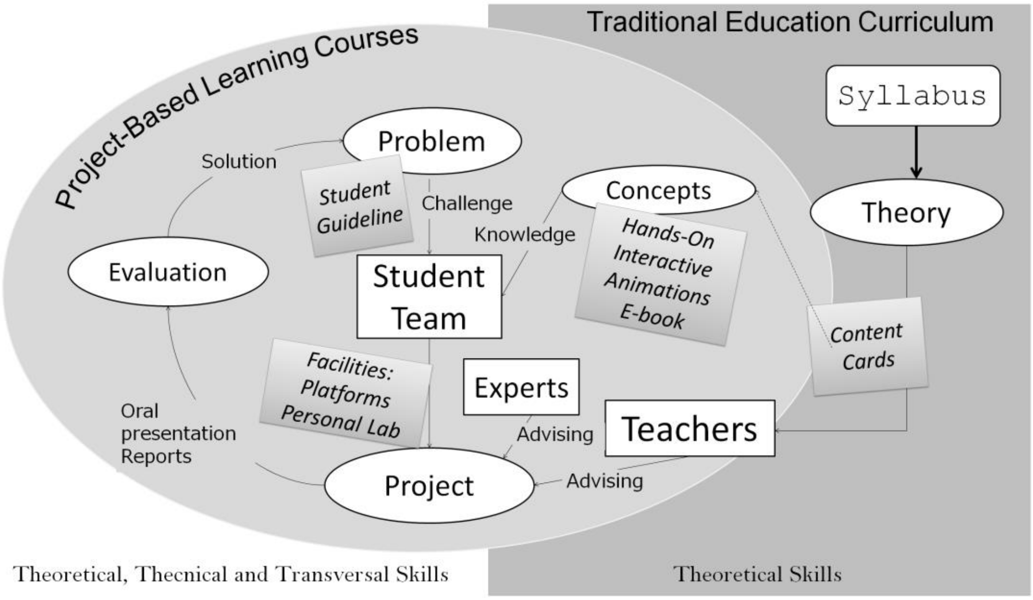
Figure 2: Content card for Transfer Function topic. Project stage # 2

The PBL model considers two types of learning outcomes, those own of control learning, and the development of transversal competencies. Taking into account that the proposed PBL model searches to motivate its application in other engineering programs and be as a reference to other knowledge fields, this considers the analysis of contents of the previous traditional courses as a 'connector' between traditional curriculum and PBL courses, and as a start point to change the educational approach. It is important to identify how and where the topics are used, update the course contents and reorganize them according to their use in real applications of the professional field, (Fernandez-Samaca and Ramirez 2010). For the management of student learning regarding to disciplinary knowledge, researchers developed 'Content cards' with the most common topics in syllabus of Control System courses. Figure 2 shows an example of a Content card for the topic 'Transfer Function'. Teachers in each institution are free to adapt and adjust the cards according to the contextual requirements and constrains.

The content cards relate the stages of project, content, course objectives, learning outcomes and possible support resources that teacher can use in each topic. Each card provides an overview of recommended aspects for learning the key concepts. Learning outcomes and competences that are not explicitly on the cards can be associated or related to concepts presented through other learning or evaluation activities. Each competency and learning outcome has a specific code that identifies it; likewise, this code allows knowing which other contents deal for the same competencies or learning outcomes. Note that the content cards are guides for teachers about how to orient the learning of the subject and a connection between the content and project. However, content cards are not guidelines for the project execution, this depend on the own PBL approach of each institution. Usually, the student guideline describes the PBL approach by presenting the problem definition, course assessment and schedule of the deliveries.



a) Traditional Education course



b) PBL Course in a Traditional Education Curriculum

Figure 3: Comparison between a Traditional Education Course and PBL single courses

Figure 3 presents a representation of a Traditional Education course, and the PBL model and its relation with Traditional Education. Whereas the Traditional Education course (Figure 3a) follows a vertical development, in which the project is only an assessment activity, the PBL courses (Figure 3b) are an exchanging environment, in which elements are correlated around the project execution. In other words, the PBL model focuses on the student work and its main characteristics can be summarized as follows: *i)* The use of several kind of problems, which are defined by the teacher taking into account the context, for example, industrial problems or research challenges, (Fernández-Samacá, Ramírez, and Orozco-Gutierrez 2012). *ii)* The project execution by using stages centred on learning outcomes, where each University can define stages according to their facilities, policies about grades and academic periods (duration, deliveries and evidences related to each stage). *iii)* The design of learning activities and didactic resources that offers an active learning environment for students. *iv)* Advising by teachers and experts in the project issues. *v)* Planning of academic activities according to the project execution. *vi)* Teachers working in teams to organize the course activities. *vii)* The use of resources to encourage the self-management of the learning process. Moreover, *viii)* Content cards for connecting the traditional education curriculum to the PBL in single courses.

The problem definition, project execution, assessment, delivery requirements at the end of each project stage, and the availability and use of the designed resources, all these elements define a framework that encourages the development of transversal competencies, which are considered essential in the model. Transversal competences are not in the content cards because its development does not depend directly on the disciplinary content.

As it was highlighted above, another important aspect in pedagogical dimension is the 'advising', usually in traditional education this is a task of the teacher. However, in PBL, the role of facilitator and expert is very important to support the student work; therefore, to define strategies for orienting students during the project execution and helping them to solve opportunely their doubts and misconceptions, it is important for the learning process. An important step to walk from traditional education to PBL is to have a teacher team instead of a single teacher. This means, for example, two teachers together working in both courses instead of each one in a course.

In short, the objective of the ‘pedagogical dimension’ in the proposed PBL model is to have a PBL space into a Traditional Education Curriculum.

2.2 Facilities

Applying project-based learning to single courses that belong to traditional education curricula demands support resources that allow students to have different facilities to achieve the learning outcomes, manage the project execution and encourage the self-learning.

Table 2: Comparison of a PBL approaches. Pedagogical dimension of PBL Model

Access Nature	Local	Remote
Real	1) Personal Laboratory 2) Prototype plants * 3)Home-made plants 5) LEGO kits *	4) Remote Platforms (inverted pendulums and servomotors)
Simulated	6)Specialized software * 7) E-book	8) Interactive animations 9) Simulator and Analyser 10) Emulation tool

* Learning Resources that are considered within the PBL approaches but were not developed by researchers

The designed PBL model provides a comprehensive learning space that promotes the development of different skills and competencies from a PBL approach. One of the most important challenges is to design support resources taking into account the PBL philosophy. The developed approaches consider 10 types of resources that can be classified based on topology given by (Dormido 2004), see Table 2. Among the resources developed to support learning in control are: a Personal Lab for local experimentation, Remote Access platforms (inverted pendulums at UPTC and servomotors at UV), an e-book, a simulator and analyser, and an emulation tool (real-time simulation), see Table 2. These resources search to face diverse issues of control education and satisfy each one of the needs previously discussed in the Introduction of this work, as follows:

For achieving *i*) a balance between theory and practice as is claimed in (Kheir et al. 1996), the PBL model includes an e-book, a personal lab and interactive animations for the conceptualizing, and LEGO robots, simulation tools and remote platforms for the skills. The Personal Lab is a local and inexpensive resource, in which students can set different systems, allowing the experimentation with dynamics of first order, dead time and integrator; the main purpose of this lab is to facilitate the experimentation at classroom. Moreover, the platforms have user interfaces with interactive menus similar than those available in the Human Machine Interfaces (HMI); thus, the learning environment provided by platforms also search ii) to be according to the needs of industry and the requirements to work in professional fields.

The design of resources takes into account their access, students can manage the resources via Internet according their needs, contributing to *iii)* encourage the development of generic skills (Fernández-Samacá, Ramírez, and Orozco-Gutierrez 2012), mainly those related to autonomy like decision making, information and time management, self-learning and problem solving. Likewise, the PBL model promotes the *iv)* use of new technologies and web- based resources, as it is suggested in (Dormido 2004).

The PBL model considers problems and systems from diverse nature and contexts; therefore, the model motivates the study and application of control *v)* in other engineering fields to meet the requirements of new research areas. Many homemade prototypes have been implemented to recreate case studies and research challenges (*e.g.* pendulums, ball and beams, helicopters, quad rotors and magnetic levitator, among others, have been also central topics in the projects). An important resource is the emulation tools that allow the simulation of systems in 'real time', which are not available physically and whose dynamics are interesting for control education (as examples of these systems are distillation columns, boilers, power generators, etc.) The emulation tools have the advantage of observing the behavior of actual plants or controllers with emulation models in real time; in other words, these tools allow connecting Hardware in line with the simulation model of a system.

The proposed PBL model considers experts from different knowledge field as advisors for the projects for encouraging the interdisciplinary work. Likewise, the contextual problems, which deal diverse topics and challenges, offer a special learning environment that stimulates *vi)* the solution of problems in an interdisciplinary way as it is proposed in (Samad and Annaswamy 2011). Finally, the designed PBL model involves tools as Hands-On (interactive animation) centered to facilitate the understanding topics that result difficult for some students (Ramirez-Ramirez, Ramirez-Scarpetta, and Fernandez-Samaca 2013, Fernández-Samacá and Ramírez 2011). Although, the model does not consider the primary and secondary education as a previous stage to motivate the control study, as it is proposed in (Murray 2002), *vii)* this if stimulates the learning of mathematics and science.

3 Student Feedback

In order to know the impression of the students about the application of PBL in Control courses when these belong to traditional education curricula, researchers designed a survey focused on aspects like the 1) development of transversal skills; 2) concept learning and 3) PBL approach features. The first aspect asks about how the course contributes to the development of transversal skills; the second aspect examines the achievement of learning outcomes; finally, the third aspect aims to characteristics of PBL approaches like the relation between projects and learning, support resources and academic activities.

Table 2: Survey queries

Transversal competences	Learning	PBL Approach
Subject aspect: *The course helps me to acquire:* 1. Skills for working in a team 2. Skills for working in interdisciplinary teams 3. Capability for working by myself 4. Capability to communicate effectively with others 5. Capability to communicate with experts from other disciplines 6. Capability to write reports and respect the copyright 7. Capability to follow standards and templates 8. Capability to manage references and follow academic styles for citing 9. Capability to performance in an oral presentation 10. Capability to solve engineering problems 11. Ability and attitude to research 12. Ability to manage information 13. Capability to manage time 14. Capability to apply the knowledge in the practice 15. The course includes activities that involve the economic analysis of solutions	18. We achieve the course objectives 19. I can model mechanical, electrical, thermal and hydraulic system by using physics laws 20. I can represent the obtained model in transfer functions 21. I can represent the obtained model in block diagrams 22. I can obtain the model of a system by using a step test. 23. I can define the desired specifications for the time response of a system 24. I can identify the control actions by observing the behavior of a system	25. The course uses few lectures 26. The course includes activities for learning concepts different than lectures 27. The developed projects have been encouraging 28. The course includes the use of new support resources that facilitated the concept learning 29. The course includes the use of new support resources to facilitate the development of skills 30. The course evaluation allows monitoring of the learning outcomes 31. The course uses resources in a different language from the native language 32. The problems defined for the course motivated the learning 33. The development of projects allows to manage my learning

16. The course encourages my creativity and innovation 17. The course encourages my resourcefulness innovation		

*The original text of questionnaire is in Spanish

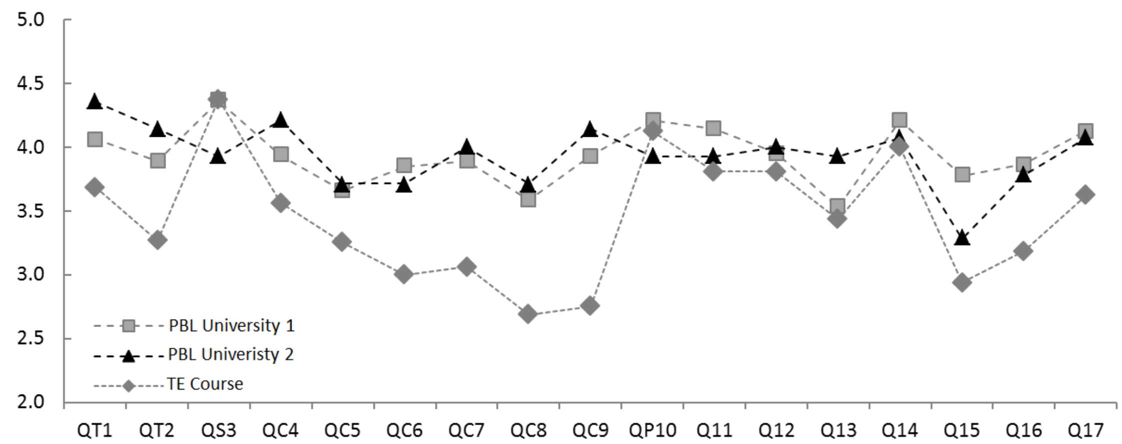
Table 3 has queries of the questionnaire. In the survey, queries are presented as statements and students must choose a score that ranks between 1 to 5 (1 = no compliance and 5 = excellent level of compliance of the statement) to grade the level of agreement or disagreement with the level of compliance of the statement.

The reliability of the survey was evaluated by using the Alpha Cronbach Coefficient (Ledesma 2004); each aspect was independently evaluated. The Alpha Cronbach coefficient is obtained by using Equation (1).

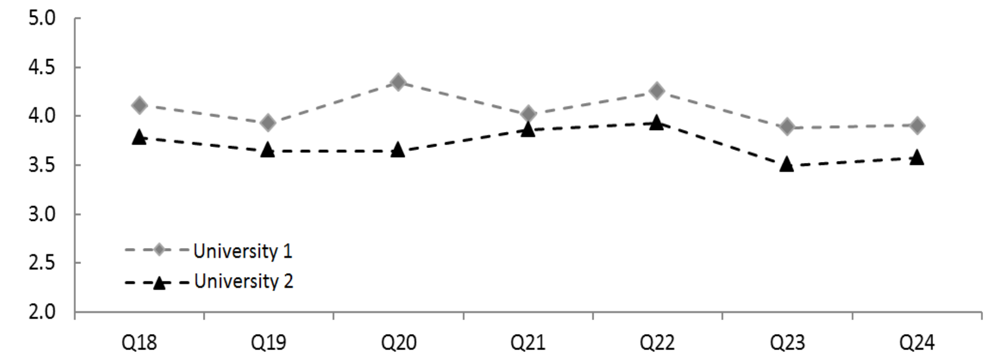
$$\alpha = \left(\frac{k}{k-1}\right)\left(1-\frac{\sum S_i^2}{S_{sum}^2}\right) \tag{1}$$

Where k is the number of the survey items, Si^2 is the item variance, and S^2_{sum} is the total test variance. Coefficient values between 0.8 and 1.0 indicate a good reliability of the survey. The coefficient was 0.951 for transversal competencies aspect and nearly to one for the other aspects.

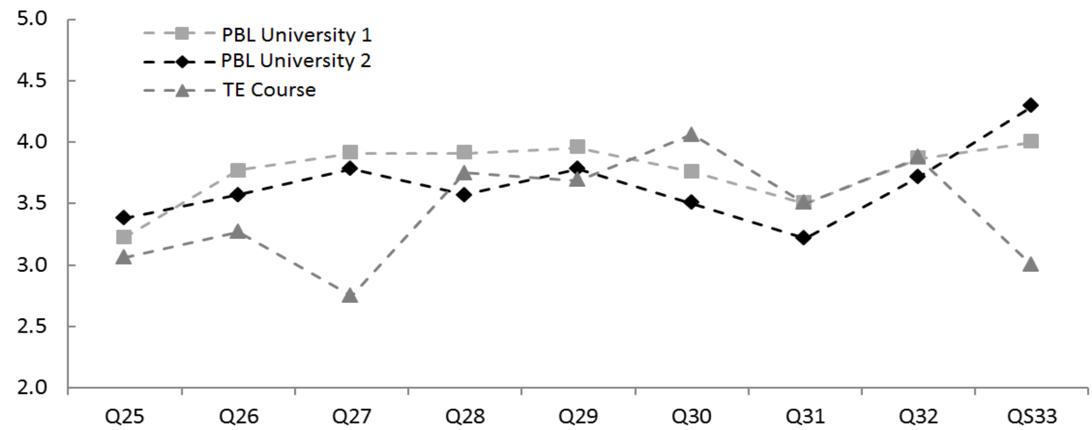
Students of both Universities responded the same questionnaire. Figure 4 shows the obtained results. For 'Transversal competencies' and 'PBL Approach aspects', the results of survey were compared with those obtained in a course that used Traditional Education (ET), which was previously surveyed to the PBL application. In order to avoid the comparison of the performance of Universities, the data present the results without to specify the University. The reader can observe that the tendency is similar in the both Universities because the scores gave by students are comparable; for example, it is enough just to look responses to queries related to the development of transversal competences whose score average obtained in the both programs was 4.1, and standard deviations are between 0.037 and 0.2.



a) Results for Transversal Competences. T=Teamwork, S=Self learning, C=Communication abilities and P=Problem Solving



b) Results for 'Concept Learning' aspect



c) Results for 'PBL features' aspect

Figure 4: Results of student survey. The horizontal axis corresponds to the number of query. The scale used is from 1 to 5, 1 = no compliance and 5 = excellent level of compliance of the statement.

The data shows that PBL approach favours the development of the Teamwork competency, this is evaluated through questions QT1 and QT2; queries that obtained a greater scores in PBL courses, see Figure 4a. Regarding to autonomous learning, the query QS3 was graded with a similar average in one of the PBL courses compared to the average grade given by students in the Traditional Education course and a slightly less in the another course with PBL. This similar behaviour can be attributed to the use of assignments that encourage the autonomy in Traditional Education courses. Another reason could be the use of evaluation strategies as the 'self-assessment', which influence directly skills related to self-learning and self-criticism.

Other skills that are favoured by the PBL approach are those related to the oral and written communication, which was assessed by the set of questions QC4, QC5, QC6, QC7, QC8 and QC9. Figure 4a shows that all questions had significant improvement in their average score in the courses that used PBL compared to the ET course.

Questions Q11, Q12, Q13 and Q14 are related respectively, with the investigative attitude, ability to manage information and time, and the ability to apply knowledge in practice. These queries were graded similarly in both approaches and Universities.

Finally, the queries related to the economic analysis of the solutions (Q15), creativity and innovation (Q16) and resourcefulness (Q17) obtained greater scores in the PBL courses; this means that this approach favours in a better way the development of these competences. However, it is needed to address strategies for strengthening the economic analysis of solutions of problems.

Regarding to the aspect 'Learning', students' scores show the effectiveness of PBL model to achieve the learning outcomes. In this instance, students graded the queries of this aspect with an average score of 3.9. See Figure 4b. They consider that the course achieved its objectives and dealt topics related to modelling in an interesting way. It is important to clarify that teachers performed the following of the learning by using other activities like performance in oral presentation, reports, exams and labs. In other works focused on assessing the PBL impact, researchers have demonstrated the success of PBL in single courses of control education (Fernández-Samacá, Ramírez, and Vásquez 2013, Fernández-Samacá, Ramírez, and Orozco-Gutierrez 2012).

In PBL approach features, the scores have a similar behaviour than in the transversal competences aspect; the query with the best score is Q33, which obtained a score average of 4.0 and 4.3, respectively, in each university. This means that students recognize PBL as a good educational approach to manage their learning. The queries with lowest scores were Q25 and Q31 that correspond, respectively, to the use of classical lectures and resources in a different language from the native language. See Figure 4c. From the survey responses, teachers observed that it is necessary to strengthen activities aimed to study economic issues of problem solutions and improve the use of resources in foreign languages.

4 Conclusions

In both Universities, the courses have similar contents, objectives and learning outcomes, and the PBL approaches follow the guidelines set by the PBL model. Among these guidelines are: the use of several kind of problems, definition of stages for developing the project, advising by an expert in thematic of the project, planning of academic activities according to the project execution, staff teamwork to organize the course activities, lectures that involve active learning activities, use of resources to encourage the self-management of the learning process and the use of content cards to connect the traditional education curriculum to the PBL in single courses. However, each University has adjusted the PBL model through a particular PBL approach, which takes into account constraints own of the contexts. Elements of the PBL approaches have some differences in the order of the topics, contexts and variables involved in the projects and its organization, evidences of learning, academic activities, the evaluation parameters and the use of resources. These differences diversify experiences and scenarios for developing the proposed PBL model.

The designed resources search to facilitate the learning of control, develop technical skills, and offer available tools to students anytime and anywhere, this in order to strengthen their transversal competences like time and information management and decision-making. These resources give to students the needed freedom to manage their learning process responding to their needs and to requirements of the problem and the project. Thus, students have access to physical and virtual labs from the Internet and their work is not limited to traditional curriculum spaces.

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Critical thinking skills assessment with PENCRISAL test in a hybrid approach to PBL

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Abstract

Undoubtedly, the level of achievement that can be expected when implementing PBL methodology is linked to substantial changes in connection to the institution, faculty and students, in such a way that a successful transition towards a learning-centered environment can be achieved. The different PBL approaches, commonly called hybrid methods, frequently show experiences in single courses belonging to a traditional curriculum, which are much more sensitive to the effects of different institutional, administrative and academic factors on expected achievement. The benefits in developing higher order thinking skills than can be achieved in implementing the PBL model, particularly in the training of engineers, are well known. However, in hybrid PBL approaches, these benefits may be affected. Our previous studies in the context of implementing a hybrid PBL approach with freshmen engineering in a Peruvian university showed that one of the most sensitive points was the consolidation of an efficient teamwork dynamic, which is one of the fundamental pillars on which PBL entire process is sustained. These results also showed the influence of this factor on indicators of students' academic performance. In this paper the results of the evaluation of achievements in the development of critical thinking skills in a similar context to the above studies are reported, in addition the level of influence of the teamwork dynamics on the development of these abilities are examined. For the evaluation of the critical thinking skills PENCRISAL test was used, this instrument was developed by a research group at the University of Salamanca (Spain) and validated in both Spanish and Peruvian population. PENCRISAL is set on five factors: deduction, induction, practical reasoning, decision making and problem solving.

Keywords: critical thinking assessment, hybrid PBL, teamwork, higher order skills, engineering education

1 Introduction

Incorporating the development of critical thinking skills in higher education, has become an important need in any professional profile, as they are key tools to address the complexity of life and workplace. It is now recognized that traditional science education does not meet the needs of individuals and societies, as it does not prepare individuals to face current and future challenges of their environment and the world. It is necessary to prioritize the acquisition of methods and ways of thinking in higher education, promoting the acquisition of knowledge through a series of intellectual methods, such as: documentary research, experimental and systematic practice, verification and testing information, modeling, argumentation and performing simulations and stimulating critical reflection on the knowledge handled.

Halpern (1998) remarks the growing demand for a new type of worker who can perform multiple operations, manipulate symbols, abstract and complex ideas, acquire new information efficiently and be flexible enough to recognize the need for continuous change and new paradigms for lifelong learning. On the other hand, the exponential rate at which knowledge grows and people can access a wealth of information; constitute another reason underlying the need for teaching critical thinking. If people do not develop skills to select, interpret, digest, evaluate, learn and apply information, they likely can access many answers but without being able to give them a meaning. Education, then, should prioritize the development of the skills to know how to learn and how to think clearly and with this goal in mind, it is necessary to define precisely the concept of critical thinking and its constituent aspects, particularly those that can be improved through education.

Consequently, it has started the review and reconsideration of curricula and teaching strategies that encourage the development of higher order skills inherent to a person who assumes the leading role of their learning processes and capable of facing challenges beyond their field of expertise, using a relevant and reasoned judgment. In this context, Problem-Based Learning (PBL) has become a useful tool for the development of these desirable skills in university education, among which are critical thinking skills.

1.1 Problem-based learning, teamwork and critical thinking

Hmelo-Silver (2004) refers to PBL as "a pedagogical technique that situates learning in complex problem-solving contexts. It provides students with opportunities to consider how the facts they acquire relate to a specific problem at hand. It obliges them to ask what they need to know. PBL offers the potential to help students become reflective and flexible thinkers who can use knowledge to take action".

Effective problem solving skills development is one of the main goals in PBL and it includes the ability to apply appropriate metacognitive and reasoning strategies. In Gueldenzoph and Snyder (2008) review, some research results are reported whose conclusions showed that Problem-Based Learning activities promoted critical thinking and problem-solving skills; active participation in the learning; teamwork and knowledge acquisition.

The PBL facilitator plays an important role in modeling the problem solving and guiding the development of higher order thinking skills. This is made by encouraging students to justify their thinking and by directing appropriate questions to individuals.

The learning process in PBL begins with the presentation of a problem in a real or realistic scenario. The design of this scenario is critical to ensure that the desired learning outcomes occur. Hung (2006) proposes an interesting model (3C3R model) that clearly illustrates the different components of the scenario or problem design. The core components of the model: content, context and connection are mainly related to the ownership and adequacy of content knowledge, and their contextualization and integration. The processing components: research, reasoning and reflection facilitate conscious and meaningful involvement of students in their learning process. Researching and reasoning components are critical to PBL problem design in activating the effects of the core components and directing learners to construct knowledge and develop problem-solving skills. The cognitive activities involved in the researching and reasoning processes are higher-order thinking skills. Frequently, students require training to enhance their critical thinking skills, and this must develop along the university education.

In PBL, students work in collaborative groups. The influence of interpersonal relationships and communication with others about learning is recognized in both learner-centered psychological principles proposed by APA (1997), and the constructivist view of teaching and learning (Coll, 2001). In a team work dynamic the students develop learning skills through positive interaction among group members. This implies establishing common goals, resolving discrepancies, negotiating the decisions that a group is going to take, and coming to an agreement. These tasks require an active exchange of ideas and engagement by all members of the group, so an efficient teamwork dynamic enhances learning and promotes critical thinking (Hmelo-Silver, 2004).

1.2 Critical thinking assessment in this study

To find a precise definition for critical thinking has long been an extremely complex task. The main difficulty has been the nature of the underlying basis for the various theories and models proposed, which can be located in the philosophical or psychological tradition.

An important reference is the theoretical approach to critical thinking proposed by Diane Halpern (1998, 2003). Halpern defined critical thinking as: "the use of those cognitive skills or strategies that increase the probability of a desirable outcome". Thinking is described as purposeful, reasoned, and goal directed – the kind of thinking involved in solving problems, formulating inferences, calculating likelihood, and making decisions. Critical thinkers are predisposed to think critically, that is, they are evaluating the outcomes of their thought processes –how good a decision is or how well a problem is solved.

All the skills considered in Halpern's taxonomy for the critical thinking teaching are present in a PBL process, despite PBL is not a specific program for the instruction of thought. As the student addresses the problem, develops skills related to identify problematic situations, ask questions, investigate, reasonably support his own ideas, compare his ideas with those of others, reformulate the problem and strategies for addressing it, and draw reasoned and thoughtful conclusions and judgments.

Based on the theory of Halpern and others as Ennis (1996), Facione (2011) and Walton (2006), Saiz and Rivas (2012), researchers at the University of Salamanca, developed an instrument (PENCRISAL) to assess critical thinking skills. The concept of critical thinking they assume is: "thinking critically involves reflection and action, all aimed to achieve our goals. In a simple way: critical thinking is reasoning and making decisions to solve problems as effectively as possible".

PENCRISAL test was validated in Spanish population with very good results (Rivas, Saiz, 2012). It was shown that this instrument is an appropriate tool to assess reasoning skills, problem solving and decision making.

The content of the items have been prepared taking care to use culturally neutral situations, in order that the instrument can be applied in contexts other than Spanish. In order to study the applicability of the test in a Latin American context a linguistic adaptation to Peruvian context was made and applied to freshmen of Science and Engineering (PUCP). The results indicate that the Peruvian version of PENCRISAL has good psychometric properties that corroborate the results obtained in the original version (Rivas, Morales Bueno, Saiz, 2014).

The PENCRISAL test was used to assess the achievements in the implementation of a strategy for the explicit teaching of critical thinking skills with seniors of psychology at the University of Salamanca. The strategy includes the use of PBL methodology and the results showed positive and significant achievements in all dimensions of the test (Saiz & Rivas, 2013).

In Latin American Universities, the necessary change to student-centered environments has different levels of difficulty in higher education institutions mainly due to more conservative convictions and beliefs that still prevail. The different PBL approaches, commonly known as hybrid forms, most often show implementation experiences in isolated courses belonging to a traditional curriculum. These approaches involve a greater tutor's intervention, assuming the role of facilitator for learning through individual or group pre-designed activities, classroom demonstrations, mini-exhibitions, etc. These adjustments to PBL process make possible their implementation in a variety of disciplines and contexts (Wilkerson and

Gijselaers, 1996). However, students keep on working in collaborative groups, assigning roles, distributing responsibilities, exchanging information, contrasting, reflecting and discussing new knowledge with their peers.

The hybrid PBL approaches are much more sensitive to the effects of different institutional administrative and academic factors on the expected achievements, as discussed by Bouhuijs (2011). The benefits in developing higher order thinking skills than can be achieved in implementing the PBL model, particularly in the training of engineers, are well known. However, in hybrid PBL approaches, these benefits may be affected.

Our previous studies in the context of implementing a hybrid PBL approach with freshmen engineering in a Peruvian university showed that one of the most sensitive points was the consolidation of an efficient teamwork dynamic, which is one of the fundamental pillars on which PBL entire process is sustained (Morales Bueno, 2014). These results also showed the influence of this factor on indicators of students' academic performance. In this paper the results of the evaluation of achievements in the development of critical thinking skills in a similar context to the above studies are reported, in addition the level of influence of the teamwork dynamics on the development of these abilities are examined.

2 Research

2.1 Participants

The participants in this study were first year engineering students of a Peruvian university who were enrolled in a General Chemistry course. In this course a Hybrid PBL approach was implemented. Table 1 summarizes the participants' characteristics.

Table 1: Characteristics of the participants (N = 57)

Age	Age mean	Gender (%)	
		Male	Female
16 - 20	18	66,7	33,3

2.2 Context of the study

The hybrid PBL approach implemented in the general chemistry courses implies that the groups of students work independently their solution proposal to the PBL scenario presented at the beginning of each unit of the course, but, in parallel, develop a series of learning activities related to the content and designed previously by the teacher. Learning activities are worked in classroom sessions, collaboratively, under the mediation of the teacher. Thus, it was ensured that the contents were properly worked by students, while the teacher could monitor the development of skills for teamwork in the student groups.

2.3 Instruments

- PENCRISAL test: consists of 35 items which raise problems of everyday situations, have open response format, propose different thematic issues of knowledge and have unique answers.
  The items are configured on 5 dimensions:
  Deductive reasoning: evaluates propositional reasoning and categorical reasoning.
  Inductive reasoning: evaluates analogical reasoning, hypothetical and inductive generalizations.

Practical Reasoning: evaluates the skills of argumentation and identification of fallacies.

Decision making: evaluates the use of general procedures of decision, implying making accurate judgments of probability and using appropriate heuristics to make solid decisions.

Problem solving: evaluates the implementation of specific strategies to solve the situations presented.

Scoring criteria assign values between 0 and 2 points depending on the quality of the response. 0 points is assigned when the answer is wrong; 1 point is assigned only when the solution is correct, but not adequately argued (identifies and demonstrates understanding of basic concepts); 2 points are assigned when in addition to the right solution, justify or explain the response (where more complex processes that involve real production mechanisms are used). The maximum test score is 70 points (14 points for each dimension).

Cronbach's alpha value is 0,734.

- Team work questionnaire: the instrument allowed students to identify positive and negative attitudes displayed by individuals and also identify the attitudes held by the group as a whole during the team work. The first part of questionnaire describes ten most frequent personal attitudes in a working group. The student must select three attitudes that best describe each of the members of the group, including him. The score for this part is calculated as the percentage of positive attitudes assigned to each individual. The second part is composed of 10 semantic differential items related to different aspects of teamwork: mutual confidence, collaboration, coordination, implementation of goals, conflict management, engagement, monitoring, feeling toward the group and compliance roles. These items are valued on a gradient of 1 to 4 points. The score for each aspect assessed is calculated as the percentage of maximum value. The sum of the scores achieved in the two parts of the questionnaire corresponds to the total score, the maximum value is 1000.

2.4 Procedure

The PENCRISAL test was administered to all participants, as pre- and post-test. The time between the application of pre- and post-test was 4 months. There is no time limit to answer the test; but it is estimated that the average length is between 60 and 90 minutes.

The team work questionnaire was administered during the last week of the course. The average time to answer the questionnaire is between 20 and 30 minutes.

2.5 Analysis of data

The data were analysed using Statistical Package for the Social Sciences (SPSS) 19 software ®. The level alpha was established a priori in 0,05. From the data collected, a descriptive analysis of the scores obtained in each PENCRISAL dimension and the whole test was performed. To verify significant differences between the results obtained in the pre and post-test, t test for related samples was performed.

Additionally, descriptive analysis of the scores obtained in Team work questionnaire was performed. In this case total score was transformed to z score, then the participants were organized into three categories, they are shown in Table 2:

Table 2: Participants categories according Team work questionnaire total score

Category	z	N° participants
Higher	> 1	26
Intermediate	-1 < z < 1	19
Lower	< -1	12

In order to verify the differences between the categories, the analysis of variance (ANOVA) was used, considering as dependent variable the difference between the scores of post and pre test corresponding to each PENCRISAL dimension and the whole test and, as independent variable the team work category.

3 Results

Table 3 shows the descriptive statistics for pre- and post-test PENCRISAL scores and Table 4 the descriptive statistics for Team work questionnaire scores expressed as percentage. In both cases the results for the whole group of participants were considered. It can be seen that post test scores were higher in all PENCRISAL dimensions except decision making. The PENCRISAL total score was higher in the post test too.

The results in Team work questionnaire scores show a higher mean in the first dimension "positive attitude". Means for the two dimensions and total score were higher than 70%.

The inferential analysis performed with a t test for related samples showed statistically significant differences in the total score, $t(56) = 2.607$, $p = 0.012$; in solving problems dimension, $t(56) = 2.128$, $p = 0.038$ and inductive reasoning dimension, $t(56) = 4.753$, $p < 0.001$. No significant differences were found in the dimensions: deductive reasoning, $t(56) = 1.717$, $p = 0.091$; practical reasoning, $t(56) = 0.106$, $p = 0.916$ and decision making, $t(56) = -0.534$, $p = 0.596$.

Table 3: Descriptive statistics for pre- and post-test PENCRISAL scores (N = 57)

Dimension	Pre-test		Post-test	
	M	SD	M	SD
Deductive reasoning	2,51	2,229	3,05	1,968
Inductive reasoning(*)	3,89	1,633	5,02	1,788
Practical reasoning	5,04	2,383	5,07	2,389
Decision making	4,56	2,036	4,40	2,103
Problem solving(*)	5,46	2,472	6,11	2,358
Total score(*)	21,46	7,476	23,65	6,828

(*) Significant differences between post and pre test

Table 4: Descriptive statistics for Team work questionnaire scores expressed as percentage (N = 57)

Dimension	M	SD	Minimum	Maximum
Positive attitude	81,95	15,198	42	100
Group performance	78,98	10,494	63	97
Total score	79,35	10,592	63	97

In Table 5 the descriptive statistics for Team work questionnaire obtained for each category (described in Table 2) is reported. In the first two categories "positive attitudes toward the group" had higher scores than "group performance". The opposite occurred in the third category, where "positive attitudes toward the group" obtained the lowest score.

Table 5: Descriptive statistics for Team work questionnaire scores for each category

Category	Positive attitude		Group performance		Total score	
	M	SD	M	SD	M	SD
1 (N=14)	96,57	2,766	92,14	2,445	92,57	2,277
2 (N=31)	83,87	7,839	78,68	6,046	79,26	5,739
3 (N=12)	59,92	13,681	64,42	1,311	64,17	1,115

The ANOVA analysis performed to verify possible differences in critical thinking achievements, considering the team work categories described in Table 2, showed homogeneous variances for all dimensions and total score. The Tukey-b post hoc test revealed that there was not significant differences between the team work categories, comparing the PENCRISAL score difference between pre and post-test. A Linear regression analysis, introduce method, using PENCRISAL total score as dependent variable and the scores obtained in team work questionnaire as independent variables confirmed this result. None of the dimensions of the questionnaire teamwork and the total score were predictive variables for the PENCRISAL score.

4 Conclusions

There is no doubt that social factors play an important role in the learning process and are influential aspects on expected achievements in PBL implementation. Collaborative work allows students to share their opinions and individual perceptions on certain issues. In this way the student is motivated to use prior knowledge to identify, based on his observations and discussions with his teammates; relationships, difficulties, needs, discrepancies, etc. that should be addressed to deal with PBL scenarios. This promotes the use and development of skills for problem solving, critical thinking, communication, creativity, among others.

When the implementation limits the space and opportunity for this dynamic to develop with adequate autonomy (as unfortunately happens in PBL hybrid modes implemented in isolated courses of a conventional curricula), the influence of team work achievements will be lower than expected, as it has been seen in the results reported in this study. However, the general results have shown positive achievements in the total score of PENCRISAL test, revealing that critical thinking skills have been enhanced. The dimensions with significant positive achievements were “inductive reasoning” and “solving problem”. The latter are skills especially promoted in PBL process and further in the case of engineering education. Commonly, hybrid PBL models are used in situations where students do not have previous experience as autonomous learners, so that the scenarios and the process have a more controlled design to scaffold the learners’ researching and reasoning processes. However, with a more controlled process it is common to expect lower reasoning ability in the student.

According the results obtained, the adoption of hybrid PBL approaches could have the risk of not considering essential aspects of the underlying educative vision of this methodology. It is necessary to incorporate opportunities to promote the enhancement of self-learning skills, and if it is required, some activities for the explicit learning of some critical thinking skills, as deductive and inductive reasoning. The other three dimensions considered in PENCRISAL test are more directly related to the PBL process characteristics. Students learn to face professional discussions in situations such as the definition of the problem or argument to support a proposed solution. In PBL context, students develop their abilities to explain in scientific terms their proposal of solution to the problem, since it is not enough to say that the approach is correct. They must also be able to convince the other members of the team explaining the reasons that support their assertion, as well as listen and analyze the reasons of others, as it is expected to occur during the performance of a professional engineer.

As it was commented above, the results of an earlier study with the same group of students showed that teamwork had a positive effect on learning achievements, particularly on “group performance” dimension. The present study has shown that it is not the same case with the critical thinking skills. Although they have improved but have not shown a significant relationship with the dimensions considered in teamwork assessment.

Finally, PENCRISAL test has proven to be a suitable instrument to assess achievements in critical thinking skills in PBL environments, whether in a context of explicit teaching of thinking as demonstrated by a previous study, as in a hybrid model such as the present study. The assessment results are useful to identify the different aspects that have been promoted and those that need special attention, so that it is a useful tool for future research.

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Reflection using a Wiki for First Semester Programming Skills

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Abstract

This paper reports on the enhancement of first semester student's performance in programming skills when introduced to writing a technical discussion in a wiki context. We have a whole day each week dedicated to programming, tried many aspects of PBL, but over the last years we did not see much improvement, until in 2014 we added this new kind of learning task. That year the students performed unusually well.

Programming skills are complex and hard to learn. Like most engineering areas we also suffer from badly prepared students that enter our universities. Students often use unsuitable learning techniques. They confuse speed with quality and do not take the time to reflect on deeper implications, possible variations, their properties, their *pros* and *cons*.

In order to slow down students and make them rethink some of the material, we introduced a wiki task in the first semester. The wiki content was a big challenge for our students. They had to understand the topics, then write explanatory text about it, then connect the pages to other concepts so that the topics form a small knowledge network including links to the outside internet and, finally, write well-chosen code example to support the explanations.

Although the resulting wikis were far from perfect, this way of working with the material might have helped with the surprisingly good results in 2014. In summer 2015 we will repeat the experiment and hopefully see the same good results.

This paper describes the problems of our freshmen to adjust to studying in general and our programming course in particular, discusses the need to reflect and our experiment with wikis.

Keywords: reflection, programming skills, individual mental concepts, wiki

1 Introduction

Programming is a hard discipline for learners and teachers alike. As in many other engineering studies, many students are badly prepared for university education. So the first year is spent with learning to learn, learning to work with different and sometimes contradicting sources of material, work in teams and work with concrete projects with a hidden agenda. Students also have to learn to work differently from the way the schools teach them. Chapter 2 addresses some of the challenges we meet there.

Especially our one-year introduction to programming is an everlasting challenge for us. The teaching of programming skills on university level is hard to do. Surprisingly so, because almost all students are highly motivated and understand the importance of this subject. So teachers and students both could be quite disappointed by the results

For years we enhanced our course with PBL issues and special tutor training. Chapter 3 addresses some of our PBL approaches in teaching and learning.

Over the years, our PBL issues did only make a difference with the performance of second semester students which have a real project, while first semester courses seem not to benefit much (Benz & Jaeger, 2009, 2011). We have a - unintentional - “control group”, because a colleague does the same course in the traditional style and also has an average success rate around 50%. With traditional style we mean: lectures, followed by small exercises, and a written exam in the end.

The overall success rate in our PBL enhanced version is still 50%. If we consider only those students who take actively part in the course, attend to lectures, tests and exercises, the rate is slightly better: around 61% (see chapter 5, table 2).

In 2014 we introduced the wiki task (see chapter 4). The idea was to make them reflect again about seemingly well understood topics and build a web of connections between them. An important part of the task was to compose own and well-suited code examples for explanations. This paper describes the ideas behind the new concept, its implementation and first results (see chapter 5) that are at least so encouraging that we will repeat the experiment in the next years.

2 Problems of Becoming a Student

The reasons for the disappointing success rate are manifold. Some lie in the complex topic of programming itself, which we will not simplify for the sake of better grades. Another area of problems is the teaching material and method which we try to develop towards PBL as much as possible (Benz & Jaeger, 2009, 2011). And some problems come with the students’ situation aside from topic or teaching method, for example:

Knowledge diversity: The students’ prior knowledge about the topic itself differs widely. Only 20% of the students have some experience with programming, and about half of those have rather to unlearn their prior training which is not on university level. About 40 -60% of our students have failed the semester before (with a different teacher and traditional teaching methods) and repeat the course with us. Those again might know almost nothing about programming, or have failed at the very end of the semester at the final written exam and have quite a good overview.

Critical admission grades: Around 60% of the students have critical grades (average 3.1, where 4.0 is the lowest to pass) from school, they are not the best performers and carry a lot of learning frustration.

University learning differs a lot from school learning. We observe the following most important differences:

Unsuitable learning techniques: The prior learning experience in school does not prepare for the work at the university. We observe many to work the wrong way: they busily collect simple unconnected facts and learn them by heart. Many take refuge to cheating. They hope we do not see their mistakes. They are used to getting at least some points for just writing/doing something.

Lack of responsibility: Freshmen often take less responsibility for their own learning and tend to blame others for failures.

Unexpected university level of learning: University level is unexpected: we not only want an isolated solution, but orientation about variations and *pros* and *cons* of different approaches. Since many of our students have no academic family background, they are unprepared.

Teamwork: Teamwork on projects is new to many students. They would rather fight alone and keep everything under their individual control. What they do not anticipate is that the projects are - intentionally - too elaborate for a single person.

Social role changes: Last, but not least: life as student differs in most cases a lot from life as pupils. Accommodation and money issues arise, the social role in family and peer group changes. All this can be very distracting. Failure and frustration at the university might question the whole decision to study, so problems tend to multiply.

In our software engineering field, many students start as "code warriors" (Stein, 1994): they fight the compiler, then fight the runtime system and as soon as the machine does not respond with error messages any more, students think they succeeded. The truth is: No error does not mean that everything is perfect. Students tend to work too hasty, jump to the next task as soon as a task is (seemingly) finished. There is a small window of awareness and topics from the actual week, before which soon become hazy.

Instead of rushing our students through a lot of material, our course tries to slow them down so that they have some time to reflect, to think, and to experience that working on variations is not a waste of time but helps with the deeper understanding we demand from them.

3 Learning Environment

Our classes have around 50 to 70 enrolled students, some of them never showing up, but 40 to 60 active students (see exact numbers in chapter 5). Since we have to tackle many problems at the same time, we changed the introductory course for programming.

Small example projects: Project work in the sense of PBL is widely used in the second semester, but our first semester course does not have a single big project. We define smaller units based on a textbook (Barnes & Kölling, 2012) with a lot of additional material and questions. Students are encouraged to work with this book in their individual pace, so that some are quite far ahead, others take more time. This is nice when dealing with the diversity of prior knowledge. On the other hand, many students tend to turn the pages too fast and confuse speed with understanding. There seems too little time to reflect and spend some more thoughts on the concepts.

Less lectures, more exercises: We switched the emphasis from lectures to exercises. Lectures are shorter, lesser and optional, while exercise time became longer and mandatory. We want the students to be present, so that we have a chance to work with them on their individual task and questions. We offer them two big lecture classrooms, as well working tables for small groups in the long hallway. This helps with the new role as student in teams, helps them to understand the importance of exercise and experiment, and encourages them to ask questions, get guidance to help themselves rather than ready-made answers that can be copied and pasted.

Trained Tutors: We organize tutors and assistants for a ratio of 1:10 students. The tutors are students who have experienced the course the year before; not necessarily the best performers, but those who remember their own difficulties and have a friendly and open way of communicating. Those tutors receive two training units by an extern trainer. The training bases on Rogers (Rogers, 1969). We train them to listen carefully, start a discussion rather than answer too directly, look for the picture behind a problem and give a lot of formative positive feedback, encouragement to try new things, and create an open, friendly environment, where students lose their shyness to communicate. This helps with a series of problems: inhomogeneous prior knowledge about the field, irritation about the new role as student, lack of learning techniques, the importance of questions and tutor feedback (Rosenauer & Jaeger, 2014).

Learning goals: During the semester, we have weekly predefined learning goals with small programming tasks for checking the individual progress. Each student has to pass those checkpoints eventually, but their progress is monitored and they see their position in respect to our expectations. Those weekly goals are formative feedback. This helps with the individual awareness of the learning progress while preparing for the graded tasks.

Cumulative tasks: We do not have a written exam at the end of the semester, since that one-time evaluation offers no possibility to correct, to rethink, and to adjust to our expectations. The written exam would be a single point in time with a binary result: pass or perish. We rather have a series of graded tasks during the semester, which add up to the overall grade for the complete course. See chapter 5 for more detail.

4 Reflection with Wikis

"Any significant learning involves a certain amount of pain,
either pain connected with the learning itself or
distress connected with giving up certain previous learnings".
(Rogers, 1969)

The transformation from pupil to student (Mezirow, 2000) requires a substantial change in learning techniques, otherwise the sheer amount of the material as well as the required level of understanding will overwhelm most of our students.

4.1 The Role of Reflection

The cumulative learning style of school days helps students to store masses of simple unconnected data and produce those facts again at exam time. However, we demand more. The facts themselves are often simply available in textbooks, articles and, of course, on the internet, so we allow students to use those sources within limits. With this material they should work out complex solutions, patterns and variations, discuss the respective strengths and weaknesses, transplant ideas from one field to another. This is a transformation from *cumulative learning* to *accommodative learning* (Ileris, 2007).

Another issue is that university learning is no longer a clear black-and-white world, where the teacher decides what is right and what is wrong. Exams are not tests to "hit" the right answer. Variations have properties, tasks and environments have a set of requirements, which could be used to define more or less suitable solutions. So students need to learn to generalize, to identify patterns, requirements and properties rather than find the one single silver bullet that solves all problems.

We have to slow them down, to help them understand that questions and irritations are a good thing and that those moments are the heart of any real learning process. In theory, this leads to a learning process that includes questions, experiments, plans which are evaluated and lead to new approaches, like in Kolb's learning cycle (Kolb, 1984).

A sometimes irritating dimension of university learning is the role of fellow students. At our university, team projects make a big amount of the work. Not only the teacher but fellow students could also be helpful experts on some fields. Peer reflection and peer feedback has to be learned and appreciated. We want students to form groups, to connect their findings, to remark on the work of others. Students should develop a sense of quality which is not defined only by the teacher. By and by the teacher steps aside and gives less and less support.

Our course tries to give our students some methods to learn in the required way. Reflection is --- in our eyes --- one of the keys to success. But you cannot simply order: “Think more or longer about it”, because most students tend to confuse quantity/speed with quality and might just collect more of the same shallow material. They do not know that they do not really think deep enough. The next chapter describes how we introduce reflection to our learning environment.

4.2 Reflection with Wikis

Our university uses Ilias® as learning platform. The wikis in Ilias® have improved over the last versions, so we started experimenting with a wiki we wrote for students in 2013. We first thought that students might benefit from something closer to their social networks (Decker et al., 2009) than a traditional linear textbook. However, our first attempt was too naïve. We had to make students actual owners of the material.

Wikis organize knowledge in a non-linear way, draw connections between concepts, connect to other material on the web and spin a conceptual model of any material according to your own perception. A wiki is also mostly work-in-progress, since the level of understanding changes during the work, and the network of connection is not only growing, but reorganized all the time. This created a mental map that helps with the accommodative learning. Wikis are also cooperative tools, since authors can add, change, and comment on the material, so the idea of wiki commons leads to teamwork.

In 2013 we wrote a wiki ourselves. It was intended as the “missing link” between the first and second semester when students come back after a two-months’ break and want to reactivate their material from the last semester. While composing the wiki, we ourselves learned a lot about the topic and the connections between concepts, checked many pages on the web about their value as additional material for our students. Whereas the definitions and explanations were often useful, we found the code examples in web forums often insufficient for our purposes. (For the Java programmers under our readers: many examples take place in the minimal and special kernel of the `main()`-method, whereas in professional code that’s the place where usually almost nothing should be programmed.) So we wrote examples embedded in more sophisticated programs, which were better adjusted to our own teaching projects.

But as much as we as authors gained from the wiki work, our students as mere readers became passive and did not really make use of the highly linked web of concepts and examples. Although they browse in webs of information all day, the web of concepts in our wiki was too complex to follow, most students lost orientation and interest quite soon.

Instead of rearranging the wiki material into a linear version, we decided to make the students owners and authors of their own wikis. We hoped that the same would happen to them that we had loved so much: gradually growing understanding, connections to other concepts, collaborative work with other students and feedback by teacher and peers. This we applied to the first semester course.

4.3 The Wiki Task

Our first semester students have some experience as wiki authors in Ilias®, since it is one of the topics of our one-week introduction to the software-engineering program and studying techniques. So each student already owns an individual wiki. Some of our weekly learning goals include the writing of small wiki pages and links to other material. At week 10 of 15 students received the full description of the wiki task which had to be completed within two weeks. It was worth 25% of the overall grade. We organized it as follows:

Teams: Students worked in small teams (2 to 3 members). Ownership and workload can be monitored by authorship and versioning in the wikis.

Choice of topics: Students were free to choose a certain topic from a given choice of different concepts, e.g. *inheritance and constructors, method polymorphism, types and interfaces*, and so on.

Plagiarism: In order to avoid plagiarism, those topics always combine two advanced concepts and are not as easily found on the internet as simple ones. We also checked elaborately for plagiarism of texts.

Questions drive the text: The wiki should contain explanations which describe the topic based on a sequence of questions the students had to start with. Those questions drive the answers they give. If a team had no questions, or did not know where to begin, tutors sat with them and worked out some useful questions.

Code examples: The wiki must contain code examples that illustrate the effects of the concept. This code has to be original, to meet our software engineering requirements, and should be extensions of our code examples given in the lectures. This rules out many ready-made code examples from the internet, which often is a basic kernel within the `main()`–method, as mentioned above. Again, this helps to avoid plagiarism.

Conceptual model: The wiki must contain links to other well suited material on the web. If students explain a topic, they rely on simpler concepts which they should not explain in detail, since this would force them to start with "Adam and Eve". Instead, they are encouraged to look for well written definitions and examples from other authors. It could be another team that describes that concept, or any other source. This part of the task requires decisions based on quality and suitability of the material.

Peer feedback: we encouraged students to comment on the pages of other teams. The feedback had some influence on our evaluation.

5 Evaluation of Students' Performance

We measure the students' performance by a series of tasks which gain them points. So students get feedback about their performance, as well feel safer with the points they already collected. Until 2014, we had four tasks:

Table 1: Tasks until 2013

Task1	Live programming. Students write a simple method, test it, and deliver it within 40 minutes.	25 points
Task2	Written test about given code and some changes and adjustments, 60 minutes.	25 points
Task3	Live programming task again with more elaborate code in a given timeframe of 40 minutes.	25 points
Task4	Written test about given code. Students write some more code and discuss small variations and test cases, 60 minutes.	25 points

As table 2 shows, the overall success rate for all students is usually under 50%. If we consider only those students who take actively part in the course, attend to lectures, tests and exercises, the average rate increases to 61.25% successful students.

Table 2: Success rate of first semester course in recent years

Year	2010	2011	2012	2013	average
# Students (all)	62	58	71	57	
# Students (active)	49	50	62	41	
# Passed	29	32	37	26	
Passed% (of all)	46%	55%	45%	46%	48,00%
Passed% (of active)	59%	64%	59%	63%	61,25%

In 2014 the students' evaluation was different: we introduced the wiki task instead of the second written test, and we changed the order a little:

Table 3: Tasks in 2014

Task1	Live programming. Students write a simple method, test it and deliver it within 40 minutes.	25 points
Task2	Written test about given code and some changes and adjustments, 60 minutes.	25 points
Task3	**Wiki task, see chapter 4.2**	25 points
Task4	Live programming task again with more elaborate code in a given timeframe of 40 minutes.	25 points

The success rate changed for the better:

Table 4: Success rate of first semester course including 2014

Year	2010	2011	2012	2013	average	2014
# Students (all)	62	58	71	57		55
# Students (active)	49	50	62	41		37
# Passed	29	32	37	26		27
Passed% (of all)	46%	55%	45%	46%	48,00%	49%
Passed% (of active)	59%	64%	59%	63%	61,25%	73%

One might argue that the wiki task was easier than the old written test, thus influence the good overall results, but that Task 3 alone had an average success rate of 50%, which was about the same in recent years. The resulting wikis were really only “work in progress”. We graded quality of text, code and projects, links and remarks. The task was hard and we had an average grade of only 3.4, which made a dent to the overall grades. However, the overall grade of this class was surprisingly good, as table 4 showed.

6 Results and Future Work

We are still confused, but on a much higher level.
(Anonymous)

To reflect and write explanations in their own words was hard for most of our students. Writing precise and readable text reminded them of the mostly dreaded essays in school. So, we encouraged them to start with the questions they themselves had about the chosen topic, and write answers and examples along those questions. That resulted in a sort of story along the questions and looked more like a process than a ready-made perfect definition.

The choice of topics were always a combination of two concepts they already had learned during the semester, but not necessarily in that connection. We observed many interesting discussions, where students suddenly started to ask themselves about things they thought they already had understood and stowed away. This was what we wanted: we wanted them to revisit and question their knowledge again. The question-technique then helped with finding a first structure for their wikis.

Substantial code examples were even harder. At first, our students looked for material on the internet, but soon found out that those code examples are unsuitable bad programming style and not necessarily to the point of our course. This part of the task was reflection on a higher level, since they developed criteria of “suitability”, applied their understanding to a concrete example. This part was hard work, since all code examples had to be part of correctly running programs they had to submit as well. Writing and testing took a lot of time.

This is, of course, only a first experiment and we will continue to explore the effects of reflection with wikis. But even if the wikis themselves are not of high quality, it might be one technique to help students to reflect and think again about material, before racing on.

Bad grades for insufficient wikis do not incense students to work with wikis again. Only a few students liked this way of thinking and reorganizing their thoughts. Those later on extended their wikis to other topics and courses as well.

We will support the wiki work more sufficiently: after the introduction in week one, we will encourage students to work with individual wikis in several courses, some colleagues are ready to try it. We will give them clearer guidelines and examples of high quality material, which hopefully do not turn into formative templates.

What if a student really hates to write wikis and suggests forums, refactoring platforms and the like? We will try to show them that a forum with questions and answers result in a comparably interesting train of thoughts, which also explains a concept. The task is the same: find questions and a story that explores a topic more deeply than the lecture did. The material might be organized within a forum with references to other material or within a wiki: it is the same work of reflection.

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Problem-Based-Learning and epistemology
Cognitive processes hiding in reflexive evaluations

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Abstract

To make sense of the continuous, unstable flow of information and knowledge coming through the Internet, this case study shows that a competence-based methodology such as PBL facilitates the development of stable data-handling skills and a high level of analytical and synthetic cognitive competences.

So, the present classroom-based exploratory case study focuses on one of Aalborg's model's fundamentals i.e.: the process of creative and critical thinking involved in concept and knowledge capacity-building. Set in France, the author focuses on 2 main questions. 1) What does it take to be a reflexive teacher involved in action-research, and a reflexive learner following a PBL-oriented single module? 2) What kind of pedagogical interventions are needed for student engineers to develop the high level of cognitive skills involved in creative critical thinking?

Aware of the limitations of single case studies and of the semantic instability of creative critical thinking, the author exploited some of the existing contemporary theories and the duality of formative evaluations. On the one hand, formative evaluations were used as an evidence-collecting method at action-research level to explore some of its underlying notions, as well as some of its epistemological and epistemic boundaries and obstacles. And on the other hand, a coherent cluster of formative evaluations was deployed at the pedagogical engineering level as an autonomous in-action and on-action self-evaluating system.

Using students' academic writing as evidence, an interpretative qualitative technique was specifically designed to visualize some of the cognitive mechanisms in action, to identify changes over a period of time and to expose some of the major scientific and cultural obstacles preventing creative critical thinking to occur. Some effective solutions were suggested to help students move from what Aalborg calls an experimental stage to a hypothetical one and what Gaston Bachelard refers to as moving from pre-scientific to scientific reasoning.

Keywords: PBL, epistemology, creative critical thinking

1. Introduction

Philosophical concepts such as knowledge-based society, lifelong learning, unlimited and democratic access to education for peaceful ends leading towards understanding amongst people, have filtered through many educational systems around the world. Paradoxically, as Eli Pariser warns us, online filter bubbles are used by search engines to provide people at large with links, not according to referencing criteria, but according to one's searching and social networking habits. In short, everyone entering a same key word into search engines would get a list of links aligned with their search memory (Ted. 2011). The consequences of the filtering of links are yet unknown. Nevertheless, the risk of single mindedness, as a group of users might develop similar search habits and get similar links has to be counteracted. Therefore, humanities lecturers teaching engineers ought to double their effort to offer students opportunities to access a large variety of courses, archives, opinions of data, and books, as much as presenting them with challenging divergent research questions, since the question of the question is of crucial importance in Problem Based Learning

(PBL) (Palle Qvist, 2004). As Biggs proposes, promoting deep approaches of learning instead of surface approach is a priority (Biggs, 2003). A cognitive gap in the access and the management of the constant flow of information might also be an added obstacle preventing access to knowledge, education and reliable resources needed if critical thinking is to be developed.

Today, widely available, the fundamental principles embedded in the Aalborg's PBL model try to solve this paradox, since, on the one hand, there is an unstable knowledge-based society whose boundaries are constantly expanding, and on the other hand, a competence-based multi-layered method of education, Problem Based Learning. *'Why Problem Based?"* asks Kjaersdam Finn at the Sorbonne in Paris*, '...because we are drowned in information and starved for knowledge.'* (Finn, 2013). In short, PBL targets critical, stable, transferable and durable cognitive competences. Starting from common sense and building on experimentations and reflexions, student should reach an eagle's view of problems and gain reflexive competences in collective concepts and knowledge capacity-building. Creative critical thinking are therefore essential in Aalborg's aligned pedagogy (Kolmos & Egelund Holgaard, 2007), and in relation to what Aalborg refers to as the *'Kolb circle 'of process competencies by reflection, experimentation and creativity*. (Kolmos & Egelund Holgaard, 2003). Active experimentation facilitates this interaction as students move from the first level '*common sense or explorative experiment* to the second, where they combine *'horizontal comparative reflection'*, a '*move-testing'*, in which analysis, comparison of experiences and peer interactions lead to innovative processes, and then to a third level, '*hypothesis testing'*, including reflection, conceptualisation and abstract conceptualisation built on concrete events and experiences. In the ongoing debate, critical and creative thinking are still ill-defined. (Runco, Weisberg, Fasko. Jr**,** 2006). Therefore it offers an opportunity for exploration.

This case study starts from two main classroom observations, which are: 1) students have difficulty answering divergent research questions; 2) students do not seem to transfer research methods and related analytical and synthetic skills from one type of science to the next. As a result, underlying concepts involved in the study of heritage, which is the discipline concerned here, are not understood or not even acknowledged in their academic writing. This, in turn, seems to prevent them from constructing scientific reasoning, and so their writing is narrative since very few reach a scientific approach while tackling divergent research questions in humanities. The case study here will present some of the thinking processes involved in the part of the corpus that deals with the construction of memory and identity, two fundamental concepts necessary in heritage studies to engage in a research project later on in the course.

In addition to Aalborg's view on critical thinking, the work of Gaston Bachelard (Bachelard, 1938) on epistemology and pre-scientific reasoning and scientific reasoning will be used to determine the research model, which cannot be presented here in full. This case study can be situated in the early doings. Following Bachelard's reasoning, the researcher-practitioner's objectives are to record and evaluate some of the boundaries of creative critical thinking in action. The choice of a classroom-based exploratory case study seems aligned with its purpose, which is to observe critical thinking using formative evaluations as a qualitative method traditionally used both as a evidence-collecting technique in research, and also as a self-assessment technique in pedagogical engineering. (Yin Robert K. 2008, Muir Josephine 2010, Kolmos & Kofoed 2003, Hmelo, Lin 2000)

As complex cognitive mechanisms are involved, students' academic writings will be used to uncover cognitive competences in-action. Although very relevant to this case study, the model proposed by Anne Clerc-Georgy (Clerc-Georgy, 2014) to analyse students' academic writing and cognitive competences will not be applied. Instead, this case study will concentrate on a qualitative analytical technique that can visually manifest the articulation of different kinds of knowledge being woven together using cognitive competences. It has therefore been necessary, first, to identify and collect evidence of the presence or absence of critical thinking, and to develop an interpretative and synthetic method of analysis of the collected qualitative data. The California Critical Thinking Disposition Inventory test (CTTDI) (Du et al. 2013), would not be relevant here, as the author is not interested in measuring critical thinking, but in finding data about the complexity of creative critical thinking, and data about PBL as a methodology facilitating its development. The solution chosen here is a colour code to differentiate the different types of knowledge and skills involved in creative critical thinking. This article will therefore present results to 2 main questions, what does it imply 1) to think critically; 2) to be a reflexive learner, teacher, and researcher in the field: i.e. the classroom? It will be followed by an evaluation of the analytical technique and the formative evaluations before reaching a conclusion. All the extracts of students' texts are used anonymously and in no way reflect a complete picture of their ability.

2 How can critical thinking be observed as a process?

As grounded theory tends to demonstrate, knowing about methodological approaches, and the recurring obstacles as much as the epistemology of one's own discipline, are essential when launching action-research in a classroom. (Glaser et al. 2004). If action-research situates the researcher in relation to the object of research and the participants' social and educational context, it still needs a structural approach to decide what to do, when and why. Therefore, to structure the ongoing decision-making process involved in this research, the scientific model chosen comes from Gaston Bachelard's who points out the difference between a science historian and an epistemologist. The former perceives ideas as facts, and the latter, facts as ideas to be inserted into a thinking system (Bachelard, 1938). Following Bachelard's reasoning, which had to be schematized here, the researcher-practitioner will attempt 1) to define some of the semantic boundaries and obstacles of the notions found in creative critical thinking, while adopting a reflexive oriented teaching posture. Doing so includes, isolating each notion or obstacle in order to to give them a semantic value in relation to academic references and theories, 2) to reinvest the knowledge gained from theoretical references into the design of a coherent evaluating system, 3) to insert the findings collected from the formative evaluations into a thinking system applicable and adapted to classroom activities in view to facilitate engineering students' passage from pre-scientific to scientific thinking while exploring divergent research questions in humanities, 4) finally, to evaluate both the methodology and the impact formative evaluations had on the quality of students cognitive competences.

2.1 What kind of cognitive competences are involved?

Kurt W. Fischer and Samuel P. Rose (Fisher & Rose, 1998) mention that the capacity for learning and thinking, although happening in spurts according to age, is grounded in neural networks. Feeding on previously formed networks and readapting to new ones, neural activities and networks are only activated when optimal support is given via the learning environment. So, cognitive competences seem to be dependent on the environment, and in this sense the role of the teachers is crucial to their occurrence, and their development. This highlights the fact that learning does not occur in a linear fashion, and that a constructed analysis needs several types of data woven together through time in a variety of contexts before being internalised, processed, and synthesised.

Jerome Bruner (Bruner 1966) says that, using words and symbols allows children to go from self-accounting of events to self-consciousness and logical behaviour. In reference to philosophy he calls analytical mode. In his opinion, language is used to bring an order to the world that surrounds us, and through this ordering process, going from enactive actions to iconic representations and symbolic word language, depends on one's ability to internalise a system and to go beyond this system, i.e. to get into the world of abstraction. According to him, language is therefore an '*instrument of thoughts*' and this instrument can interfere with behaviour and cognitive processes. To be able to see several alternatives is therefore linked to the level of encoding experience, manipulating grammar, vocabulary and syntax to express this experience, but also at a higher level of the manipulating of categories, classifications, conditionals, hypotheses and counterfactual information. On this basis, experiences are constructed and then stored for later use. Bruner's concept of the layering of experience, solving problems and self-consciousness through language, which helps building a database of models based on having physically experienced the world, is today reflected in the constructivist theory of learning and the way the mind is perceived. The concept of unconscious storage boxes, or repertoires in which experiences, knowledge, know-how, cognitive and interpersonal skills can be much more solicited while thinking critically is also developed by Frédéric de Coninck (de Coninck, 2009). Although not fully developed here, the question of the categorization of knowledge highlighted by Kaufman James C., Baer John (Richard, 2006) and their colleagues has influenced the colour coded qualitative evaluation technique. Their approach to creativity as being ill-defined and unstable means that *'the correlation between analytical and creative abilities becomes non significant, sometimes even negative (Sternberg & O'Hara, 1999). These results suggested that these two thinking modes may be independent and follow different cognitive trajectories. However, great a reasoning master a person may be, the strategy he or she uses with proficiency in solving analytical problems may not transfer to make him or her a highly creative person..'(Niu et al. 2006).*

Interesting categorizations and findings coming from the Torrance Tests of Creative Thinking (TTCT), further demonstrate how unstable the concept of creativity can be, especially in terms of cultural impacts on creativity, motivation as a non-negligible factor, and the fluctuation of the semantic view according to an academic or an artistic point of reference. In this case, the study will be situated more in the pre-scientific/scientific configuration than the concepts of creative/non-creative thinkers because the objective is not to measure creativity but to visualize occurrences of creative critical thinking.

Therefore, creative and critical thinking will be framed here as a process moving from a pre-scientific to a scientific stage. The underlining notions include 1) that none of the keywords of the case study are semantically and scientifically stable, and that they present subjective interpretations according to the field of study ; 2) that creative critical thinking as opposed to pre-scientific reasoning implies an intellectual construction of different kinds of knowledge about an object of research over time involving both an analytical and a synthetic stage; 3) that the scientific environment and its procedures and the participants' culture can have an impact on the way one constructs knowledge. Cultural influences are unstable with important fluctuations according to internal and external unpredictable factors; 4) that divergent research projects seem to be conducive to its development, and finally; 6) that the act of writing is an acceptable tangible proof of a creative thinking process.

2.2 What is the place of formative evaluations in PBL?

Widely adopted by the science of education, fully or partially including PBL influenced classroom settings, formative evaluations have been used in class-based action-research both as an epistemic research technique and a pedagogical tool to collect tangible traces of critical thinking processes. In this case study they will be used while students are developing an understanding of the construction of identity and memory. This step is necessary to tackle the next stage, identifying and formulating divergent research questions needed for the first normative evaluation. They are usually used alongside normative evaluations, even if their main objective, as it is the case here, is to give an insight into the cognitive mechanisms involved in the processes and to raise learning awareness among learners. (Kolmos & Kofoed (2003), (Hmelo & Lin. 2000). On the one hand, action-research means that practitioners have to be actively engaged in the analysis and the synthesis of the students' response to the interaction between targeted core knowledge and the development of process competences. On the other hand, researchers also have to be aware of their own competencies and strategies, in order to plan appropriate activities. Refining strategies and adjusting to the level of the class or individuals is essential and it means that the researcher-practitioner has to be constantly aware of the relationships between the parts and the whole. Philippe Perrenoud (Perrenoud 2005), a leading figure in the theory of reflective teaching, quoting Schon says that teachers also need to move from the in-action reflection which targets the success of an activity, to on-action reflection after the activity which targets the transformation of the experience into knowledge. The latter is the target here.

2.3 What impacts do formative evaluations have on a course?

What is presented here is the 3rd formative evaluation that ends the first cycle of the course. At this point students have gone through 4 weeks of brainstorming, initial data input and knowledge gathered in class through individual and pair activities, and two formative evaluations via Moodle, an e-learning platform.

As students are new to the subject, instead of lecturing on the corpus linked to heritage as a discipline, knowledge gathering activities on the students ' side was mostly done through the teacher posting questions and quests on Moodle. Sets of questions targeted by the teacher were conducive to knowledge gathering collectively or individually and always started from the students' empirical experience of the concepts to be explored. The role of facilitation does imply a different posture and position in relation to knowledge transmission but does not mean an absence of intervention. Therefore, transmitting knowledge remains a teacher's priority. It is the way that it is transmitted that differs according to the space the development of competences is given, hence, the aligned Aalborg's model (Kolmos & al. 2008), (Biggs 2003).

In fact, in autumn 2009, after the first normative evaluation, it was observed that their overall capacity to engage in constructed reasoning weaving together different types of data was on the whole rather poor when conducting research in humanities. It became obvious that the students' concept and knowledge capacity-building essential to critical thinking needed to be consciously developed. Therefore, more time was needed to develop them, which led to the use of brainstorming, questionnaires, and removing some of the teacher-led case studies and elements of corpus as figure 1 below reveals. The more formal formative evaluations targeting critical thinking were inserted, the less it was possible to cover the targeted corpus, until it stabilized in the spring 2013.

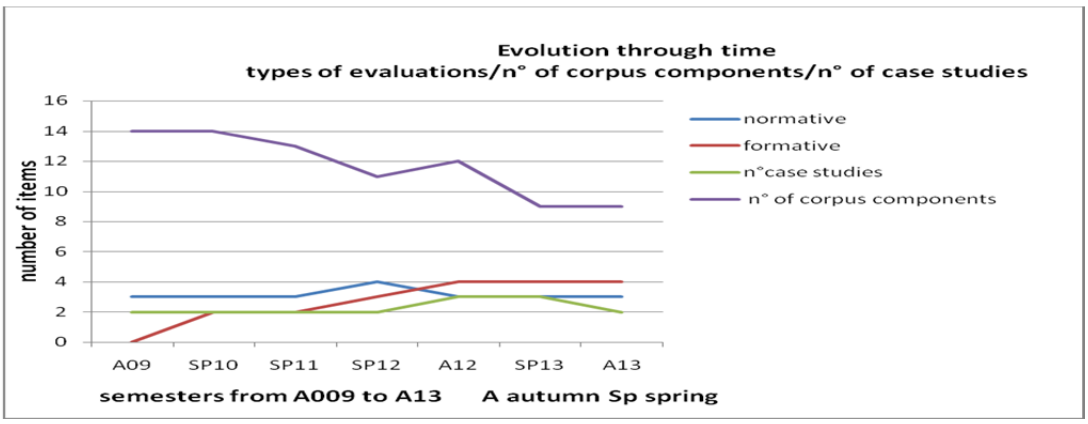

Figure 1: Overview of the ratio of evaluations, elements of corpus and teacher-led case studies

It also made the need to implement Project Based Learning at curricular level and the importance of collective planning from year 1 to year 5 more salient. The risk here is that students might not be able to transfer cognitive analytical and synthetic skills from one type of science to another as interdisciplinary projects are rare. This disassociation and a rigid classification of sciences represent a non-negligible epistemological obstacle as students might have real preconceived ideas about social and human sciences. Hence, culturally and scientifically inclined to have a convergent rather than a divergent predisposition, a large number of lecturers seem to be sceptical about competences-based curricula and qualitative interpretative research methods, as opposed to knowledge-based curricula and systematically verifiable evaluation systems. As Clive L. Dym's paper recalls, (Dym et al, 2005)'*divergent inquiry takes place in the concept domain, where concepts or answers themselves do not have truth value*', as opposed to what his paper calls: 'Aristotle's *epistemological convergent inquiry process*. Students need opportunities to question the multiplicity of answers, and need to be made aware that answers can diverge because of the stand point from which one answers, and also because of the theories one chooses to use. The work of David Hay (Hay, 2013), for example, shows how much scientific cultural laboratory habits might in fact lead students to replicate their tutor's habits, he calls *signature*, and in doing so, might prevent creative critical thinking.

3 Collecting and analysing tangible traces of critical thinking.

In order to analyse the gap between the typical types of academic writing produced by engineering students from 2009 to 2013, the first text given below is as an example of typical narrative articles in 2009. Most teachers are used to getting this type of article when asking university students to write on a given subject. This is an example of a normative assignment which was done following the same course, except for the formative evaluations. Students in autumn 2009 went straight from the end of the 4th week to the first written evaluation, which was on books. A book had to be selected, a first part was meant to give an overview of the factual information, and then, students had to ask a research question in relation to its cultural identity and memory, to propose an answer using class and individual research and to draw a concluding.

Keys: yellow: facts; green: opinion/ conclusion from facts giving a solution; blue: hypothesis/questioning/forecasting/challenging opinion/; white: quotes/names/academic or other references; light grey: experience

The Encyclopedia comes from the project to translate the Cyclopaedia or a Universal dictionary of arts and sciences published in 1728 in Great Britain.I will introduce the political regime, second, I will give some information referring to The Encyclopedie and I'll end with an open-ended question.

First, The Encyclopedia was written during the 18th century. The project of writing such a large book came from the philosopher d'Alambert and Diderot. "The aim of the Encyclopedie was to gather all the knowledge of the earth; to expose its general system to mankind in order to preserve the past century's research tasks, so it would not have been useless for the next centuries …". *Also, the 18th century is known as the century of the "Enlightenment" and the political regime was an absolute monarchy of which the king was Louis XIV. This kind of political regime means that the king is like god for his people, in fact, he held all three powers, legislative, executive and legal. All these facts imply there was no liberty of communication and expression. Blaming the absolute monarchy is the main century of Enlightenment's claims.*

Do you think France would be the same without the writing of this book? In my opinion, France would not be the same if years ago philosophers did not take the opportunity of defying the absolute monarchy by writing The Encyclopedia. In fact, I think that without this book, the political regime still would be a monarchy. In fact, the

knowledge provided by this book, was essential to the construction of today's society. It allowed the expansion of knowledge for all social classes without any distinctions. Also, from my point of view, this book was the first step in the way of liberty of expression. It led in to the French revolution of 1789. *'*

The colour code used to analyse this piece of writing, made it possible to see that most of the students remained at the announcing factual information stage, with some attempt to construct an opinion. The narrative style seems to limit the analytical mode, although a beginning of constructed analysis based on the facts started to appear after the question. However, the research question was not tackled at all, no evidence of critical thinking was really present as only an opinion was submitted and no constructed synthesis weaving different types of data together was visible. The question of identity was formulated but the theoretical and empirical data needed to answer the question is absent. The blocks of colours show that the layering of factual knowledge does not lead to the understanding of the targeted concepts. The lack of experience in the construction of very difficult concepts such as identity and memory, and the inability to reuse knowledge became the main pedagogical targets.

If brainstorming was used after 2009, it proved to be insufficient. Activities leading students to identify links and manipulate facts and knowledge in different contexts until they could use it in their own writing were needed. To reach a presupposed abstract stage, as Bruner's theory puts forward, meant that it was necessary to put in place a coherent cluster of formative evaluations alongside class activities. Each one had a role and specific cognitive targets. Table 1 below summarizes why some of them were used from a student's point of view. The one presented next is in bold in the table.

Table 1: Types functions and typology of formative evaluations

Types	**Functions**	**Types**
Brainstorming	Build-up awareness from raw data retrieved from memory of experience Mapping concepts, identifying links Becoming aware of the whole/the parts Defining boundaries/questions, sub-questions of research and necessary steps and resources	Spider webs Lists of parts Diagrams Tables
Syntheses	**Becoming aware, summing up and linking ideas, experiencing knowledge and individual research and proposing a synthetic written piece**	**Piece of academic writing prior to normative evaluations**

In comparison, the student's text in autumn 2013 presented below shows how a student was able to use different types of knowledge to put forward her own conclusion. In the instruction they were asked to bring together all the previous formative evaluations and the class activities in a synthetic piece of formative writing. On the researcher's side it was designed to show how students were putting together facts and experience of knowledge acquired over time, through an active process to generate knowledge, and to see if they were conscious of it. Although it was an individual piece of writing, it summarises the collective activities, so as to balance what belonged to the group and what was processed by each individual, both at a collective and an individual level.

Keys: yellow: factual knowledge; green: opinion/ conclusion from facts/ giving a solution; blue: hypothesis/questioning/forecasting/challenging opinion/; white: quotes/names/academic or other references**; light grey: experience**

'Memory and Identity are basic concepts in humanities and social science in the same way as the concept of culture. First our identity is defined by our interaction with ourselves and our interaction with our environment.

Our interaction with ourselves can be defined in subjective and almost philosophical ways. It can be the link between our unconscious and our conscious […] This aspect raises more questions than it brings clarifications on our exact nature because our knowledge concerning our brains is limited. I will not analyze more those problems and let Freud, Nietzsche and Descartes give their reflections about it.

Our interaction with ourselves can be more simply an introspective work. ***For example our perception of ourselves. Am I confident and do I have a good self-esteem of myself? Or maybe it's also about our feelings or our aspirations. Do I have career goals and ambition? In a more global way it's the personality we have and all the distinctive choices we made to construct what we think we are or what we have decided to be.*** *[…]This raises the question of our link with the environment. […]*

Let's focus now on memory. If we assume that our identity relies on our memories, we can admit that our identity in not invariant in time but evolves as we get new memories or as we forget. My point is that our identity is malleable such as our memory and has no delimited frontiers. It grows like the universe expands but we forget old or useless information. I want to develop the fact that memory can have a bad influence on our identity. Thus, our memory can be tricky and lie to us. Sometimes you can't rely on it. ***About our childhood,*** *we have "flashbulb" memories of what we have been. Even if some of those feeling memories seem detailed and clear, our brain can restructure blur memories and it might happen that we remember things that in fact never happened. We can't bring up a memory in our mind without altering it!'*

These 2 extracts from students' academic texts show both ends of the spectrum, and so, it gives the researcher-practitioner a framework in which to work on for later evidence-collecting oriented case studies. In the first one, the student is merely stating factual information, most of it not substantiated, and the limited English skills might also restrain the writing ability. Some facts are given but not inserted in a thinking process. Although a question is asked and a semi-constructed opinion is given, the question is not fully answered. The structure of the text shows that facts and opinion are separated and juxtaposed as opposed to being linked and woven together. Personal constructed class experience was not used to construct the opinion.

The second extract shows what the other end of the spectrum could be at this stage of the course and what still needs to be worked on. Consequently, it gives the teacher an indication of what activities need to be put in place. The student manifests the mechanisms behind the process of raw data internalization extracted from experience mingled with the data that was uncovered during group class activities and individual research. The construction over time is visible. The researcher-practitioner can see evidence, and visible traces of the cognitive competences that were built through time, pre-scientific thinking acquiring the necessary cognitive skills to become scientific. Although, referencing and stating where the facts or theoretical opinions are from has not been fully mastered. If only some of the students reached this stage so early in the course, the collections of extracts give the practitioner a partial view of the scope of cognitive competencies and the dynamic nature of doing a research project. They also reveal the decision-making nature of any type of research, and therefore reaffirms the idea that concept and capacity-building depend on the handling and choosing of facts or theories , as much as the cognitive capacity to weave them together and to transform facts into knowledge for oneself and others.

The first obstacle with the colour code as a qualitative interpretative analytical technique is the software's limited palette of colours. As an analytical technique, the colour code is obviously entirely subjective, and it is debatable whether or not it is a reductionist way of interpreting qualitative data. Nevertheless, it was firstly useful to manifest the different types of data constructed or not, and the gap between what is a fact and what is knowledge. The constitutive elements of pre-scientific reasoning started to appear, mainly based on stating facts and using opinion based on non-constructed experience of data, as opposed to scientific reasoning which is meant to integrate constructed experience, what Gaston Bachelard calls knowledge in expansion. An internal cognitive process that was absent in 2009 was expected to emerge. An active thinking process was needed to transform facts into knowledge. What also became clear is that critical thinking does not occur by chance, that training over time was needed to construct the necessary cognitive skills essential in selecting and linking data. The technique developed here needs refinement because it also limits the decision-making process while analysing the data, since it is sometimes difficult to decide in which category to enter some of the sentences. The subjectivity of the decision-making process involved in a qualitative interpretation of qualitative data is a recurrent question, as Bent Flyvbjerg highlights (Flyvbjerg, 2006). However, quantified data would reach one of its boundaries in this case, as qualitative data, although unstable, reveals more about the process than numbers in tables.

It was possible to further verify some of the advantages and pitfalls of a colour coded qualitative interpretation technique with a short text extracted from Gaston Bachelard *La philosophie du non.'* (Bachelard, 1966). The number of colours used had to be increased.

Keys: yellow: facts; green: opinion/conclusion from facts/giving a solution; blue: hypothesis/questioning/forcasting/challenging opinion; white: quotes/names/academic or other references; light grey experience; pink :philosophy, analogies; dark grey : new concepts/theories

'Destouches says over and over again that if arithmetic in far distant developments were to reveal itself contradictory, reason would be reformed to efface the contradiction and arithmetic would be kept intact. Arithmetic has given such numerous proofs of efficiency, exactitude and coherence that there can be no idea of abandoning its organization. In the face of a sudden contradiction, or more exactly, faced with the sudden necessity of a usage contradictory to arithmetic, the problem of a non-arithmetic would arise, of a pan-arithmetic, that is to say of a dialectical prolongation of those intuitions of number which would permit the wholesale amalgamation of classical doctrine into the new doctrine. In the interests of clarity we must have no hesitation in pushing our thesis to this extreme. To be sure such an extension of arithmetic has not been made. In supposing it possible we simply want to affirm that arithmetic is not the natural outcome of an immutable reason any more than geometry is. Arithmetic is not founded upon reason. It is the doctrine of reason which is founded upon arithmetic. Before knowing how to count I could hardly know what reason was. In general the mind must adapt itself to the conditions of knowing. It must create in itself a structure which corresponds to the structure of knowing. It must mobilize itself around articulate expressions which correspond to the dialectics of knowledge. What good would a function be without occasions to function? What good would a reason be without occasions for reasoning?'

The categories in pink and in dark grey show creative zones and creative thinking as they lead to a new understanding or a new perception of concepts or abstractions using facts, opinions and hypotheses. It is possible to see the constitutive cognitive mechanisms of the inductive and deductive interplay in both a pre-scientific and scientific posture as table 2 below reveals.

Table 1: the interplay between induction and deduction

Pre-scientific posture	Scientific posture
Reasoning is based on instinct, emotions only **Not being able to give a definition** **Having preconceived ideas about a subject and forging an opinion from them**	Can intellectually reason some aspects using previous constructed memory of knowledge previously accumulated **experience, emotions or feelings about the environment in which they occurred** to synthesize

Relying on memories, feelings in the analysis of past experiences **and the environment in which they occurred** to synthesize	Being able to include multi-facets in one’s reasoning outside mathematical or other convergent scientific constructs
Being able to define some of the parameters **without being aware why it is how it is**	Being able to verify and to synthesize within the boundaries of the scientific culture
Can intellectually reason some aspects using previous constructed memory of knowledge previously accumulated **experience, emotions or feelings about the environment in which they occurred** to synthesize	Being able to define parameters, limits of reasoning, to go beyond scientific boundaries
	Being able to apply theories to a variety of clinical, empirical and other experiments using scientific procedures in view to propose new applications in real complex problems
	Relying on convergent theories only to theorize and model

4 Conclusion

To summarize the functions of formative evaluations , it can be said that they are conscious acts on which pedagogical decisions are made, that they come in a variety of shapes and formats and must be adjusted to the discipline, as much as to the teachers’ and the students’ cognitive targets. The competences-based curricular approach designed by Aalborg presupposes that to give space for the development of cognitive competences, lecturers have to rethink their pedagogical mapping, and the interactions between the transmission of knowledge and the development of competences at some point in the 5-year course. What is more, it confirms that facilitation does not imply letting students ‘get on with it’, but on the contrary it means framing critical thinking, and making it visible and accessible to be reflected upon. It also comforts the idea that PBL cannot be copied and pasted from a scientific culture to another, as the postures can be antagonistic.

The construction of concepts, such as identity and memory, specific to the study of world heritage, gave engineering students the possibility of exploring multifaceted questions, which are proven to be difficult for engineers, perhaps, because like their tutors, they are more used to systematic questioning and answering. Most of what is known about creative thinking tends to demonstrate that it is a multi-faceted and multi-directional and dynamic process whose occurrences are unpredictable but linked to experience, expertise and mastery of a discipline as much as the ability to manipulate, categorise and organise the same data in a variety of ways. Writing syntheses is an effective practice which necessitates time and space to be practised if the quality of academic writing is to be improved. The degree of creativity in scientific thinking seems to depend on a diversity of previously constructed memories of knowledge. However, this case study does not establish if creativity in art is the same, or not, as creativity in science.

As regards to PBL as a methodology, it remains a scientifically complex system to put in place because of its multiple layers. Pedagogical engineering level has been identified as an empirical methodology used to deploy the chosen curricula and related competences over time. If the results from engineered pedagogical scenarios can influence theories, the reverse is also true if they are to continue to evolve and to be creative. Below is an individual schematized vision of the different layers of PBL which has been useful to gain an overview of it. A top-down as much as a bottom-up dynamic can be imagined here

Table 3: Layers of PBL in Concept/knowledge capacity building

Philosophical approach UNESCO	Democratic access to knowledge, knowledge for the construction of peace and a better understanding between people, for a free access to knowledge. New technologies used to share the findings of investigations. The right to be a free creative scientific and reflexive thinker is promoted.
Theoretical approach epistemology, action-research, concept/knowledge capacity building	Paradigm in contemporary science of education: grounded, socio-constructivist, naturalist and critical. At theoretical level: based on results of action-research, case studies, classroom observations and qualitative interpretative evaluations. The researcher's scientific background and epistemological posture can have a real influence on the curricula and how it is delivered. The researcher is a free creative scientific and reflexive thinker
Empirical approach pedagogical engineering	Competences-based, hands-on and student-centered real and collectively constructed learning scenarios. Divergent research projects are used to encourage students to make decisions and become in charge of team projects linked to reality. The student is trained to be a free creative scientific and reflexive thinker.

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Inventiveness and Society, an experience from the Problem Based-Learning approach for a post-conflict scenario in Colombia (South America).

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Abstract

The National University of Colombia is the main public university in Colombia (South America), it is a public university with the mission to study and analyze national problems and propose, independently, relevant formulations as well as pertinent solutions to these challenges. In this sense, the Inventiveness, Science, Technology and Society course was created as a space of PBL (Problem Based-Learning) in the Faculty of Engineering in 2014. There are three criteria for its operation, namely: Diversity, as the course is open to all University programs, development of a study and research according to social issues, and finally, prospective in a Post-Conflict scenario for vulnerable communities. In this article we try to summarize the experiences we had, the lessons learned, after a year of its creation.

Keywords: PBL, Diversity, Interdisciplinary, Marginalized communities; Post-Conflict.

1 Introduction

The purpose of this paper is to communicate the experience of the Inventiveness, Science, Technology and Society course at the National University of Colombia This course was inspired on the PBL strategy with a particular focus on possible post-conflict scenario learning. The structure of this paper is as follows: at first an introduction to the Colombian context and the Faculty of Engineering of the National University of Colombia, then an exposition of the characteristics of problem-based learning, to continue with the characteristics of post-conflict scenario, and finally, a presentation of the experiences of the course and the lessons learned.

Education is a human right, and according to the Colombian Constitution, should be protected and promoted conforming to the needs of all sectors of the country (Art. 67). In this sense, the Colombian panorama with poverty rate of 30% (Departamento Administrativo Nacional de Estadística, 2013) and a scenario of peace talks between the guerrillas and the national government, calls for significant changes in the education of the youths, particularly for higher education. Orienting these changes to find solutions for the challenges of the most vulnerable population and historically marginalized communities.

In Colombia the most important actor inside the higher education system is the National University of Colombia, public state institution with 148 years of history, 8 locations around the country and the main source of scientific knowledge. This university has the mission to study and analyze national problems, in order to present possible solutions. In addition, this institution must try to produce benefits from their academic and research activities for all social sectors.

The Faculty of Engineering is the largest of Bogota, having nine (9) programs for undergraduate, four (4) of specialization, seventeen (17) Masters and seven (7) PhD, 64 groups research (recognized and unrecognized), 77 laboratories and 3 solidarity outreach projects. Tables No. 1 and 2, show the number of undergraduate and graduate students of the Faculty.

Table 1: Number of students for each "Undergraduate" program in 2014.

Program	Agricultural Eng.	Civil Eng.	Electrical Eng.	Electronic Eng.	Industrial Eng.	Mechanic Eng.	Mechatronics Eng	Chemical Eng.	Systems Eng.	**Total**
Total	415	1123	569	548	514	730	449	1131	760	**6239**

Source: Academic Vice-dean, Faculty of Engineering, National University of Colombia in Bogota. 2014.

Table 2**:** Number of students in the Engineering Faculty in 2014.

Level	Undergraduate	Specialization	Professional Master	Research Master	Doctorate	**Total**
Total	**6239**	**34**	**360**	**384**	**152**	**7169**

Source: Academic Vice-dean, Faculty of Engineering, National University of Colombia in Bogota. 2014.

As described in the tables above, the number of students is significant compared the number of students in Bogotá 29,788, corresponding to 24.06% (Rectory, National University of Colombia 2012). This indicates the responsibility of the University, and of this Faculty in particular, in the processes of social progress both nationwide and internationally. In this sense, the mission of the faculty is presented below:

> *"To educate the Engineering professionals and graduate that the society needs, based on the commitment to scientific research and technological and social development. This, in order to contribute to the transformation of the country through the generation, storage and transmission of knowledge, expressed in the transfer of expert knowledge and technological innovation, and produced by members of the academic community of the faculty both in the public sector and the private sector." (Engineering Faculty, 2015).*

In order to increase the social impact of engineers, in 2010 the group of Inventiveness Without Borders (from now on ISF) was created. This group includes both undergraduate Engineering students and students from other faculties in Bogotá (Cortés, Martinez, Leon, & Peña, 2013). This team was generated to create spaces of reflection and action, thereby promoting awareness and solutions from science and technology to problems of vulnerable communities in Bogotá and its surroundings. A leading ISF project has been called TRASHWARE, which seeks the redefinition and re-use of electronic devices with communities (León, Martinez, Reina, & Romero, 2012; Martinez & Diaz, 2014). The main objective of the group is to promote the autonomy and empowerment of communities in the context of poverty, internal conflict and climate change in Colombia.

This group of students has led academic process through postgraduate programs, and several of its members participate in networks such as International Development Innovation Network (https://www.idin.org) and Engineering, Social Justice and Peace Network (http://esjp.org/), which create new interests to develop institutional-level impact and strengthen networks. Now, at the end of 2013 in conjunction with the Dean of the Faculty of Engineering, the course called, Inventiveness, Science, Technology and Society, finally opens.

The main issues addressed in this course are about the challenges of marginalized communities and economically vulnerable and the co-creating process. According to the United Nations Development Programme (UNDP, 2014) about 1,200 million people live on less than $ 1.25 per day and 1,500 million live in multimodal poverty condition. In the meantime, in Colombia according to the National Bureau of Statistics, 30.6% of the population lives in poverty and 9.1% under the conditions of misery (National Administrative Department of Statistics, 2013).

2 Problem-based learning for an interdisciplinary course

Problem Based Learning (PBL) is a pedagogical strategy that has been successfully used for over 40 years and continues to grow in various disciplines (De Graaff & Kolmos, 2007). According to Boud & Feletti, (1997), this approach emerges in the 1960s in higher education institutions in North America, particularly in schools of health sciences, as an innovation in the curriculum. Is the School of Medicine at McMaster University in Canada, the pioneer in PBL, presenting the tutorial process as a central concept of its philosophy of curriculum structure, also promoted multidisciplinary student-centered education and lifelong learning in professional practice (Barrows & Tamblyn, 1980).

Over the years PBL has been used in many fields of health sciences, as Dentistry, Nursing, Radiology and Paramedics (Savery, 2006). Likewise in other fields of knowledge as MBA programs (Stinson & Milter, 1996), higher education (Bridges & Hallinger, 1996), Chemical Engineering (Woods, 1996), Engineering (de Graaff & Kolmos, 2007), Economics (WH Gijselaers, 1996), Architecture (Kingsland, 1989), and the initial education of teachers (Hmelo-Silver, 2004), among others. Duch, Groh, & Allen, (2001) describe the specific skills developed, including:

- Ability to think critically
- Analyze and solve complex real-world problems
- Find, evaluate, and use appropriate learning resources
- Work cooperatively
- Demonstrate effective communication skills
- Use knowledge and intellectual skills to become continuous learners.

A key to the success of this strategy is the selection of ill-structured problems (often interdisciplinary), and a tutor who guides the learning process and conducts a briefing about the conclusion of the learning experience (De Graaff & Kolmos, 2003). On the other hand, De Graaff & Kolmos (2003, p. 2), argue that according to some researchers the PBL is related to a variety of theoretical constructs, such as Experiential Learning (Kolb), Reflective Practice (Schön) and constructivism (Piaget, Vygotsky, Lave and Wenger).

2.1 Characteristics

This approach is mainly characterized by being focused on the learner, because empowers them to develop the research, integrating theory and practice, and apply knowledge and skills to create a viable solution to a defined problem (Savery, 2006). Similarly, Boud & Feletti (1997) provide a list of 10 practices which are considered characteristics of philosophy, strategies and tactics PBL then presented in summary mode.

- Students must take responsibility for their own learning.
- Simulations of problems used in problem-based learning should be poorly structured and allow free inquiry.
- Learning should be integrated from a range of disciplines or subjects.
- Collaboration is essential.

- What students learn during their self-directed learning should be applied back to the problem with a new analysis and resolution.
- A close analysis of what has been learned working with the problem and a discussion about what concepts and principles learned are essential.
- Self-assessment and peer assessment should be conducted at the completion of each problem and at the end of each curriculum unit.
- The activities carried out in problem-based learning should be valued in the real world.
- Tests students must measure student progress toward the goals of PBL.
- Problem-based learning should be based on the educational curriculum and not part of a teaching curriculum.

The above features are clearly synthesized by Savery (2006), in 1) The tutor's role as a facilitator of learning, 2) The responsibilities of students to be self-directed and self-regulated learning, and 3) Essential elements in designing instructional unstructured problems as the driving force for research. As PBL models, Savin-Baden (2000, 2007), propose five models that state the amplitude of PBL, among them are posed: PBL for epistemological competence, PBL for professional action, PBL for understanding interdisciplinary, PBL for trans-disciplinary learning and PBL for critical contestability.

2.2 Aalborg Experience Center

The experience of PBL with a higher level of consolidation is the Aalborg Center for Problem-Based Learning in Engineering, Science and Sustainability at the University of Aalborg, which it has the auspices of UNESCO. The engineering program at the University of Aalborg is based on PBL, which began with the formation of the university in 1974. All engineering programs undertake a common program first year and take core courses in mathematics, physics and computer science, mainly taught in a traditional format (Mills & Treagust, 2003).

A driving force for the center is the integration of sustainability on engineering education and science. It also contributes to a reform strategy for higher education by combining project-based learning and problems, Research and Education in Engineering Education for Sustainable Development. This is a unique combination of the areas of research and development is interdependent and complementary. Thus, knowledge and skills require complex learning processes between existing disciplines, and PBL is a learning methodology that successfully serves this purpose (Kolmos, A., & Fink, 2006).

2.3 Misunderstandings in PBL application

It should be noted that the widespread adoption of the teaching-learning PBL method, by different disciplines, in different content domains and for different age levels, that according to Maudsley (1999), has produced some misconceptions and misapplications of PBL. Boud & Feletti (1997, p 5) describe various situations to consider that can lead to failure in order to achieve a significant result, which are:

- Confusing PBL as an approach to curriculum design of teaching problem solving.
- The adoption of a proposal PBL without sufficient commitment of staff at all levels of the institution.
- The lack of research and development on the nature and type of problems that will be used.
- Insufficient investment in the design, development and continuous renewal of learning resources.
- Inappropriate assessment methods that do not match the learning outcomes sought in problem-based programs.

- Assessment strategies that do not focus on the key issues of learning, and re-implemented and act accordingly too late.

3 Post-conflict scenario

The current internal conflict in Colombia has been about 50 years long, facing various actors among institutional (Armed Forces and Police), and non-institutional groups (Guerrillas and Paramilitaries). However, since 2013 a process of peace talks with the FARC guerrilla has been taking place, and in 2015 is expected to begin talks with the ELN guerrilla. These processes generate expectations of a post-conflict scenario in Colombia, an event that would change the course of the Colombian population, generate new opportunities for young people and builds the way to address the priority needs of vulnerable communities. Post-conflict is defined as *"a process that involves achieving a range of milestones peace in this sense post-conflict countries should be seen as a continuous transition to peace"* (Brown, Langer, & Stewart, 201, p 2).

Similarly, is expected to generate a reflection of engineering education for this period, as was the Report of the Committee on Engineering Education after the war (American Society of Engineering Education, 1944).

It is necessary to observe the current conditions of marginalized communities in Colombia, according to the Departamento Administrativo Nacional de Estadística (2013), the poverty level is 30.6%, while extreme poverty (misery) is about 9.1%. In this context 1 of 3 Colombians live in conditions of economic vulnerability. However, the gaps between rural and urban areas are evident (Figure 1), where 2 out of 5 people living in rural areas are extremely poor; which shows the territorial inequality between rural and urban in Colombia.

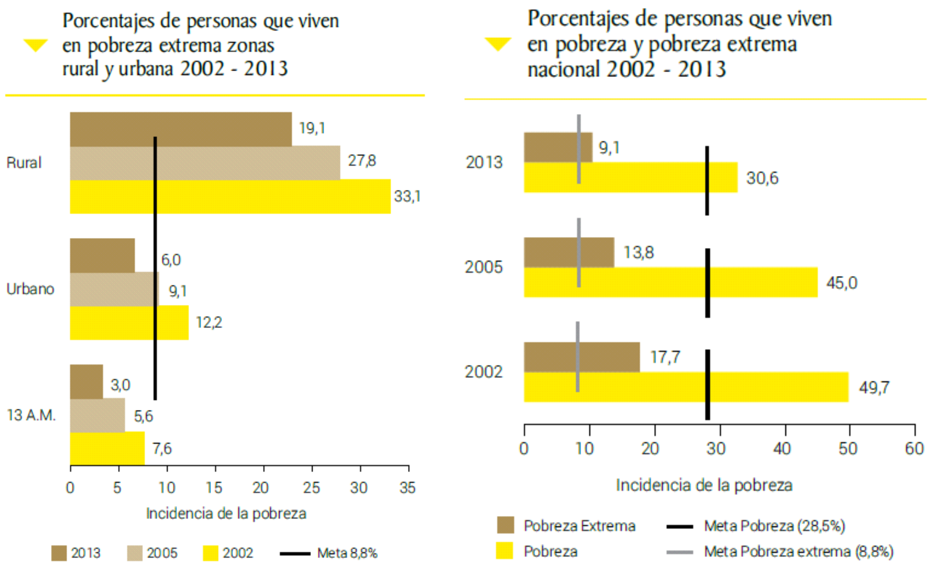

Figure 1: Percentage of people living in poverty and extreme poverty (Rural and Urban)
Source: UNDP Colombia (2014b).

Now it is necessary to go beyond poverty indicators and analyze the complexity of the Colombian landscape and especially priorities in a post-conflict scenario. For this, appears the Social Progress Index, which measures the ability of a country to meet social and environmental needs of its citizens, where 100 is the Optimal and 0 is the unwanted scenario (Social Progress Imperative, 2014). This index is the composed of fifty-two indicators in the areas of Basic Human Needs, Fundamentals of Welfare and Opportunities and these show the relative performance of countries in these areas. In Figure 2, the index for Colombia is observed at general level and individual level in the three sub-indices:

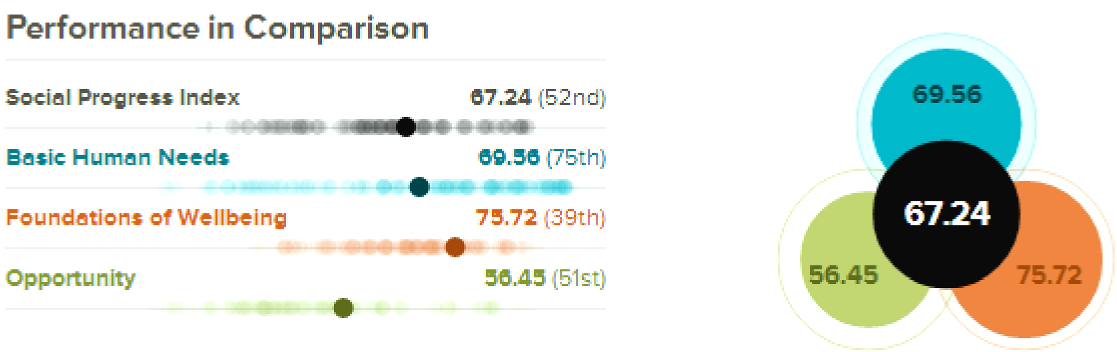

Figure 2: Index of Social Progress 2014 for Colombia.
Source: Social Progress Imperative (2014).

As seen in the figure above, the critical areas are the Opportunities (56.45) and Basic Human Needs (69.56), so in a context of post-conflict the priority of the State and the University's efforts is to resolve jointly with communities mayor issues in a co-created way (Participatory and Inclusive). According to the index, the sub-areas with poorer performance are: nutrition and basic health care, water and sanitation, personal security, access to basic knowledge, access to information and communications, and access to higher education.

There is one opportunity to work from the engineering education to solve social problems from new approach. An emerging field within engineering is the Humanitarian Engineering, as a theoretical and methodological approach should encourage learning and practice scenarios for future engineers in a post-conflict scenario (Colledge, 2012; Mitcham & Munoz, 2010, 2012). This is conceived as a field of engineering that aims for the co-creation of innovative solutions, with criteria of social justice and sustainability priority problems of marginalized communities through processes of teaching, reflection, research, design, manufacturing and construction.

4 Inventiveness and Society

In science and engineering, the work with vulnerable communities does not reflect a significant impact, among other reasons, because the theoretical and methodological foundations from academia needed to develop projects with a socio-cultural approach are not evident. It is necessary to provide tools to develop initiatives with social impact and alternatives to solve problems, with help of the academy influence in a relevant way within communities.

The Inventiveness, Science, Technology and Society course, provides tools and concepts to work with communities from the field of basic sciences and engineering, providing theoretical and historical perspective, elements of public policies and successful experiences. For that reason, students from the perspective of problem-based learning can enhance the ability to propose possible solutions to the needs identified in conjunction with communities.

The motivation behind the creation of this course was and still is the lack of spaces for reflection and action with an interdisciplinary focus within the National University of Colombia. Allowing students relate with various, backgrounds (peasants, indigenous, Afro-Colombians and even international students), experience and knowledge to solve problems of communities. The content of the course has evolved in 2015 three modules, starting with critical studies of science and technology and the role of the university. Then it reflects on science, technology and innovation in a post-conflict scenario and finally, alternatives to conventional paradigms.

The course methodology is developed through problem-based learning, particularly challenges of science, and technology in vulnerable communities, which is applied through groups of 5 students of different programs in the university. Problems are identified together with communities and the approach of technical, social and cultural solutions is performed autonomously by themselves.

The course start the first half of 2014, in a year one hundred and fifty students from different programs such as engineering, basic sciences, political science and law, health sciences, economics have completed the course, also have had 34 guests, 10 work experiences, 30 projects and 138 licensed Creative Commons trials (Content with free licenses - http://creativecommons.org/) (see Table 3).

	2014 I	2014 II
Students	90	60
Guests / Experts	18	16
Work experiences	4	6
Projects	18	12
Essays CC Licensed	83	55

Table 3: Summary of the results of the course in 2014 I and II

In terms of diversity, the course has been built by students from 25 undergraduate programs National University, being mostly taken by students in Chemical Engineering (17 students) and Industrial Engineering (17 students), however, students of Pharmacy, Physics, Industrial Design, Business Administration, Geology, Mathematics, Sociology, Medicine, Political Science, have been part of the course as well (see Figure 3). This creates an interdisciplinary learner-centered environment and provides an opportunity to integrate prior knowledge of apprentices and generate more holistic solutions, addressing social problems involved in the course.

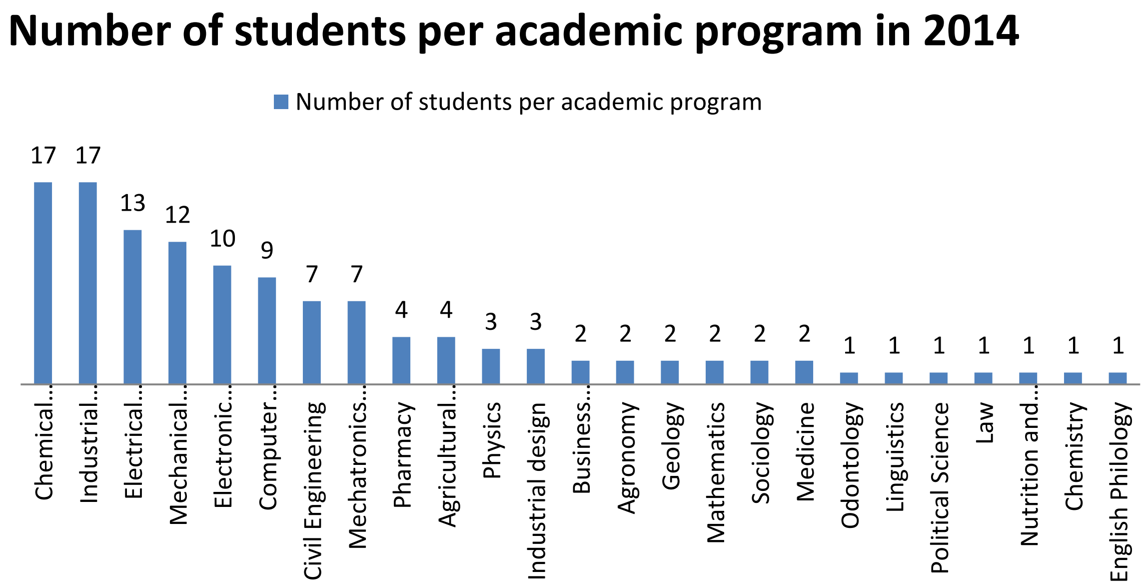

Figure 3: Students per Academic Program in 2014.

Also the Engineering Faculty has been around with 96 students, along with the Faculty of Science, 12 students and the Faculty of Humanities, 4 students, the faculties with more interest in the course. It is important to note the participation of 9 of the 11 faculties of Bogotá in the course (see Figure 4), demonstrating the interdisciplinary nature of the course.

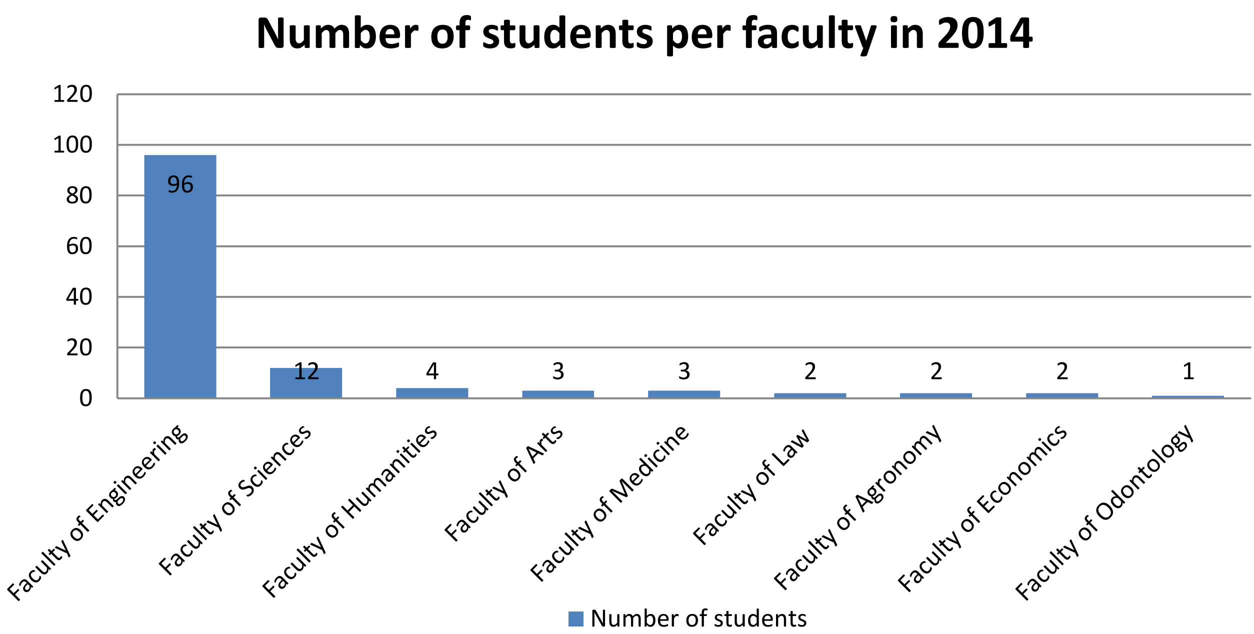

Figure 4: Students per faculties in 2014

Meanwhile, in an experience and time at university level, the students are mostly from sixth to tenth semester, showing that wish to apply their theoretical knowledge, including 30 students in tenth semester, but none student of first year (See Figure 5).

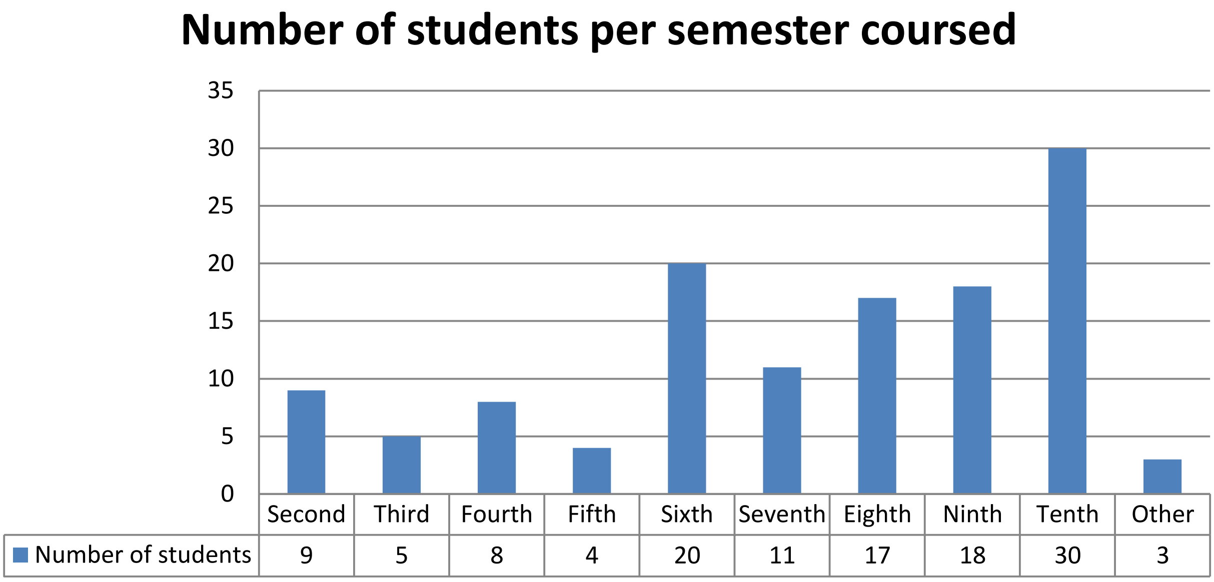

Figure 5: Students of the course per semester completed in 2014

The methodology of the course focuses on guest keynote speeches, that are developed by thematic sessions, which weave together elements to reach sustainable human development from engineering (Amadei, 2014; Lucena, Schneider, & Leydens, 2010a, 2010b; Schneider, Lucena, & Leydens, 2011; UNESCO, 2010), and dual interdependent relationship between Engineering and Social Justice (Lucena, 2013; Riley, 2008) and learning through service (Bielefeldt & Joshua, 2012). Students must develop a preliminary report in interdisciplinary groups to co-create alternative solutions to problems of vulnerable communities, also must write a critical essay about their area of study and topic of the course. The models of PBL that the course tries to develop are: PBL for understanding interdisciplinary and PBL for critical contestability according to Savin-Baden (2000).

5 Lessons Learned

The process of creation and consolidation of a collective academic space in the Faculty of Engineering, offers lessons of learning and sharing with other groups and colleagues. In a first step the thematic evolution of the course, which over time has been deepening and generating debates in the teachers group, focuses on problems of vulnerable communities and towards a post-conflict scenario in Colombia.

The problems identified during the course, are approach from the perspective of knowledge dialogue and from validation of tacit or traditional knowledge of communities in the academy. Therefore, communities are at the same level of student participation, which has been observed since the interest of generating processes of co-creation together with communities. You need to have continuity throughout the learning process of students, and so far no institutional commitment to develop this strategy throughout the academic programs of Engineering.

A more rigorous groups accompaniment must been settled to achieve their objective, since being a large number of students and groups, it is a risk of not advancing the learning process. In this regard, since 2015 it has been holding an assistantship of mentoring graduate students of the University, to strengthen the development of students' work.

Students who complete the course may be linked to the course's planning group, as it is conceived as a participatory and open space. In this sense, they decide on the content and development of the course, and can collaborate with the working groups to generate a greater impact on the development of its proposal.

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Development of a Global Network for PBL and Engineering Education

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Abstract

In November 2013 the General Conference of UNESCO approved the Aalborg Centre for Problem Based Learning in Engineering Science and Sustainability (Aalborg Centre), which encloses the UNESCO chair in PBL and Engineering. The overall vision of the Aalborg Centre is to contribute to a greener and more democratic society by reflecting on the role engineers and scientists play and what kind of education they need.

Engineering education is challenged by the profession and society to educate engineers prepared to develop sustainable and innovative technologies, which calls for new kinds of knowledge, skills and competencies. Problem based learning (PBL) is a student centred learning approach enhancing students' problem solving skills, critical thinking, interdisciplinary learning, self-directed learning, which are claimed to be key-competencies needed to face the challenges of the global society.

As part of the strategy to accomplish her vision, the Aalborg Centre aims to establish "*… a global network of practitioners, researchers, experts and institutions within the field of Problem Based and Project Based Learning (PBL) in Engineering Science and Sustainability from developing and developed economies, and thereby exchange knowledge on how to change engineering and science education for PBL and sustainable development at the national, regional and international levels*" (Aalborg Centre, 2014). Furthermore, the Aalborg Centre established a Global Network task force in order to develop, organise and carry out several activities and initiatives namely research symposia, workshops, open access resources, webinars and international online master programmes for staff development. Some of these activities were initiated in 2008, under the UNESCO chair, such is the example of the international research symposium for PBL (IRSPBL) organised and held every two years, or the master in PBL for staff development (MPBL).

The success of a network depends to a large extent on the commitment of the participants. In order to gain insight in the factors motivating the potential members of the network the authors constructed a questionnaire and send it out to 1300 potential collaborators and partners, which are part of e-mail database of the Aalborg Centre. The responses from the questionnaire allow Aalborg Centre to adjust its strategy to an updated overview of the needs and expectations and, consequently, to better organize and structure its activities.

Keywords: Problem Based learning; Project Based Learning; Global network, Knowledge sharing

1 Introduction

Aalborg University has a long-standing reputation for its innovative PBL curriculum. In particular, in engineering education, the Aalborg model has been a source of inspiration to many (Kolmos et al, 2004). In

2007 the UNESCO Chair in Problem-Based Learning in Engineering Education was established at Aalborg University, Aalborg, with professor dr. Anette Kolmos as chair holder. Prominent among the objectives of the UNESCO chair for PBL is the creation of a global sustainable society of researchers, experts and institutions in Problem-Based and Project-Organized Learning (PBL) in Engineering Education and the dissemination and exchange of knowledge among partners both in terms of how to implement PBL in education, in carrying out research in PBL and in applying PBL methodologies to issues in society.

In 2014 UNESCO showed their appreciation for the work of the UNESCO chair by approving the establishment of a UNESCO centre in Aalborg. With four professors, several associate professors and a number of PhD students, the Aalborg Centre for Problem Based Learning in Engineering Science and Sustainability (Aalborg Centre) constitutes a more solid base for the dissemination work on PBL. One of the main activities of the Aalborg Centre is to develop a global network. The objectives of the global network are to bring researchers, teachers, practitioners, companies and policymakers together to share knowledge and experiences on how to develop engineering and science education. In the past years the Aalborg centre has initiated several activities aiming to disseminate knowledge and expertise on PBL, like:

- Giving keynote lectures and invited workshops on PBL
- Publications in the form of books, book chapters, journal and conference papers
- A master programme for PBL in engineering
- The organisation of a bi-annual Research Symposium (IRSPBL)
- Visitors' workshops
- Consultancy and capacity building (i.e. support institutions in management of change towards PBL)

2 A Research Approach to the Development of the UCPBL Global Network

The success of a network depends to a large extent on the commitment of the participants. In order to gain insight into the factors motivating the potential members of the network, the authors constructed a questionnaire and sent it out to 1300 email addresses from a database that has been built over the years. A secondary objective of this approach is to filter out inactive email addresses and persons that are not interested in further contact.

2.1 Construction and distribution of the questionnaire

The Aalborg Centre strategic work plan, from 2014, which describes the central vision and the activities, is the point of departure for constructing the questionnaire. The questionnaire consists of an Introduction letter and four main questions. The letter introduces the Aalborg Centre, its vision, and explains the reason for contacting and the goal of the questionnaire (see box 1).

Box 1: Introduction letter to the questionnaire

> Dear sir/ madam
>
> In May of 2014 the new Aalborg Centre for PBL in Engineering Science and Sustainability, under the auspices of UNESCO (Aalborg Centre) was officially opened. The Aalborg Centre expands on and encompasses the UNESCO chair in PBL. One of the main visions of the Aalborg Centre is to build a Global Network on PBL in Engineering Education.

In the course of fulfilling this purpose, we aim to contact all our relations and partners and enquire their insights trough a questionnaire. This way, we expect to gain better understanding on which kinds of activities are needed to build the Global Network.

We have retrieved your name from the e-mail database of UCPBL, which means you have contacted us before or visited Aalborg on one or more occasions. Filling in this questionnaire will take less than 10 minutes and all the responses will be processed anonymously.

Thank you very much for your collaboration.

Sincerely,

The questionnaire contains four main questions and two sub-questions. The questions are based on: 1) the main activities the Aalborg Centre organises and promotes; 2) areas of expertise of the Aalborg Centre; 3) means of dissemination of knowledge. The answers to the questions are of two types: multiple choice and text (table 1).

Table 1: Questions and type of answer which compose the questionnaire

Question	Type of answer
1. How did you learn about Aalborg Centre/ UCPBL? (Please, choose only one option)	Multiple choice Text
2. Have you ever visit the Aalborg Centre/ UCPBL?	Multiple choice
2.1. If you answer yes in previous answer, please specify when.	Text
3. Would you like to visit the Aalborg Centre in the future?	Multiple choice
4. What kind of activities would you like to participate? (You can choose more than one option)	Multiple choice Text
4.1. Please explain what you expect to gain from these activities.	Text

Table 1 presents the four main questions and two sub-questions as well as the type of answer to each question. Notice that question no. 1 and questions no. 4 includes both multiple choice and text answers. In both questions, the last choice is ‘Other (Please specify which)’ and includes the space for a text answer.

The questionnaire form was created using the internet-based system SurveyXact (SurveyXact, 2013-2014). After creating the questionnaire, a quick pilot was run to spot unclear questions. In this study the method ‘distribution through a link’ has been used, which means SurveyXact generates a link to fill the questionnaire, which is sent by e-mail. Next, the questionnaire is sent to 1300 e-mail address from Aalborg Centre e-mail database. The authors used their institutional e-mail to distribute the questionnaires.

2.2 Data collection and analysis

Beside the generation of the questionnaire form and its distribution, SurveyXact also helps to handle the entire process of data collection, analysis and communication of results. For each respondent who clicks in the provided link a 'respondent' is created by SurveyXact. By their turn, the respondents created can be categorized in three levels, which are:

- Distributed (i.e. respondents who click in questionnaire link but did not answer any of questions);
- Incomplete (i.e. respondents who click in questionnaire link, started answering it but did not finish);
- Complete (i.e. respondents who click in questionnaire link and answer all the questions).

The questionnaires were distributed on January 20, 2015, and on February 23, 2015, the data collection were closed. The following section presents the questionnaires' results.

3 Results

The responses from the questionnaire allow Aalborg Centre to adjust its strategy to an updated overview of the needs and expectations and, consequently, to better organize and structure its activities. The results are presented by overview (number of questionnaires distributed and answered) and questions.

3.1 Overview of questionnaires sent and collected

Only a small proportion of the 1300 distributed questionnaires resulted in an answer. SurveyXact provides the total of number of questionnaires collected, independently from its status (i.e. complete, incomplete, and distributed). The sum of these values shows the authors that only 14% of the distributed questionnaires resulted in a response (figure 1). This means we now have a clean data base with 181 email addresses of people who are willing to reply.

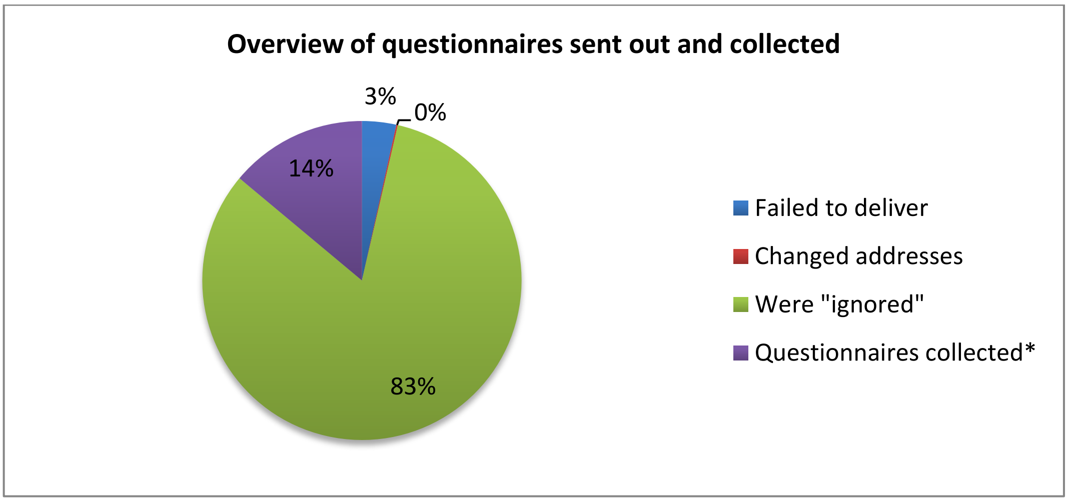

Figure 1: Overview of e-mails send and questionnaires collected through SurveyXact (n=1300)

However not all the questionnaires collected have the same status. From the total of 181 returned questionnaires only 60% (n=108) concern complete and closed questionnaires (figure 2).

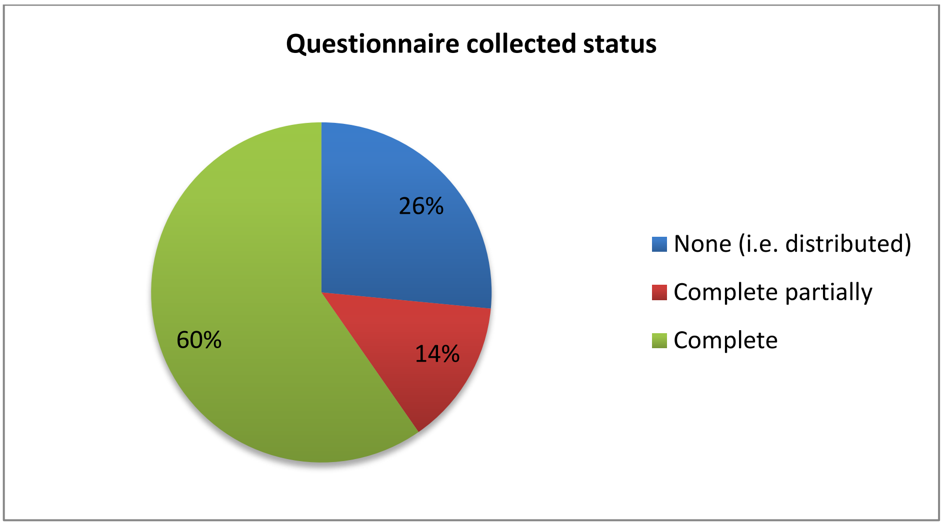

Figure 2: Response status of questionnaires (n=181).

The results presented below are based on completed questionnaires.

3.2 Source of knowledge about the Aalborg Centre

The first question was: How did you learn about Aalborg Centre/ UCPBL?

The results show that most respondents (31%, n=34) get to know about the Aalborg Centre/ UCPBL from a colleague, followed by Internet (20%, n=22) (figure 3).

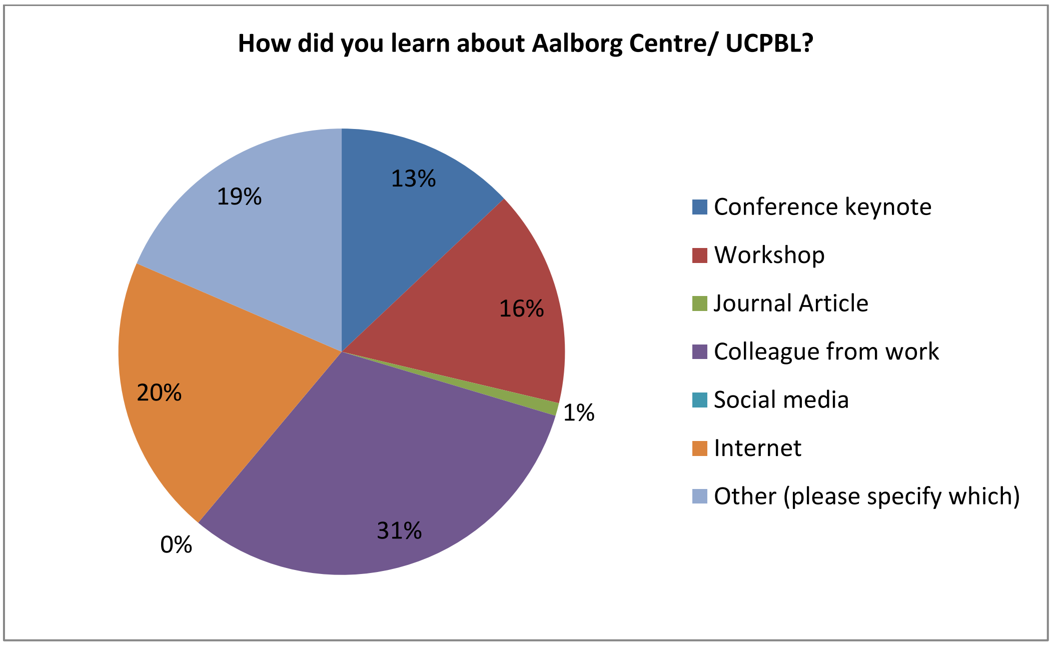

Figure 3 Answer to the question 'How did you learn about Aalborg Centre/ UCPBL?' (n=108)

The third most selected option is 'Other' (19%, n=20). The specifications show the following answers:

- Through collaboration in internal projects (e.g. Erasmus);
- PhD defenses;
- In conferences (ALE or IRSPBL);
- Known as part of Aalborg University research groups
- When invited by member of PhD assessment committee or Aalborg Centre consultative committee
- Through the head of Aalborg Centre research group, Prof. Anette Kolmos

Social media (0%, n=0) and journal articles (1%, n=1) are the least mentioned ways through which respondents got to know the Aalborg Centre.

3.3 Visiting Aalborg

Question 2, is: Have you ever visit the Aalborg Centre/ UCPBL? This is followed by an open question asking participants to specify when. The results show half (50%, n=54) of respondents visited Aalborg Centre/ UCPBL (figure 4).

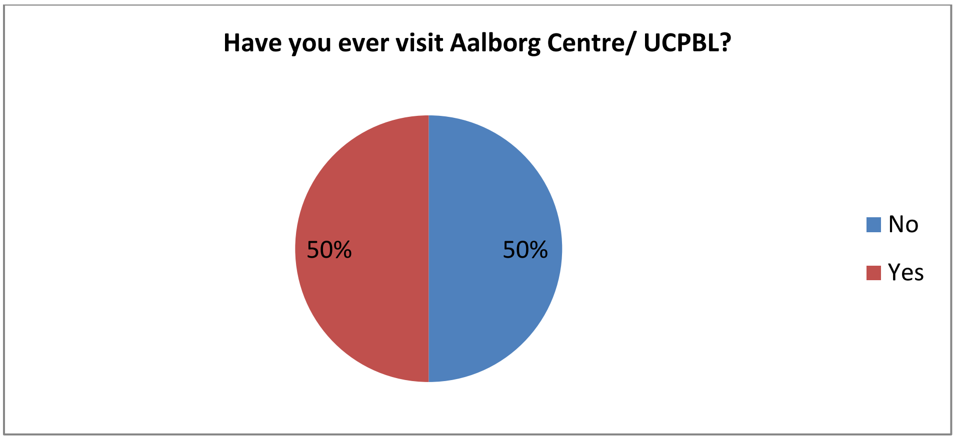

Figure 4 Answers to the question 'Have you ever visit Aalborg Centre/ PBL?' (n=108)

Some respondents indicate that their visit was about 8 or 10 years ago, while others provided specific events and dates. Examples of events are: PhD defenses, visiting delegations to observe PBL in practice, IRSPBL 2008, SEFI conference in 2008 (figure 5).

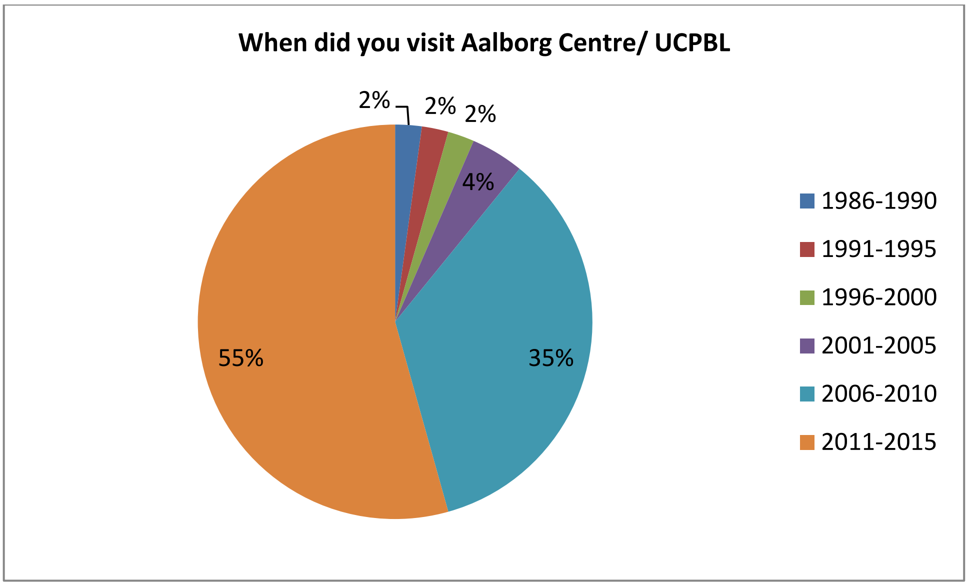

Figure 5 Date of visits to the Aalborg Centre/ UCPBL' (n=46).

The graph shows that there are few visitors in the early years and more in recent times. A number of 25 (55%) respondents visited the Aalborg Centre during the last 4 years, with 2014 as a top year with 12 visits for the Launch of the Aalborg Centre or for visitor's workshops. Several respondents indicate they visited the Aalborg Centre/ UCPBL more than once.

3.4 Wish to visit Aalborg Centre.

Figure 6 shows that 94% (n=102) of respondents would like to visit Aalborg Centre.

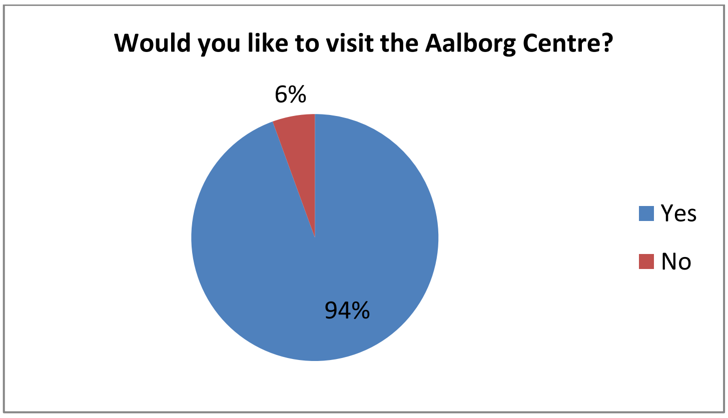

Figure 6 : Answers to the question 'Would you like to visit the Aalborg Centre?' (n=108)

Even though 50% of the respondents have already visited Aalborg Centre (see figure 5), the above graph shows that most of them would like to visit again.

3.5 Preferred activities to participate in

Question 4 asks the participants to indicate: What kind of activities would like to participate (you can choose more than one option)? The results show that most participants (19%) prefer symposia, conferences, followed by education programs (14%) and teaching materials and open access resources with 13% (figure 7).

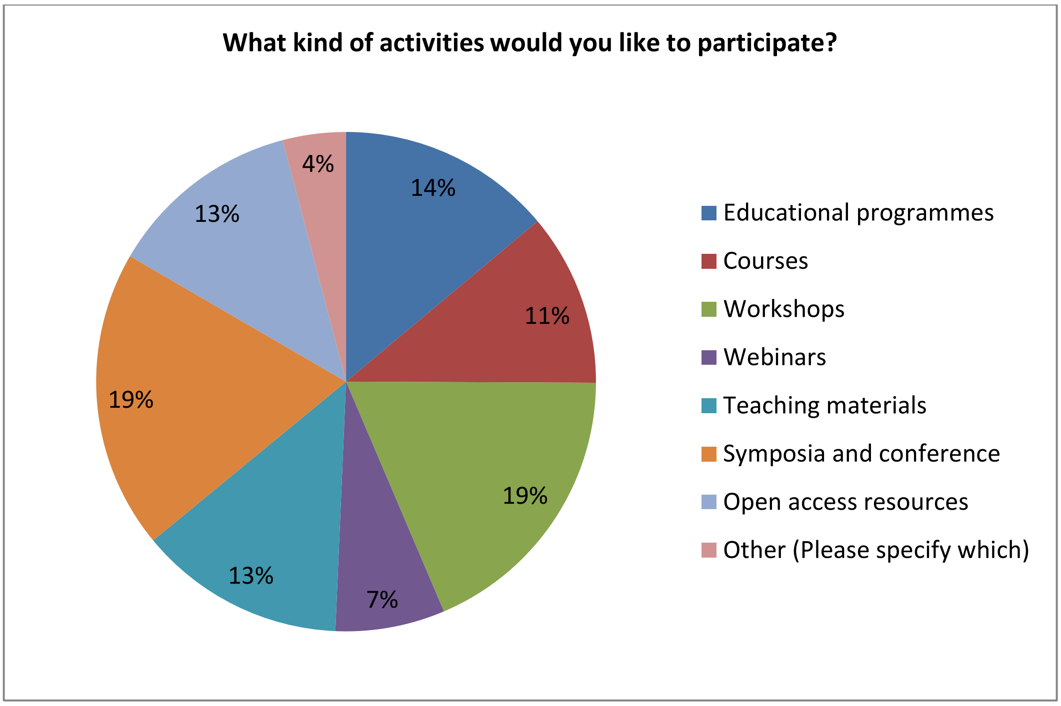

Figure 7 Answers to the question 'What kind of activities would you like to participate?'

Only 4% of the respondents preferred other activities then the ones given in the multiple-choice. Examples of the specified activities by respondents are: partnerships and research collaboration; networking; meeting people; exam process; direct observation, meeting faculty; best practice workshops; assessment methods; learning environments for PBL; visiting teachers and researchers; learn more about PBL method; ad hoc contacts.

The last question of questionnaire, question no. 4.1, asks respondents to elaborate on their expectations regarding the activities pointed out in question 4. The answers provided by the respondents vary and give relevant insights regarding kind of support Aalborg Centre can provided to its potential collaborators and partners.

The answers not only highlight the different needs and challenges of participants but also give an indication what kind of activities Aalborg Centre can develop further. For example, respondents point out the need to exchange knowledge on PBL and to share practical examples of implementation, management of change, case examples, as the following statements illustrate:

> '*Exchange information, ideas on PBL and current related issues to the PBL implementation from other countries*.' (Respondent A)

> '*Enhancing my knowledge on PBL especially latest best practices*' (Respondent B)

'*How to use PBL to supplement current curriculum re-design effort (I am using CDIO Framework for Chemical Engineering).*' (Respondent C)

'*Experience, information and case studies*' (Respondent D)

Participants also explain the need to find up-to-date knowledge, tools and activities regarding PBL theory and practice, as the following shows:

'Understanding the major educational trends in PBL and how they are implemented'. (Respondent E)

'[…] *I use PBL in my classes. So I would like to be strong and up to date in these matters...*' (Respondent F)

'*To learn more about PBL in terms of theory and practice. To network with other researchers in similar areas. To build skills and expertise in tutoring via PBL*. [...]' (Respondent G)

'*Deeper understanding on the PBL-tools and examples in order to keep developing good teaching models*.' (Respondent H)

There are also responses indicating specific aspects like academic staff training or students' learning support.

'*For me are important all processes about teaching innovation. Increasing my knowledge about new techniques, I can explain mathematics better to my students.*' (Respondent I)

'*Issuing some advises, sharing experiences, partnerships from your side, to improve knowledge, teaching methods, for enhancement of faculty development, teaching and learning skills, new assessment methods of program and student abilities.*' (Respondent J)

Finally there are some answers stressing further development of PBL through cooperation, research, appropriate technologies and/ or Education for Sustainability (ESD).

'*Benchmark and learn about EESD and Transdisciplinarity approaches for EESD*' (Respondent K)

'*Proof that dedicated technologies, platforms and ecosystems can tremendously accelerate learning outcomes and effectiveness of introducing PBL*.' (Respondent L).

4 Conclusions and reflections

The results of this questionnaire provide Aalborg Centre relevant information about the participants in the network and their areas of interest. Even though less than 14% of the 1300 distributed questionnaires returned as complete, the results give us a good picture of who the participants in the network are and their interests. This information regarding active and inactive e-mails addresses of Aalborg Centre database and the people who are willing to respond will be used to update our database.

The results also allow the Aalborg Centre to adjust its strategy with an updated overview of the needs and expectations of our target group, and consequently, we are better able to organize and structure our activities. The responses show that the Aalborg Centre is on the right track and should continue developing activities that will enable our network members to:

- Participate in programmes and courses for staff development;
- Share materials, tools and case studies to support teaching, PBL implementation, assessment, etc.
- Cooperate to develop further PBL theory and address new contemporary challenges (e.g. sustainability, new technologies, etc.)

Several participants express the wish to exchange knowledge, establish researcher partnerships, network, up-to-date knowledge on PBL, etc. The Aalborg Centre already started with some new activities, which can be developed further to promote these objectives, such as thematic webinars. The Aalborg Centre should also create new activities such as interactive blogs, new letters, on-line courses and workshops, by making using of internet-based platforms.

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Problems and Solutions of PBL Implementation in Nursing at Duy Tan University

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Abstract

Nursing is increasingly an important profession as the population is getting older. Qualified nurses today require both formal and practical training as they take on many more responsibilities in patient care than in the past. In Vietnam as well as in Asia, however, the stereotypes about this profession still cause difficulties for its education. Having adopted PBL at our Nursing School for only a year, Duy Tan University (DTU) has run into many challenges, which are likely to be the same at other Asian nursing schools, and so, the sharing of our experiences and solutions here will definitely help those in the same situation. The challenges encountered by us include: Firstly, nursing is considered a low-level profession in East Asia; thus, unlike other medicine- or pharmacy-related disciplines, nursing can only attract average or below-average students. Most of these students from the beginning only think about nursing as some mediocre manual vocation, making it hard for us to integrate the teaching of scientific knowledge and on-the-job practices. Secondly, traditional practice at many hospitals in Vietnam does affect the mentality of our students; specifically, nurses are usually considered only as assistants to medical doctors. Our students, as influenced by this tradition, are very passive in class: They listen to whatever we have to tell, and rarely challenge us on anything that may not agree with. This is not to mention that very few of them would step forward to take charge in the group projects assigned. As a result, additional use of Active Learning methodologies should be of help to our not-so-confident nursing students. Overcoming students' lack of confidence may be only second to our concern, a third major problem has to do with the structure of the Nursing curriculum in Vietnam, in which clinical training traditionally comes in the third year of the program. This is where the PBL model did help us greatly through evidence-based learning and clinical outcome evaluation. Still, our problem remains with how to persuade local hospitals to accept our second-year (instead of third-year) Nursing students for clinical training. Finally, with the increased use of case studies and nursing practice models, while the learning efficiency and effectiveness have been greatly enhanced by PBL, the question about proper and accurate student assessment becomes a bigger issue. Many times, under complex case handlings, the instructors simply did the grading based on their subjective experience or perception. The assessment problem is further worsened by the fact that the grading convention in Vietnam is much harsher than those of Western countries.

Keywords: PBL standards, career guidance, nursing education, simulation

1 Introduction

For a long period of time, the teaching and learning methodologies for Nursing in Vietnam were very much "fixed" because of traditional mentality of people working in the field. In fact, there has been very little change in nursing education during the last thirty years in Vietnam: the whole country only has fewer than 10 Ph.D. in Nursing, who were all trained from overseas, and there are only 3 Master's programs in Nursing across the whole nation. Indeed, the root of problems with nursing education in Vietnam mostly has to do with the followings:

- Nursing is socially perceived as a low-level or even mediocre profession in Vietnam, thus attracting only average or below-average students (Ng'ang'a, 2014).
- Traditional practice at many hospitals in Vietnam refers to nurses only as low-level assistants of medical doctors, making them very passive in their activities and approach.
- Most nursing schools in Vietnam are using outdated curriculum with great emphasis on theoretical aspects and little practical or clinical training (Ng'ang'a, 2014).
- Assessment and evaluation of nursing students' performance in Vietnam are still mostly based on paper-based exams, which do not create strong incentives and may even mislead the students about their actual capabilities for the profession.

Understanding those major issues, in early 2014, the Nursing School of Duy Tan University has decided to adopt the PBL framework in order to "revolutionize" its teaching and learning methodologies as well as to better prepare students for the real-world market, in which there are more and more elders after every single year. Some basic information about the Nursing School of Duy Tan University is included: the Nursing School of DTU was established in 2009, and up to now, it has a student population of around 770 in both Bachelor's and Associate Bachelor's degree levels. The school is aiming to open a Master's program in Nursing over the next couple of years.

2 PBL Implementation For Nursing Programs At Duy Tan University

Since the Nursing School of DTU has produced the first two batches of graduates during the last two years, its staff members had certain time to look back on the quality and capability of their graduates. The good news was that all of the graduates in the first two batches got booked in advance for employment by a number of local hospitals and medical organizations while the bad news was that a significant number of graduates, in an employment survey, indicated that they were not well-prepared for clinical practices as well as interpersonal communication because most of them would need another half a year to a year of retraining in hospital to be able do the actual work. Feedbacks from the hiring organizations about our graduates were generally good, but whether those feedbacks were really truthful or only for face-saving purpose was never quite clear. In any way, in an effort to improve the general teaching and learning quality at DTU, around four years ago, the management at DTU requested that the faculties would need to choose between the CDIO (Conceive-Design-Implement-Operate) framework or PBL (Problem-based or Project-based Learning) model for their pedagogical approach. Most engineering faculties went for CDIO while others went for PBL. Being slower than other faculties but more than a year ago, the Nursing School at DTU eventually decided to follow certain PBL guidelines to improve on certain current shortcomings. The main reason to choose PBL mostly has to do with the fact that most clinical situations are of some problem-based nature:

- In order to overcome the low social notion for the nursing profession, we set up 3 new courses (1 credit hour each) of "Career Guidance", in which experienced nurses, medical doctors and other medical professionals are invited to give talks to students about different potentials of the nursing profession. A major point to emphasize through these courses is that nursing is not a low-paid job in Vietnam; in fact, many nurses earned very good income. The only problem here, given the circumstances in Vietnam, is that much of that income is not formal, and may come directly from the pocket of the patients or their families to the nurses'. For this, while we cannot change that social norm and practice, we try to teach our students certain ethical codes so that they will not be swayed away by certain income and ignore their core duties. With the setup of these courses, we actually followed PBL Standard 5 (i.e., "Allows some degree of student voice and choice") in providing students with more interaction freedom through our offering of real-world information and meetup with experienced medical professionals (Kaikkonen & Lahtinen, 2011). Following the guidelines of PBL, we also allow certain time for our students to self-reflect (through self-reports) on what they have learned after each class session. It should be noted that these courses are provided at a very early stage, during the freshman and sophomore years so that students can actively obtain an overview about their future profession.

- In order to build up students' confidence in themselves and in their profession as well as to move away from the notion at many hospitals in Vietnam that nurses are only low-level assistants for medical doctors, we have managed to accumulate a big number of case studies, in which the roles of the nurses stand out or their decision-making capability is life-changing. For example, in one case, a nurse is ordered by the doctor to give the patient certain medication; the nurse is subsequently presented with a series of information about the patient's blood pressure, heart rates, blood sugar, etc. and/or other complications, then he or she would need to make the decision whether it is proper to give the patient the medication or not. Such cases come a long way in educating our students about their professional roles, and since it comes down to specific details about what is right or wrong scientifically, those cases serve as a strong reminder to our students that a higher-ranked professional in medicine is not necessarily always right. With the use of case studies here, we have introduced an important component of Active Learning in PBL, plus we also have utilized PBL Standard 4 (i.e. "Requires critical thinking, problem solving, collaboration, and various forms of communication, often known as '21st Century Skills'") in fostering critical thinking and problem-solving skills (Kaikkonen & Lahtinen, 2011). Another requirement that comes along in this effort is the need to set up some clinical environment and settings which resemble those of the real world to provide students with a sense of reality.
- In order to reinvent our curriculum for nursing and to sort out outdated materials and approaches, a number of efforts were carried out, including the introduction of evidence-based learning and clinical outcome evaluation, additional use of nursing practice models, a series of PBL-project coursework, and early offering of clinical training and internship (Pang, et al., 2002). At the heart of these efforts, the 3 PBL-project courses stand out as the most important component. In these PBL-project courses, students are taught about various analyses, problem-solving and team-building skills in order to tackle some open-ended medical problem or clinical situation, making our study approach more of a problem-centered and student-centered orientation. Of the 3 PBL-project courses, the first two are carried out in our lab settings while the last one is carried out at one our partnering clinics or hospitals. The annual search for an adequate number of clinics and hospitals for the PBL team projects is still less daunting than the quest for early clinical training and internship opportunities for students in the second year. This is because clinics and hospitals in Vietnam usually only accept nursing students from at least the third year on. Still, students who managed to get their internship in the second year usually gained more experience and excelled over their classmates later on.
- Alongside with the changes in course materials and curriculum structures, it is also important that our instructors are well trained and prepared for the new implementation of the PBL framework. The ultimate goal is to train our instructors into facilitators who help guide students through various medical processes and models, facilitate group dynamics under difficult circumstances, and support students in the buildup of skills and knowledge for various medical activities (AllynWalsh, 2005). This goal, however, is not easily achieved under the dogmatic educational and medical environment of Vietnam. Making students

become self-directed in their responsibility for a certain practice or project is also not easy because Vietnamese students are generally shy and reserved.

- As for the assessment/evaluation accuracy and objectivity, the choice of the assessment methods for different course assignments does play a commanding role. While basic knowledge about medical concepts or medicines can be tested using multiple-choice questions, certain case handlings and practice descriptions are best suited with the use of free-format essays or oral presentations, which in turn require additional teaching staff and grading time (Nendez, et al., 1999). This is not to mention of clinical cases, in which direct interaction with real patients should be the best option for assessment and evaluation. Of course, we should recognize that the best assessment method may not be the most feasible one in Vietnam given our big class size and low tuition fee. Fortunately, the average class size for nursing at Duy Tan University is usually between 25 to 45 students, making it feasible for us to go for some of the more costly and time-consuming assessment methods at times. This standard class size for nursing at DTU, however, is still not as good as those in Western countries. On the other hand, when subjective perception and experience interferes with the grading decisions of our instructors, not much can be done here except to continuously train our instructors for better judgment and expertise. Another important effort that we have done was to request our instructors to give out higher grades for our students. The tradition of setting 8 (out of 10) as the highest grade given in Vietnam is very much damaging to our students' record and motivation over the years. So, our improvement in assessment and evaluation here very much has followed PBL Standard 6 and 7.

While most of the PBL efforts above are very important and necessary in transforming the quality of our Nursing programs, out of those efforts does emerge a drawback as to whether our students will have enough time in every course or project to carry out all the required work by the PBL standards. Answer to this question should be available only through the test of time and empirical data from our students' experiences.

3 Study Approach & Survey

In order to assess whether our PBL efforts above actually delivered the desired learning processes and outcomes to our nursing students, a survey was designed to collect students' feedbacks on 5 different aspects:

- Effectiveness of "Career Guidance" coursework
- Development of Confidence & Autonomy in the Nursing profession
- Effectiveness of PBL-project courses
- Perceived Roles of the Instructors
- Quality of Performance Assessment and Evaluation

The survey adopts a five-point Likert scale of: (1) Strongly Disagree, (2) Disagree, (3) Neutral, (4) Agree, and (5) Strongly Agree. The incremental scale from 1 to 5 is very much standard for a Likert scale, making it easy for students to emphasize their agreement by giving higher scores, and disagreement with lower scores with 3 as the midpoint. Students were asked to rate their levels of agreement or disagreement based on the statements below. The choice of four questions per aspect was to keep students' focus and interest throughout the survey; more than that, and they may tend to rate everything closer to "neutral" or moving fast through each statement/question.

A. "Career Guidance" coursework
A1. The "Career Guidance" courses provided me with the opportunities to discuss with medical professionals about the prospects of the nursing profession in the near future.
A2. The nursing profession in Vietnam is no longer considered as a low-level or low-paid job.
A3. Ethical issues are usually raised in the "Career Guidance" courses.
A4. The individual write-up assignments in the "Career Guidance" courses allow me to effectively reflect on my learning and understanding of the nursing profession.

B. Confidence & Autonomy in the Nursing profession
B1. Theoretical and clinical case studies in our nursing program provided me with a good idea of different skills and standards required in the nursing profession.
B2. I am confident that with my education thus far, I have a good idea of what is expected of me and where I am heading for in my future career.
B3. The learning environment and facilities at DTU does provide a sense of reality for our case studies.
B4. People recognize that my critical-thinking and problem solving skills have improved significantly from the first year.

C. PBL-project courses
C1. I found the PBL-project courses interesting.
C2. The PBL-project courses helped develop my problem-solving skills.
C3. The PBL-project courses helped sharpen my analytical skills.
C4. As a result of the PBL-project courses, I now feel confident even when I run into unfamiliar nursing scenarios or problems.

D. Perceived Roles of the Instructors
D1. The instructor did a good job in explaining different PBL approaches and tactics.
D2. The instructor provided good feedback about the individual and team progress.
D3. The instructor focused more on facts than on concepts in his or her guidance.
D4. The instructor provided proper guidance and facilitation according to the PBL standards.

E. Quality of Performance Assessment and Evaluation
E1. The instructor's evaluation was not student-centered and did not reflect students' improvement.
E2. The instructor's evaluation was not problem-centered and evidence-based.
E3. The instructor's evaluation was not on group dynamics and team interaction.
E4. The instructor's grading and evaluation was not fair.

4 Results & Discussion

The survey was carried out on a sample of 90 students: 72 are senior students in our Bachelor's degree program of Nursing while 18 are senior students in our Associate Bachelor's degree program of Nursing Practices. The ratio between these two groups of students reflect the actual ratio between the real number of students in our Bachelor's degree program of Nursing to that in our Associate Bachelor's degree program of Nursing Practices (4:1). However, we only received responses from 83 students. Out of that 83, 66 are in our Bachelor's degree program and 17 are in our Associate Bachelor's degree program. Although these students are of different academic-degree levels, they shared many of the same classes because of our university's credit-hour registration system. The mixed sample of nursing students at different degree levels in our university is supposed to provide an objective viewpoint of our students' perception for the nursing profession and education.

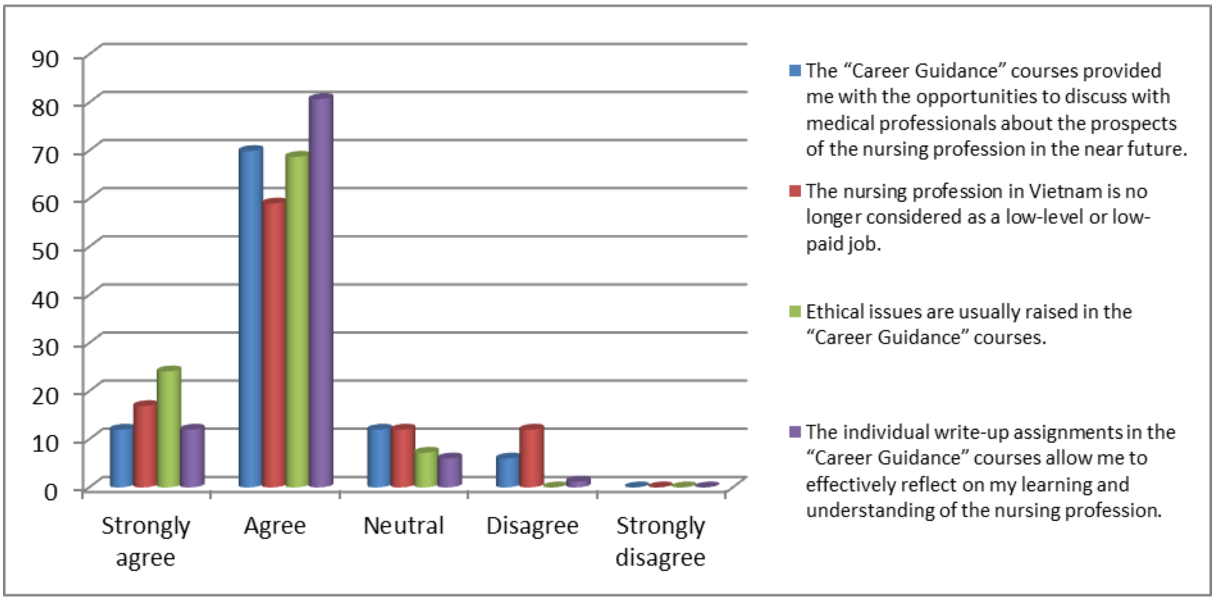

Figure 1: Effectiveness of "Career Guidance" coursework

Feedbacks on the "Career Guidance" coursework showed that up to 92.7% of the students either Strongly Agreed or Agreed that the individual write-ups in these courses have effectively helped them reflect on their learning and understanding of the nursing profession. A very much similar percentile of students showed their appreciation for the discussion of ethical issues in nursing in these courses. On the other hand, while the disagreement ratios were generally low, there were still 6% of the students who stated that they did not have the chance to actually discuss with medical professionals through these courses, probably due to the big class size that our programs currently still have. Moreover, there were up 12% of the students who Disagreed to the fact that nursing is no longer a low-level or low-paid job in Vietnam. This reflects the difficulty in changing this social notion while some students explained that the pay for nurses in most rural or remote areas in Vietnam is still very low.

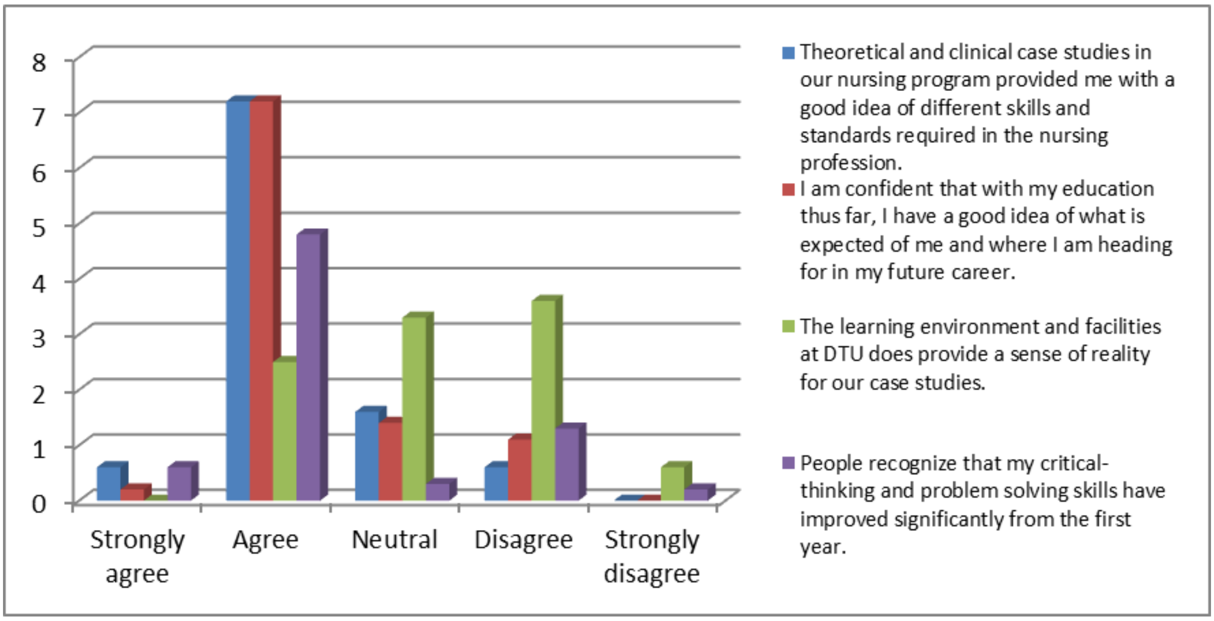

Figure 2: Development of Confidence & Autonomy in the Nursing profession

Our effort to build the confidence and autonomy of our students in the nursing profession really pays off through the use of combined theoretical and clinical case studies with up to 78.3% of the students who recognized that they have become more aware of the skills and standards in nursing as well as of what is expected of them in their future profession. Only 54.2% Agreed or Strongly Agreed that their critical-thinking and problem-solving skills have significantly improved from the first year (and 15.7% actually Disagreed or Strongly Disagreed to that), implying that there is still much work for us to do in terms of leveraging our students' PBL skillset. The biggest concern here is with the settings and quality of our learning environment and lab facilities: up to 42.7% of the students stated that our learning environment and facilities have not provided a sense of reality in their training. This can be especially damaging because much value of our case studies indeed comes from the use of in-lab simulations.

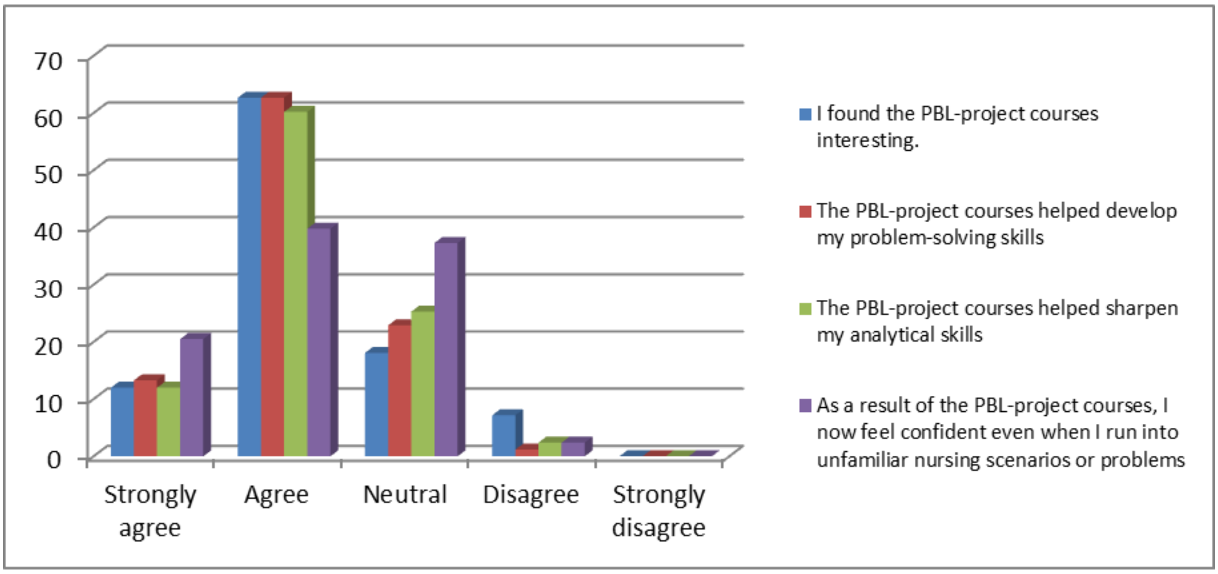

Figure 3: Effectiveness of PBL-project courses

As a result of the three PBL-project courses from the sophomore year to the senior year, 75.9% of the students found that their problem-solving skills have strongly developed while 72.3% found the same thing for their analytical skills. A sizeable percentile of 74.7% of students showed their interest in the PBL-project courses. However, all of these did not appear to add up to the expectation that students would subsequently feel confident in the face of unfamiliar nursing scenarios or problems. It seems, as suspected, that only an actual amount of real-world clinical experiences will help shape the real confidence of a nurse. In any way, the PBL-project courses still helped develp certain skills which will be important to our students' nursing profession in the long run.

The PBL adoption has, to certain extent, transformed the roles of our nursing instructors. Our students have positively perceived and recognized those transformation (as shown in Figure 4): up to 86.8% of the students either Agreed or Strongly Agreed that their instructors have satisfactorily conveyed information about different PBL approach and tactics to them as well as providing them with proper guidance and facilitation in their study according to the PBL standards, and 85.5% confirmed that the instructors have provided good feedbacks on individual and team progress. The only shortcoming that our instructors need to pay attention to is that they should focus more on facts than concepts in their teaching and guidance as there are still 25.3% of the students who believed that our instructors did not do a good job in that aspect. This will be very important because we have been moving toward evidence-based learning in our nursing programs for the last two years, and this may yet be a sign of failure in our efforts.

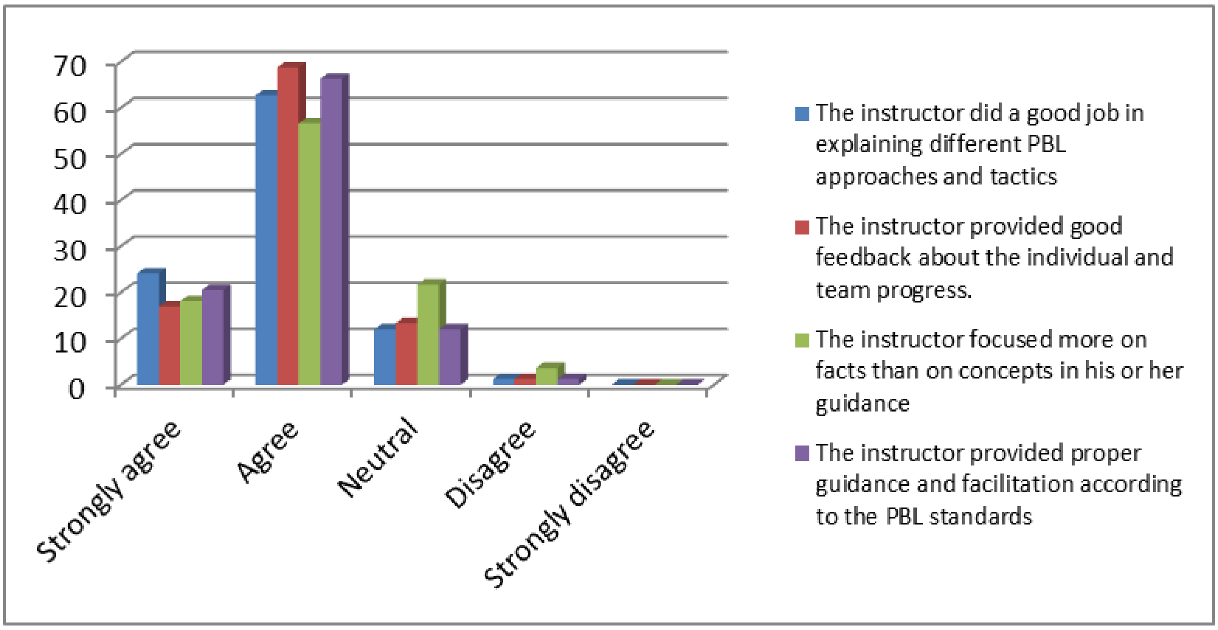

Figure 4: Perceived Roles of Instructors after PBL Adoption

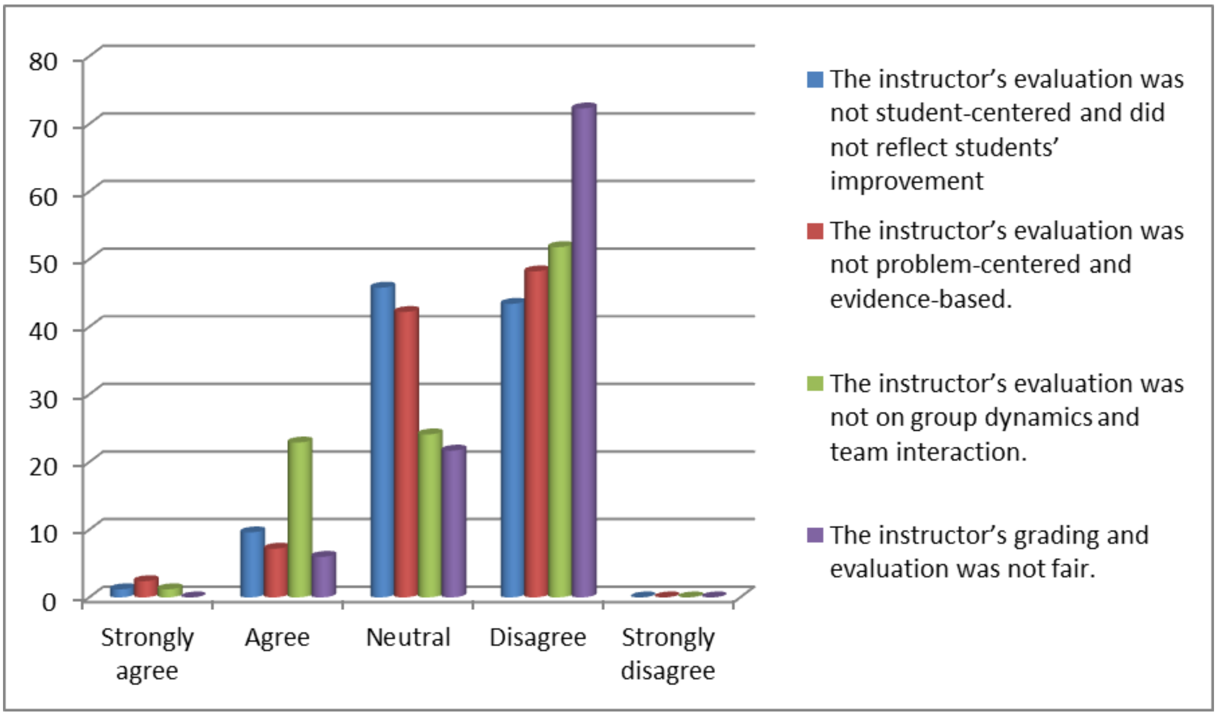

Figure 5: Quality of Performance Assessement and Evaluation

With respect to the surveying questions about the assessment and evaluation of our students' performance, the Likert scale adopted was somehow "flipped" by changing all of the survey statements from positive into negative form. By doing this, we expect students to be alerted and become more careful in their feedbacks. As it turned out, our students mostly believed that our grading and evaluation was fair with 72.3% Disagreeing to the statement that their instructors' grading and evaluation might have been unfair. While this is quite encouraging on our part as educators, it should be noted that with our PBL effort, the management already had called for easier grading approach (compared to the strict traditional approach in Vietnam), and this might have been part of the reason why our students perceived their evaluation as more "fair". Other than this, we can see that our instructors' evaluation has been perceived as more "student-centered" and "problem-centered" by the students with 43.4% Disagreeing to the statement that our instructors' evaluation was not student-centered and did not reflect students' improvement and 48.2% Disagreeing to the statement that the same evaluation was not problem-centered and evidence-based. Still, the fact that there are 45.8% and 42.2%, respectively, being Neutral to those two statements suggested that there is still more room for improvement on our part. Much of the "student-centered" evaluation feedback may have come from our use of oral-presentation evaluation and clinical-case handling assessment. On the other hand, the "problem-centered" evaluation feedback was due to the use of our PBL-project courses. In addition, block tests of multiple-choice questions, short-answer questions, and free-format essay around some specific case studies may also have done the work. The only major weakness in our evaluation and assessment at this point has to do with the fact that our instructors usually left out the evaluation of team interaction and group dynamics. 47% of the students were either Neutral or Agree with the statement that their instructors' evaluation was not at all on group dynamics and team interaction.

5 Conclusion

In conclusion, the PBL adoption has been very helpful in identifying many problems in our nursing programs, namely the separation between theoretical and clinical training for nursing in Vietnam, lack of autonomy and confidence of nursing students due to traditional Vietnamese hospital practices, simplicity and inaccuracy of outdated evaluation methodologies for nursing, etc. A series of solutions including combined theoretical and clinical case studies, "Career Guidance" coursework, PBL-project courses, evidence-based evaluation, clinical case handling assessment, etc. have been proposed with some satisfactory results. Future studies should look more into the in-school development of nursing students' experience curve, effective practices for evidence-based clinical training, proper evaluation measures of team interaction and group dynamics in nursing, and localized nursing ethics.

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Obstacles in the PBL Adoption for the Accounting Discipline at Duy Tan University

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Abstract

Moving away from the traditional teacher-centered approach in the teaching and learning of Accounting and other business-related disciplines, Duy Tan University has adopted the Problem-Based Learning (PBL) model during the last four years. The main purpose has been to help promote the spirit of creativity, autonomy and flexibility in the learning orientation of students so as to enhance their future prospect for employment. However, the PBL adoption was not without difficulties and hassles. One of the three major obstacles identified is the *change management* of our staff's attitudes and mindset. To change students' learning orientation, our instructors must first make their own changes; but many initially refused to change their syllabi and teaching methodologies or to tie up their teaching materials with those of others in the same program. Another major obstacle is related to the *gap-bridging* activities regarding our students' learning capability and the teaching materials to be delivered. More than often, we found Vietnamese students with lack of essential soft skills from their high-school education. In addition, the teaching of accounting nowadays presents certain discrepancies when it comes to local and international accounting conventions. The last major obstacle in our PBL adoption is referred to as "*PBL appreciation*". Despite widely-recognized benefits from our PBL adoption, many times, when we talked to our instructors, many would say that they had been doing the same thing for many years before that. As for our students, even though statistics showed their performance has significantly improved since the introduction of PBL, some still questioned the necessity of PBL and its Capstone projects. Lack of appreciation for PBL usually hinders further acceptance of new teaching/learning methodologies by both instructors and students. Overcoming these major obstacles would help us accumulate experience which may be of use to other business schools in the same situation.

Keywords: PBL, Accounting, PBL appreciation, change management, gap bridging activities

1 Introduction

With the aim to promote creativity, autonomy and flexibility in our students' learning orientation and our instructors' teaching approach (Kolmos, et al., 2007), around four years ago, Duy Tan University (DTU) has started to adopt the PBL model on a large scale basis, across many different faculties in the university. As it turned out, some faculties quickly realized the benefits of the approach while others are still having a hard time fully digesting the benefits of the model. With regards to the adoption of PBL for the Accounting program of the International School at DTU, it was quickly met with certain successes during the first one and a half years, and then failed to realize the full benefits of the PBL model for the rest of the time. We believed that certain structural and cultural obstacles under the circumstances of Vietnam might have been the major reasons for this, but we did not know exactly what they were and how they interacted with each other. Finding those obstacles thus has become a major task for the management at the International School of DTU.

One author of this paper, Ms. Nguyen T K Huong, Deputy Head of the Accounting academic group of the International School, was one of the leads in the task force to search for those real obstacles. The other three authors, including Mr. Tran T Dat, Ms. Hoang A Thu and Mr. Nguyen C Minh were amongst the instructors of the Accounting program of the International School. As a result, these instructors were down to earth with the PBL-adoption problems that were going on in their program. Their most important purpose and motivation was to identify the exact PBL-adoption obstacles to our Accounting students and instructors so as to help overcome the current status-quo in our PBL efforts for the Accounting program. And to a lesser extent, another purpose was to initially assess the level of success (or failure) of our PBL adoption with the Accounting program at the International School as it has almost completed one adoption cycle of four years. The research problem of this paper, as a result, is merely the identification and validation of major PBL-adoption obstacles, and with their discovery, further assessments can be made as to whether the obstacles can be overcome or fixed.

2 PBL Settings for Accounting Programs at DTU's International School

An initial overview about the choice of PBL at Duy Tan University as well as the Accounting program of the International School at DTU and its PBL adoption efforts will provide a general idea about our PBL progress thus far:

Except for our Engineering and Technology division, which chose the CDIO (Conceive-Design-Implement-Operate) framework, the rest of our university chose to adopt the PBL model. The original motivation for PBL had to do with the fact that despite many courses that our students took, they usually lost track of the materials in those courses or did not understand how to use those materials to solve some specific problem, as needed. Worse, most of the average students could not manage to integrate the materials learned from different courses to build up their skills and capabilities. Part of the reason had to do with our traditional and dogmatic approach in most courses: students were expected to follow closely with the lectures and textbooks and learn many things by heart from there in order to do well with their quizzes and exams. So, by helping students develop more of a problem-based thinking mindset, our management believe that students might become more active and effective in their study. PBL was chosen, as a result (Wigfield, 2002). But the adoption of PBL at DTU did not call for the total redesign of our curriculum structures. Rather, instructors were encouraged to update their course materials and to introduce active learning methods, case studies, and small projects into their teaching (Woods, 2007). In addition, a series of project and Capstone coursework were added into each curriculum to help tie up the materials learned from different courses.

The PBL adoption for the Accounting program at the International School also followed the general approach above, with the only difference that as part of the requirement of International School of DTU, its curriculum has to be "international" and most of the instruction needs to be in English. Our original Accounting curriculum was transferred directly from Pennsylvania State University (or Penn State) through a curriculum-development and train-the-trainer agreement. In the nutshell, the Accounting curriculum and study materials from Pennsylvania State University were originally PBL-oriented with many project assignments and active-learning requirements presented in every course. However, when transferred over to the International School of DTU, the instruction delivery and teaching approach might not be the same as the original for a number of reasons:

- Only 20% of the transferred courses are taught by instructors coming from Penn State, the rest is handled by DTU's local and international instructors.
- Even though DTU instructors of the International School are continuously trained by Penn State every summer (at Pennsylvania State) to teach the transferred courses by the American standards, most of them have their original academic background either in Vietnam, Asia or Europe, not America.
- Vietnamese students, in general, are not familiar with active learning activities because of the outdated education approach in high school.
- Vietnamese students are usually not independent or creative in their way of thinking like Western or American students because of the East-Asian cultural influence.
- Most DTU instructors and students are Vietnamese and do not have English as their mother tongue, making the English-based instruction challenging to both groups.
- Vietnamese instructors at DTU's International School are always tempted to explain difficult topics in Vietnamese to their students even if there are strict requirements by the International School of DTU that everything must be delivered in English.

To make it up for the above shortcomings, a number of arrangements have been carried out:

- The Accounting curriculum has been supplemented with some soft-skills courses like Professional Speaking, Professional Writing, Critical Thinking, and Team-building Skills.
- Students are required to take on additional English training and pass the English-proficiency requirement before they can take courses of Penn State in Accounting and Business Administration.
- 3 PBL-project courses for Accounting (ACC 296, ACC 396 and ACC 496) have been developed, according to our general PBL approach, to help tie up different knowledge:
    - **ACC 296:** This sophomore-level course provides an introduction about PBL and active learning for all Accounting and Business Administration students. The major approach of the course is "learning through playing", in which students will play a series of 8 teamwork games so as to build up their problem-defining and problem-solving skills as well as basic teamwork skills.
    - **ACC 396:** Unlike ACC 296, this junior-level course was designed specifically for accounting majors. In this course, students will have the chance to work on an accounting project, which simulates real-world activities of some major accounting operation or function. Each student would play a different role in his or her team such as book keeper, auditor, business analyst, controller, etc. The problems presented in the project are usually well-defined with a readily-available set of solutions for accurate assessment of students' performance.
    - **ACC 496:** This course is designed to prepare senior students for their internships. It very much resembles the structures of ACC 396 except for one major difference that the problems presented in the project are open-ended with no right or wrong solutions. The

problems sometimes come directly from the industry; but many times, because of the shortage of new problems from local businesses, they are simply created by instructors to simulate problems in the real world. Students will work in teams to create their own integrated solution(s), using not only skills and knowledge in Accounting but also in other related fields like Finance, Marketing, Human Resource, Information Systems, etc., under the guidance of two mentors (one from our Accounting staff of the International School and one from some outside business or organization).

• Instructors in the program are required to take frequent in-house training sessions on Active Learning. Certificates are granted to the instructors at their completion of those sessions.

• Seminars on various Accounting subjects with guest speakers from local and international territories are frequently organized for both students and instructors.

• A team of academic investigators at the International School was organized to keep track of adherence to English-based instruction and PBL-guideline requirements of the instructors.

3 Recognized Improvements from PBL Adoption

Benefits from our PBL adoption at DTU were quite visible during the last couple of years, but most of the recognized benefits were not well- evaluated or measured. Since the contents of many courses have been dramatically changed, comparisons of students' direct assessments based on old and new course materials and teaching approach may not be relevant on an annual basis. The only direct assessments we could use for evaluation were those of the new project-based courses of ACC 296, ACC 396 and ACC 496. This was done within the framework of our AUN (ASEAN University Network) accreditation, which set forth that at least 80% of students need to achieve 70% or more for the final course grades in those courses.

Table 1: Accounting Students achieving 70% and above the Final Grades of ACC 296, ACC 396, ACC 496

Percentiles of Students achieving ≥70% of Final grades	***ACADEMIC YEAR***		
COURSES	**2012**	**2013**	**2014**
ACC 296 - PBL for Accounting 1	**82.5%**	**85.1%**	**86.0%**
ACC 396 - PBL for Accounting 2	**76.3%**	**79.6%**	**83.5%**
ACC 496 - PBL for Accounting 3	**82.7%**	**80.4%**	**84.1%**

As we can see from the above Table 1, except for the final grades of ACC 396 in 2012 and 2013, more than 80% of our Accounting students managed to get 70% or more for most of their final grades. There was also an increasing trend in the percentiles in the later years, indicating that our instructors may have become more proficient in their PBL teaching methodologies and/or that our students have managed to build up their PBL learning skills. Of course, these outcomes are still limited, and a complete assessment as well as comparison of the traditional Accounting program with the new PBL Accounting program, which will be available by the end of this year (when we complete one cycle of four years improvement), will provide a better direct evaluation about specific benefits of our PBL approach. For now, the rest of our recognized benefits are more or less based on our subjective perceptions, but that does not make them insignificant. From having no PBL activities whatsoever to attaining a sizable number of activities on a frequent basis in every class, these benefits just cannot be denied: (1) Active learning activities become more prevalent in every class hour with the emphasis on building personal and interpersonal skills to facilitate better communication and interaction in learning. (2) For the instruction delivery format, there was a redesign of most class sessions around some specific problems or case-studies. The instruction delivery has been changed from a top-down structure to that of a bottom-up approach with students learning accounting principles and practices through real-world examples and/or cases. (3) In addition, the introduction of three PBL-project courses of ACC 296, ACC 396 and ACC 496 definitely has raised the bar for the required level of skills in critical thinking, problem-solving, project management and teamwork. (4) Last but not least, the adoption of PBL has created a "public show-off" mentality (*the term was coined by our students*) in most junior- and senior-level classes. Everywhere you go, you will hear our students talking about their project presentations, board presentation or product showcase.

Yet, besides those visible benefits and improvements, nothing more has really been achieved or recognized. The number of new studies or research projects of our Accounting instructors did not increase, implying that they have spent most of their time horning what they are teaching rather than being driven by the need to learn more or create new materials as signified by any truly successful PBL adoption. As for our students, they complained that they did not get more choice and voice like what the PBL model has promised; rather, they were forced to learn more English for accounting, more about international accounting conventions, and more about international business laws, etc. Worse, they do not really believe the new knowledge acquired is beneficial to their future work because most Accounting positions in Vietnam only require learnt-by-the-heart knowledge of Vietnamese accounting convention.

4 Study Approach & Results

4.1 Research Methodology

To really get the PBL effort going forward again, we need to understand specific obstacles which stand in the way of our instructors and students. The structure of our search for those specific obstacles started through a series of interviews with our instructors to assess their perceived strengths and weaknesses in their PBL methodologies as well as the kind of changes they needed to go through in their PBL adoption effort. Based on the collected information from the instructors, we would evaluate whether the strengths of our instructors did bring about any benefit to our students as well as whether their weaknesses did create any obstacle to our students, too. The effectiveness of certain changes and modifications made in our PBL adoption (as mentioned in Section 2) would also be assessed.

The reason for the use of in-person interviews with our instructors came from the fact that there are only 18 instructors for the Accounting program at the International School. Also, a qualitative approach here would be more beneficial in extracting adequate information and explanation about what had really been going on with their PBL adoption. The number of students in the Accounting program at the International School is, however, much bigger; and we would only focus on the sample of 125 senior students who had taken most of the courses in our PBL-modified program. A survey was a more proper option here for such a big sample besides the fact that not all of the students cared about our PBL adoption to spend enough time for inquiry through detailed interview questions. Structured survey questions would help collect more definite feedbacks from our students.

The interviews with our instructors would orbit around the following five general questions of:

(1) What changes do you perceive in the roles of an Accounting instructor following the school's adoption of PBL?

(2) What was going well in your PBL approach? (Please explain in more details.)

(3) What was not going well in your PBL approach? (Please explain in more details.)

(4) How much time and effort have you spent for what was going well (or not well) in your PBL approach?

(5) Do you think that your PBL adoption has been successful? What will you do more for PBL in the near future?

Note: For each question, the interviewer may dig deeper by asking additional questions about what, why, when, where, etc.

For the survey with our students, there are a total of 15 questions, which can be referred to in the appendix of this paper: Questions 1 to 4 would evaluate the matchup between our students' capabilities and the PBL materials to be delivered to them. Questions 5, 7, 8 and 13 would determine whether our teaching approach has been perceived by the students as moving away from the "teacher-centered" tradition and toward more of a "problem-centered" status. In addition, Questions 6, 9, 10 and 12 attempted to check on whether our instructors have developed more "student-centered" features in their teaching. Lastly, Questions 11, 14 and 15 would assess our students' understanding and appreciation for the PBL adoption (Bédard, et al., 2007). All together, these questions would help identify the obstacles which the majority of students ran into, and they also help assess the level of success (or failure) of our PBL adoption so far, as perceived by our students. A 3-point Likert scale of Disagree, Neutral, and Agree was utilized for the survey questions because the main purpose here was not to carry out a separate quantitative study, but rather, to continue our inquiry of students' qualitative explanations for any one answer of either Agree or Disagree to a specific survey question.

4.2 Results & Discussion

4.2.1 Major Obstacles in PBL Adoption to Accounting Instructors

For the first interview question about the perceived roles of an instructor following PBL adoption, our instructors appeared to understand very well by principles that their expected role is to help students take charge of their own learning, to guide and facilitate students' efforts through the learning process, and to provide fair and accurate evaluation of students' progress at any point in time (Kolmos, et al., 2008). Even so, up to 12 (out of 18) instructors still believed that their main task is to convey specific knowledge to the students, rather than to facilitate students' self-learning. Some of the stated reasons were that "Vietnamese students as influenced the East Asian culture are shy and inactive, so, they need to be told what to study and what to focus on." or "Vietnamese students do not have the habit of reading books or searching for new knowledge, and unless we assign them with specific learning tasks, they may just do nothing by themselves." or worse, "Vietnamese students are inherently lazy and need to be closely monitored in school." Another 10 instructors still put a great emphasis on the content acquisition rather than the learning process through their use of comprehensive tests and exams instead of projects. The reasoning again came from the traditional mindset that projects should come in the senior year, not during the first two years, when students have not yet accumulated enough accounting skills and knowledge.

Two things that were perceived as going well in our instructors' PBL approach were (1) helping students combine theoretical accounting principles with pragmatic accounting practices, and (2) promoting self-reflection and experimentation in the study of Accounting. Success in the first item above mostly has to do with the move toward "problem-centered" instruction, usually through a bottom-up approach, in which some real-world problem is always presented at the start of each lesson. The only complaint by our instructors was that the choice for textbooks turned out to be difficult because most textbooks were written in a top-down approach, and our instructors usually had to spend additional time preparing real-world problems and case studies for specific lessons. The junior and senior PBL-project courses also appeared to help greatly with students' integration of theoretical and practical knowledge as they had more chance to interact with accounting professionals from the industry through those courses. As for the above second item, the success simply came from the fact that accounting is a field which deals with figures, and it was really easy for our instructors to set up problems or case studies, in which students would play around with numbers until they find the answers. Even for problems in which the accountant's judgment would play an important role, "the answer always would be still more clear-cut than in other fields of business administration", as stated by our instructors. One possible issue behind this was that our instructors might have adopted mostly fixed and closed-ended accounting problems for their exercises and projects, which would create other problems in our PBL adoption later on.

There were quite many things which did not go well in the process of adopting PBL by the Accounting instructors at the International School; but for the purpose of this study, we will only focus on major ones. The first major obstacle for our instructors is working with each other in redesigning their syllabi and course materials. Up to 14 out of 18 instructors claimed that they had no problem sharing their materials, however, the lack of time because of busy teaching schedules and the unwillingness of other instructors in giving up certain portions of their syllabi for better course synchronization and integration made the experience a terrible one. As it turned out, our instructors did not actually "practice what they preached": they spent so much time training students about teamwork but then, they themselves could hardly work with one another. Another complaint by our instructors was that the course materials were directly transferred from Penn State, and they did not have much authority in modifying those materials for better localized use in Vietnam. However, this may not be entirely true because the trainers from Penn State as well as the management at the International School have always encouraged our instructors to make adjustments to the materials whenever needed. In any case, this together with our instructors' initial lack of knowledge about American and international accounting conventions worsened the quality of teaching right from the beginning. While this might sound quite problematic, our instructors confirmed that given additional time on their part and additional support from the part of our management, there should be no more problem in the long run. And yet, the reality that most Accounting instructors at the International School lacked the experience from the industry continued to constitute another major obstacle in our deployment of PBL-project courses. Except for around 5 instructors who did certain work before in the industry, the rest had spent most of their time in school, coming out and became college instructors immediately due to their academic merits. Even though this did not create that much of a problem with ACC 296 or ACC 396, it was a real-deal problem to ACC 496 because of its open-ended project format. In addition, our instructors also indicated that it was difficult for them to work with the other mentor from the industry in ACC 496 because many times, they did not exactly speak the same professional language. Concerns like "Should we teach our students the unorthodox ways of the real world for accounting?" or "We should only teach our students step-by-step accounting procedures and not the shortcuts." became prevalent. Whether the "by-the-book" knowledge of our instructors is a good thing or not remains a mind-tweaking question for our management.

In general, our instructors responded that they spent a great amount of time and effort for the PBL adoption. For things that were not going well, they had to keep coming back, spending even more time and effort trying to fix them. On average, our instructors indicated that they spent somewhere between 8 to 15 hours per week for the PBL efforts, which should be considered as satisfactory since we usually asked our instructors to spend at least 6 hours per week for PBL preparation. Most of our Accounting instructors also believed that their PBL adoption effort was successful. Many even stated that they had done the same thing in their classes for many years before our PBL adoption. The generally-limited appreciation for the PBL adoption and transformation of our instructors, however, made us feel worried about the whole effort, especially when 18 out of 18 instructors indicated that their continued work with PBL in the near future is to fix any of the remaining problems.

4.2.2 Major Obstacles in PBL Adoption to Accounting Students

Since the survey for our 125 senior students in Accounting is mandatory before their completion of the course ACC 496, the feedback rate was fully 100%.

Table 2: Survey results on Matchup between Students' Capabilities & Program Contents

	1: Disagree - 2: Neutral - 3: Agree		
Statement	**Disagree**	**Neutral**	**Agree**
1. High school education did not provide us with the right set of soft skills for study under the PBL model at Duy Tan University.	**14 / 11.2%**	**16 / 12.8%**	**95 / 76%**
2. The set of soft-skill courses of Professional Speaking, Professional Writing, Critical Thinking and Team-building Skills prepared us well for later PBL-project courses.	**50 / 40%**	**19 / 15.2%**	**56 / 44.8%**
3. The additional English training helped improve our English proficiency for later study of English-based Accounting and Business Administration coursework.	**35 / 28%**	**58 / 46.4%**	**32 / 25.6%**
4. The English-based instruction and tests of the Accounting program made it difficult for us to digest the materials.	**10 / 8%**	**17 / 13.6%**	**98 / 78.4%**

Up to 76% of the students remarked that they did not get the chance to learn about any soft skills in high school. Those that said otherwise were mostly graduates from international high schools (in Vietnam), which offers significant amount of soft skills and arts training instead of natural sciences. As a result, the general feedbacks were that our supplemental soft-skill coursework was indeed a beneficial preparation for later PBL-project courses. Still, there were 40% who did not believe so with the major reason that our courses of Professional Speaking, Professional Writing, Critical Thinking, and Team-building Skills were too general, and were not specifically designed for accounting students, who need a special set of oral and written communication skills for their professional field. On the other hand, our supplemental English courses did not appear to serve its purpose with up to 46.4% being neutral and 28% disagreeing as to whether such English training had helped with the study of Accounting and Business Administration in

English. The most basic qualitative explanation was that our supplemental English coursework did not really touch on the vocabulary of Accounting and other fields of Business Administration. And of course, 78.4% agreed to the fact that learning Accounting in English under a Vietnamese-spoken environment is not at all easy. The dilemma that our English instructors ran into, however, was how to teach special vocabulary when the students did not have any basic vocabulary yet. As a matter of fact, many students are from rural areas with no previous English training.

Table 3: Survey results on the "Problem-centered" Nature of Accounting Program at DTU-IS

	1: Disagree - 2: Neutral - 3: Agree		
Statement	**Disagree**	**Neutral**	**Agree**
5. The approach in most classes were still "teacher-centered", with the instructors knowing everything and determining what should be conveyed to the students.	**38 / 30.4%**	**48 / 38.4%**	**39 / 31.2%**
7. The textbooks used in most PSU-transferred courses are easy to use with many real-world examples and case studies.	**29 / 23.2%**	**62 / 49.6%**	**34 / 27.2%**
8. Most of the accounting problems presented in our exercises and projects were clear-cut, with absolute results.	**39 / 31.2%**	**41 / 32.8%**	**45 / 36%**
13. The project problem presented in our ACC 496 was a big open-ended challenge, simulating a real-world accounting project.	**45 / 36%**	**37 / 29.6%**	**43 / 34.4%**

Whether our PBL adoption has brought about a "problem-centered" approach in most of our courses is a condition that we always look at as a sign of our success or failure in adopting PBL. As previous interviews with the instructors have signified the fact that many of our Accounting instructors still believed they knew everything and should dictate what needed to be conveyed to the students, our students (of up to 31.2%) did indeed get that impression. However, it was not that bad because there were still 30.4% who disagreed. The same thing happened to the textbook issue with 27.2% who agreed that the textbooks did have many real-world examples and case studies to support our PBL approach. The only major complaint we had from our students was that the examples and case studies in the textbooks mostly had to do with the conditions in America and not that of Vietnam to be relevant for their study. The nature of accounting problems presented in exercises and projects (including ACC 496) as perceived by our students was mostly fixed and closed-ended. This actually went against the PBL spirit of presenting some open-ended challenge to students so as to encourage the learning of new skills and knowledge. It also revealed the fact that our Accounting instructors went for fixed and closed-ended problems so as to save their time and effort in grading and evaluation, especially for classes with big numbers of students (Kolmos, et al., 2007). Ironically, many students commented that this was the optimal way to learn Accounting. Some random complaints included that they did not have the chance to provide feedbacks about our PBL-project courses after ACC 396, and ACC 396 and ACC 496 were usually taken so close together (only one semester apart) that they did not have the time to digest the materials.

Table 4: Survey results about "Student-centered" Features of Accounting Program at DTU-IS

	1: Disagree - 2: Neutral - 3: Agree		
Statement	**Disagree**	**Neutral**	**Agree**
6. We were mostly graded based on our individual and team interactions as well as progress rather than by individual comprehensive tests and exams.	**25 / 20%**	**32 / 25.6%**	**68 / 54.4%**
9. The accounting courses in the program are closely tied up together with the materials from one course supporting those in another.	**8 / 6.4%**	**40 / 32%**	**77 / 61.6%**
10. Our instructors possess strong knowledge about Vietnamese, American and international accounting conventions.	**45 / 36%**	**44 / 35.2%**	**36 / 28.8%**
12. Our instructors possess good knowledge about the accounting practices in the real world.	**34 / 27.2%**	**38 / 30.4%**	**53 / 42.4%**

The good news along the way was that our instructors have been perceived (by 54.4% of the students) as moving away from comprehensive tests and exams to focus more on the assessment of individual progress and team interaction in their evaluation. Students stated that they now needed to pay close attention to various performances at different stages in doing their project rather than just focusing on the final exam or the board presentation at the end of the project. Also, 61.6% remarked that they now could always refer to materials in some previous accounting classes to support with the study of the current ones. This indicated that our curriculum structures have become inherently systematic. The knowledge balance between Vietnamese and international accounting conventions, however, was a subject of critics as 36% disagreed and another 35.2% were neutral to the statement that our instructors had strong knowledge about different accounting conventions. The common feedbacks were that our instructors with academic background from overseas did not have a good knowledge of Vietnamese accounting conventions, and this would be quite damaging because Vietnamese accounting operates by legal decisions and annual legal announcements, not by generally-accepted accounting principles. Most students (42.4%), on the other hand, believed that our instructors did have good knowledge and experience of real-world and practical accounting practices in the industry, despite the contrary.

Table 5: Survey results on Students' Understanding and Appreciation for PBL

	1: Disagree - 2: Neutral - 3: Agree		
Statement	**Disagree**	**Neutral**	**Agree**
11. Learning Vietnamese and international accounting conventions at the same time will be fruitful for our career in the long run.	**56 / 44.8%**	**12 / 9.6%**	**57 / 45.6%**
14. The PBL approach is all about active learning and project-based coursework.	**3 / 2.4%**	**33 / 26.4%**	**89 / 71.2%**
15. The PBL approach did help improve the quality of	**12 /**	**35 /**	**78 /**

teaching and learning at Duy Tan University.	**9.6%**	**28%**	**62.4%**

As for the students' appreciation of PBL and their PBL-based Accounting programs, even though there were up to 44.8% of students who did not believe that it was fruitful to study Vietnamese and international accounting conventions at the same time, there was pretty much the same percentile of 45.6% who believed that it would be fruitful in the long run. In addition, the majority of the students (62.4%) praised our PBL efforts as adding more to the quality of teaching and learning Accounting at Duy Tan University. Contrary to the low level of appreciation for PBL by our instructors, this feedback from our students is a good sign that we have been moving in the right direction. Of course, along that way, there are still some misunderstandings as imposed by the instructors on to their students like the PBL approach is only about active learning and project-based coursework, as agreed by up to 71.2% of the students.

5 Conclusion

In conclusion, the adoption of PBL for the Accounting program at the International School of our university has been a painstaking one because it requires a series of change-management and gap-bridging efforts in the mentality and activities of both students and instructors. Identifying the major obstacles to our instructors and students in this process thus became quite important in determining the right set of subsequent actions or solutions. For our instructors, major obstacles have to do with their traditional stereotypes about Vietnamese students, their difficulty in collaborating with each other, their lack of knowledge about American accounting standards, their shortage of experience in real-world accounting practices, and their ultimate lack of appreciation for our PBL adoption. As for our students, major obstacles includes inadequate proficiency in English, heavy load of study for both Vietnamese and international accounting conventions, limited schoolwork with open-ended accounting problems, and misled perceptions about the PBL model. While obstacles are always a fact of life, we do recognize that by constantly adjusting our approach and direction to overcome these obstacles, the PBL efforts of our Accounting staff have so far realized certain successes in promoting the "problem-centered" and "student-centered" features, as perceived by both our students and instructors. There is still much needed to be done, and not only in the training of our students for better English proficiency or more effective handling of their schoolwork and projects but also in the training of our instructors to better recognize their guiding role besides elevating their appreciation for the values that they are trying to bring about to our students (Biggs, 2003). Future studies should look into certain solutions that we proposed and validate them. Moreover, since our PBL adoption for the Accounting program at the International School will complete one cycle of four years by summer of this year, it is essential that a complete re-assessment using both direct and indirect methods is needed to accurately measure the extent of our success thus far.

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A Study on Architectural Education with a Local Community —The Achievements and Problems for the Last 10 Years for Approaching Project Based Learning— (IJCLEE 2015)

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Abstract

Since 2001, a new engineering education program with a local community has been implemented in the Department of Architecture and Civil Engineering of National Institute of Technology, Kumamoto College, JAPAN. It is designed to develop students as engineers who understand not only scientific technology, but also culture and local history, and who can understand problems from the local residents' point of view.

Students meet real life complex problems and they are required to propose an innovative solution by collaboration with a local community e.g. local residents, local architects, city planners, a municipal office and so on. Therefore, the local community is an ideal place to develop students' abilities in problem solving.

From the assessment of these programs by EQ (Emotional Intelligence, Golman, 1995) scores, it is confirmed that students' development is large as the school year become higher. The higher school year students have rich experiences of this program. In addition, recently the qualifier's number of the Design Competition in National Institute of Technology has been increasing. We are sure that our architectural education contributes to developing students' abilities.

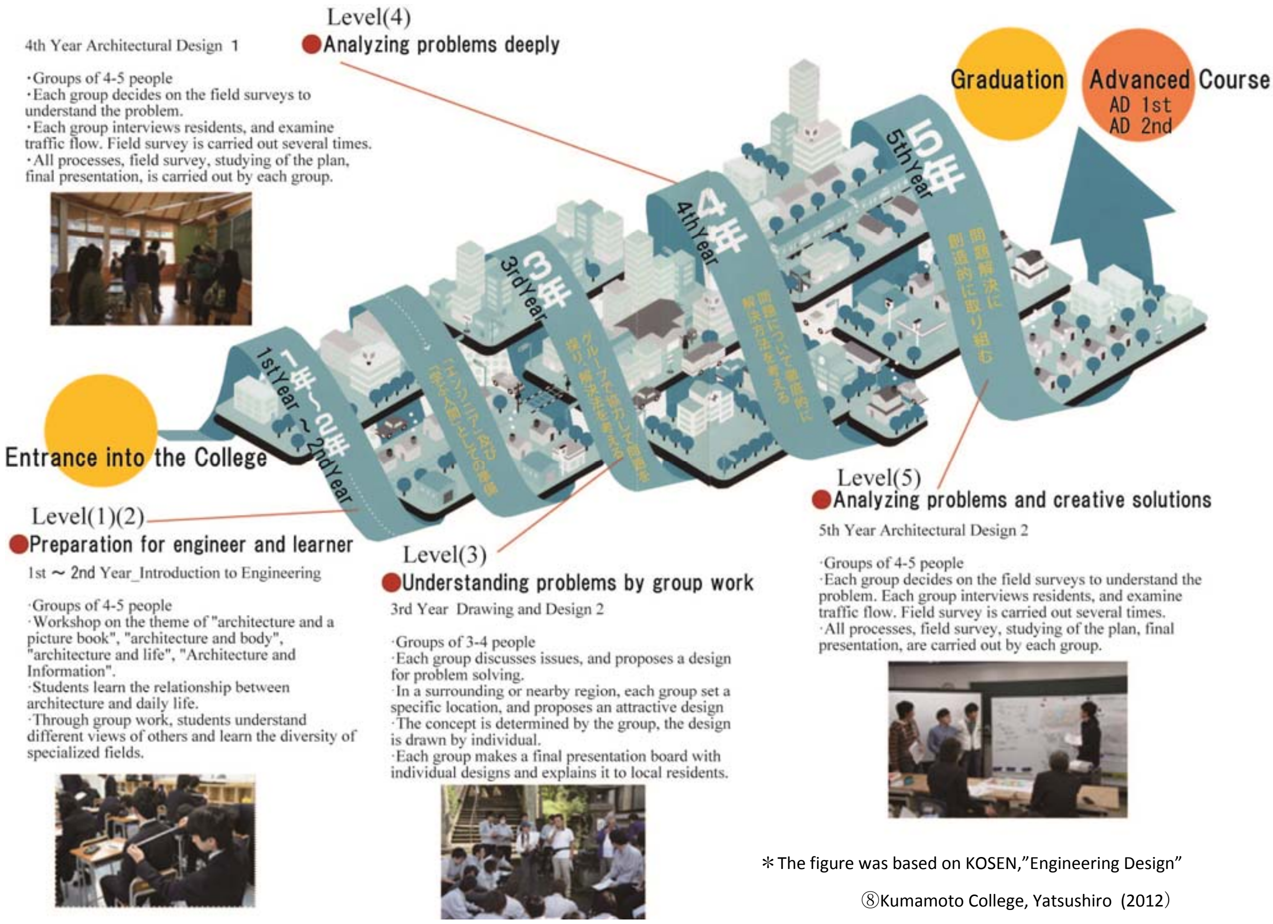
Through the inspection of the Aalborg Model of Project Based Learning at Aalborg University in 2012, it has been found that our approach has much in common with it. But at the same time, it has been found that there are significant points of difference, the purpose of learning and the curriculum. Our curriculum is traditional. To enhance the quality of our program, it is necessary to improve our traditional curriculum approaching to the project based learning.

Keywords: Architectural Education, Local Community, Emotional Intelligence, Aalborg PBL Model, Traditional curriculum

1 Introduction

It is the purpose of this paper to discuss the achievements of a new engineering education program with a local community for the last 10 years which has been implemented in the Department of Architecture and Civil Engineering (AC), National Institute of Technology, Kumamoto College (NIT, Kumamoto) and to consider the problems it needs to overcome for approaching the Problem - based and Project - organized Learning (PBL). Since 2001, our AC department has started a trial of new engineering education programs with a local community by laying the foundation of mutual reliance. As illustrated in Figure 1, approximate goals are set for each school year, which are coordinated in connection with social activities in accordance with each goal. Students acquire specific skills, corresponding to their school year while building up their overall knowledge in a spiral.

For example, the 3rd year Drafting and Design class mainly develops basic learning skills, technology skills and ability to gather information. This class involves the local community during information collection. The



＊The figure was based on KOSEN,"Engineering Design"

⑧Kumamoto College, Yatsushiro（2012）

Figure 1: New Engineering Model of AC Department, NIT Kumamoto

4^{th} year Architectural Design class focuses on applied skills such as proposals, design and involvements with the local community shifts to problem identification. The 5^{th} year Architectural Design class focuses on the ability to propose, to design, such as solutions of problems and creative new ideas. And also it develops skills that can be explained and can be easily understood presentation about designing own proposals and ideas. We considered EQ to be a fair assessment of attitudes towards work and students can realize their own growth by EQ assessment.

2 The Achievements for the Last 10 Years

2.1 Past Projects

The Department of AC has made efforts on projects based on actively involvement with a local community for over 10 years as shown in the Table 1. The 94 projects were undertaken as part of this effort in the 19 subjects, accounting for approximately 20% of all of lectures and seminar classes. The 5^{th} year has eight subjects (28 projects) that apply to this effort, which is the largest number for any year. Two of the subjects (16 projects) are in the 4^{th} year and three subjects (16 projects) belong to the 1^{st}-3^{rd} years. Extra-curricular activities outside the classroom have also been performed, including co-exhibitions of architecture with local architects and a collaboration project with the Chamber of Commerce regarding revitalization of the downtown. Extracurricular activities are multidiscipline cross the year, and have a great potential to promote active learning by students.

2.2 The Characteristics of Our Learning Methods

The characteristic learning style of our Architectural Design Class has been developing to as followings. However, it is important to develop contentiously upward.

(1) The collaboration with a local residents, craftsmen, companies, governments, specialists, our graduates and so on

The collaboration with a local community, craftsmen, governments, architects, planner, school boys and our graduates are shown in Figure 2～10. The reason that we can work these multiple collaboration without any difficulty is mainly that our city is medium scale. It's population is about one hundred and thirty thousand. And there are the historical area and down town area near by our college. They are true supporters for our education. In the students' presentation, it is very important to get opinions by various kinds of persons from viewpoint of real life. To keep our collaboration with local community, it is necessary to keep with strong mutual relationship in our daily lives.

(2) Group work

It has been considered generally that architectural design is individual work. But in our Architectural Design Classes without the lower year, all students' works are by group (Figure 11). Methods of a group formation are as follows; in the 3rd year, teachers decide group members by considering balance of group members, in the 4th year, teachers decide or students decide by talking together, in the 5th year, students decide by talking together.

Table1: Past projects which is concerned with a local community (2001 – 2012)

						GP[1](Receiving funds from Japanese Ministry of Education)			GP[2](Receiving funds from Japanese Ministry of Education)			Subject Class ●Architectural Design ( )Number of Projects	Number of Subjects	Number of Projects	School Year
2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012				
							□Architectural Exhibition Collaboration with Local Architects	【C】Film Festival/【C】HIKOICHI Display /□ Architectural Exhibition Collaboration with Local Architects	【C】Film Festival/【C】HIKOICHI Display display/□ Architectural Exhibition Collaboration with Local Architects	【C】Film Festival 【C】HIKOICHI Display【C】Kyushyu Shinkansen Opening Event /□ YATSHIRO Architectural Guide Map Project /□ Architectural Exhibition Collaboration with Local Architects	□Hospital Gallery Project /□YATSHIRO Architectural Guide Map Project /□ Architectural Exhibition Collaboration with Local Architects /□ Sea of YATTSUSHIRO Renovation project	・After-school activities (16)		16 (17%)	All years
						【H】HINAGU Guide Film Project		【H】Historical Landscape Design Project /【H】Universal Design in Historical Town Project/【H】Heat Island Survey Project			【H】Survey of Landscape Characteristics in HINAGU	●Landscape Design and Planning(2) ・Design Theory for Industrial Production(1) ・Residential Environment(1)	3 (16%)	5 (5%)	AD 2nd
		【H】Bnboo Lighting Design Project	【H】Bnboo Lighting Design Project	【H】Bnboo Rest House Project	【H】Sign Design & Creation of Japanese inn ORIYA	【H】Hearing Survey/【H】SANTOKA Installation Project	【H】Hearing Survey 【H】Paper Lighting Design Project / 【H】Bench Project		【H】HINAGU Main Street Design Project/【H】UCHIWA,Post card and Guide Video Project	【C】Vacant Shop Renovation TAMARINBA-Project	□Hospital Gallery Project	・Regional Planning(3) ●Design of Environmental Institution(10)	2 (11%)	13 (14%)	AD 1st
【H】HINAGU Revitalization Project	□ KOUD A Civic Center Project	【C】New YATSUSHIRO City Library Project	□ FRUSHIRO Public Housing Renovation Project	【Y】YATSUSHIRO City Centre Revitalization Project	【C】Usage Project of a Former Large Commercial Facility	【H】Hearing Survey/【H】Survey of Japanese Historical Inn/【H】Construction Survey of Historical Ware House/【H】HINAGU Sign Project/【H】Community Space Project for the People /【H】HINAGU ONSEN Shrine Parking Project	【H】Hearing Survey/【H】Survey of Japanese Historical Inn/【H】Construction Survey of Historical Ware House【H】Community House Sign Project/【H】HINAGU Port Development Project/【H】HINAGU Community Planning	【H】Survey of Japanese Historical Inn/【H】 Old Ware House Renovation Project/【H】HINAGU Disaster Prevention Plan Project	【H】HINAGU Main Street Urban Design Project/【C】Japanese Tea Ceremony House Project in the HOSOKAWA SANSAI Garden	Satellite Campus Open to a Community(Design Competition of National Institute of Technology) (【H】・【Y】・【C】) /□Public Transportation of the Semi-Mountainous Area/【H】Landscape Condition and Proposal	【C】EARTHTECTURE (Design Competition of National Institute of Technology) / 【C】YATSUSHIRO Town Centre Project	・Urban Design(3) ・History of Japanese Architecture(3) ・Structural Design(2) ●Architectural Design Ⅱ (14) ・Traffic Engineering(1) ・Landscape Design Ⅰ(1) ・Landscape DesignⅡ(2) ●Structural Design(2)	8 (42%)	28 (30%)	5th Year
	【H】Red Brick Ware House Renovation Project	【H】Revitalization Project	【C】Group Home Project	【C】Town Library Project	【C】Town Library Project	【H】 Old Ware House Renovation Project	【H】HINAGU Elementary School Project Collaboration with school boys	【H】HINAGU Elementary School Project	【C】Group Home Project /【C】Myouken Festival Hall Project /□ UYANAGI Elementary School Project	【C】Group Home Project/【C】Myouken Festival Hall Project/【C】TAIYO Elementary School Project /□ Marginal Settlements Problems & Proposal	□IZUMI Unified Elementary through Junior High School Project	●Architectural Design Ⅰ (15)/ Civil Planning(1)	2 (11%)	16 (17%)	4th Year
						【H】HINAGU public Restroom Project	【H】HINAGU public Restroom Project	【H】HINAGU Leafy Housing Project / 【H】HINAGU public Restroom Project	【Y】Low - Rise Housing Complex Project/【H】HINAGU Station Plaza Project	【Y】Low - Rise Housing Complex Project/【H】New HINAGU Station Plaza Project	□SASHIKI Station Project	●Drawing and Design Ⅱ (8)	1 (5%)	9 (10%)	3rd Year
【H】=HINAGU Area 【C】=City Centre Area 【Y】=YATSUSIRO Station Area □=Others UD=Universal Design LD=Landscape Design										□Local Resources Survey and Making a Map Project	□Local Resources Survey and Making a Map Project	Integrated Study for Engineering(1)	1 (5%)	2 (2%)	2nd Year
							【H】Making a Lantern Project/【H】Repairing Old Plaster Wall Project	Making a Lantern Project 【H】		□Architecture and a Picture Book, body and a Life Style	□Architecture and a Picture Book, a Body and a Life Style	・Practice of Construction Creation(3) ・Introduction of Engineering(1)	2 (11%)	5 (5%)	1st Year
		GP1:The support program for Contemporary Educational Needs of the Japanese Ministry Education GP2:the support program for Promoting High-Quality University Education											19(100%) 14(1st～5th)	94(100%) 61(1st～5th)	Total

(3) Supervision by multiple teachers

We have taken supervision in the Architectural Design Classes by multiple teachers. From last year, we have introduced "Supervisor's Studio System". We have realized to enhance more deeply learning from this result (Figure 13).

(4) The learning together and beyond the year

In this year, we have tried to open of the 5^{th}year's and the 4^{th}year's Architectural Design class at the same time. Each studio group composes 5^{th} and 4^{th} students mixed. About from last year, there are some 5^{th} year students who join in the lower Architectural Design Class presentation and give advices to junior students (Figure 12). And some students have started up a study session independently and lower-class students help upper-class students to make models in their graduate design.

(5) The real life problems in the local community

As mentioned before, students are required to solve real life problems. In the 5^{th} year, students are required to discover and to solve problems and they have to design a physical plan. In the 4^{th} year, students are given the planning area and the problems to be solved, and they are required architectural solutions. They make an on-site inspection frequently and deep relationship among the local residents as the year goes up. The planning should be in response to the wishes of the community residents.

Figure 2: HINAGU Wear House Renovation Project collaboration with local residents & Yatsushiro City_4^{th} year_2007

Figure 3: MIYAJI Project collaboration with a paper craftsman_4^{th} &5^{th} year_2014

Figure 4: HINAGU Event Court Roof Project collaboration with a bamboo craftsman_4^{th} &5^{th} year_2014

Figure 5: HINAGU Elementary School Project collaboration with elementary school boys _4^{th} year_2008

Figure 6: HINAGU Sign Project collaboration with local residents & Yatsushiro City_5^{th} year_2007

Figure 7: HINAGU New Station Project collaboration with local residents & Yatsushiro City_3^{rd} year_2011

Figure 8: Hospital Gallery Project collaboration with doctors, nurses, constructer, and high school students_AD1st & all the years_2012

Figure 9: Vacant store Renovation Project collaboration with the chamber of commerce _AD1st & all the years_2011

Figure 10: Presentation to a local government officer, architect and urban planner _5^{th}year_2014

Figure 11: Group work_5^{tn} year_2012

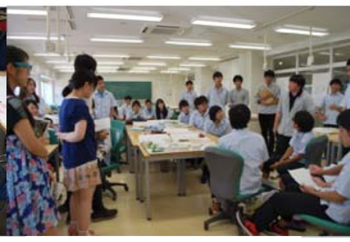


Figure 12: Senior students (5^{th}year) are giving advices to their juniors (3^{rd}year) _2014

Figure 13: Assoc. Prof. Moriyama Studio_4^{th} &5^{th} year students' group_2014

3 Assessment of our programs

3.1 EQ (Emotional Intelligence)

The Department of AC requires much comprehensive knowledge for students, because projects are closely related to a society. In addition, the engineering work environment requires extensive collaboration with other specialized fields, and ability to exchange various opinions and work together is necessary. As such abilities are related to internal attitudes towards society and others, EQ (Emotional Intelligence) as advanced by Daniel Goleman (Goleman, D., 1995) was fund to be useful. Goleman states that sense of values and ability to respect consideration, self-control, cooperation, and harmony are important. They are considered to form the background of the desire to learn and willingness to contribute to social activities. Therefore, we considered EQ to be a fair assessment of attitudes towards work. For the education of engineers in our department, EQ is related to the following. They can be learned through group activities and involvement with the community and enhance their learning motivation, so students aim to produce good work in cooperation. Trough EQ tests on a regular basis, we can continue to observe whether the students have mastered basic abilities and attitudes of engineering education.

3. 2 Methods of EQ Questionnaire

We show as in table2 an EQ test of 40 questions in total with reference to the Uchiyama's questions and analysis (Uchiyama, K. , 1997). The four questions correspond to 10 items. Each question was graded on a Likert scale of 1 to 5 corresponding to "completely disagree: 1" "somewhat disagree: 1" "cannot say: 3" "somewhat agree: 4" "completely agree: 5". The questionnaire was conducted four times between 2010 and 2013. The number of each school year students is about 40. And the number from 1st year to 5th year students is about 200 in total (Table3) .

Table3: Sample size of an EQ Questionnaire

	Nov. 2010	May, 2011	May, 2012	May, 2013
1st Year	42	43	43	42
2nd Year	45	42	46	47
3rd Year	41	48	37	43
4th Year	37	39	48	34
5th Year	42	32	31	43
total	**207**	**204**	**205**	**209**

3. 3 Results of EQ Questionnaire

Figures 14 - 17 show the averages of the four questions corresponding to the 10 items by school

Table2: An EQ Questionnaire of 40 questions correspond to 10 items

1	Smart Sense	1	I prioritize it, and I can put things in order quickly.	6	Self-control	21	Even if I fail, I remain clam without showing my feeling.
		2	I always think what I could do.			22	I endeavor not to become emotional at all times.
		3	I often become the leader of a research group.			23	I can think what should I do at first when I come to a dead end.
		4	I am good at relaxing around atmosphere by my joke.			24	It is my strong point that I am able to fight tenaciously against my goals.
2	Self-insight	5	I can convey my feelings in words.	7	Caring Hearts for Others	25	I will come to want to help people in trouble.
		6	I often start hating myself.			26	I want to do volunteer work.
		7	I understand almost my strengths and my weaknesses.			27	I try to think everything from other people's point of view.
		8	I understand almost of my weak points.			28	I don't want to do hurt the person under any circumstances.
3	Voluntarily Decision	9	I draw the line when it comes to work.	8	Empathic Understandin g	29	I can understand well the character in a play or movie.
		10	I don't take longer time in deciding my schedule.			30	I am easy affected emotional influence by around me.
		11	I can give direction very efficiently to an underclassman.			31	I don't tell what another person dislike.
		12	I speak decently when it's needed.			32	I can listen to people anytime.
4	Self Motivation	13	I believe that my effort never goes unrewarded.	9	Social Skills	33	At first, it is courtesy to listen to the partner.
		14	I have more patience than people in general.			34	I can get close to everybody but not mere everybody's friend.
		15	I throw myself into my special subject study with all my heart.			35	I can help everybody with willingness.
		16	I keep to do as hard as I could whatever anybody says.			36	For everyone I will be motivated to do anything even if something bad.
5	Optimism	17	Even if I fail, I bounce back soon I think I had a good experience.	10	Social Dexterity	37	Many people consulted me.
		18	I think that almost everything goes well.			38	Almost my friend open comfortably their heart to me.
		19	When I lack motivation, I can make myself sit up.			39	I am always thinking about the procedures of the learning subject or extracurricular activity.
		20	I persevere and achieve my daily task once I have chosen it.			40	I can understand that opposite opinion to mine is temporarily managing at the debate.

Reference to the Uchiyama's questions and analysis (Uchiyama, K. , 1997)

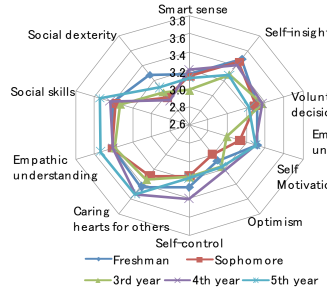


Figure 14: The Result of EQ (Nov., 2010)

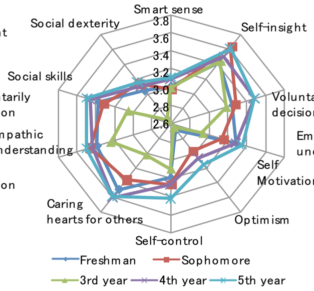


Figure 15: The Result of EQ (May, 2011)

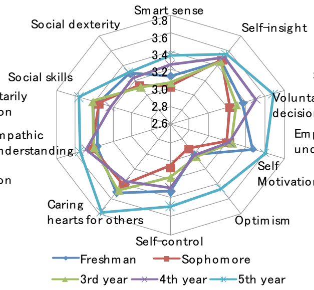


Figure 16: The Result of EQ (May, 2012)

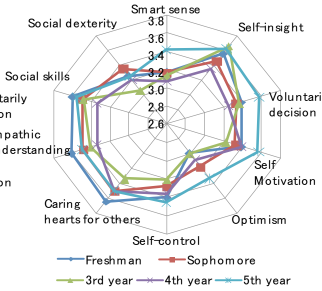


Figure 17: The Result of EQ (May, 2013)

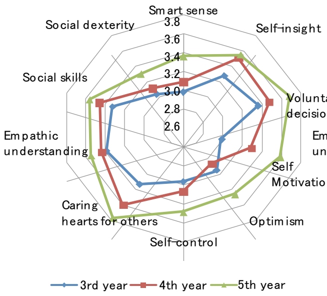


Figure 18: Changes in the same class (Graduated in the school year 2012)

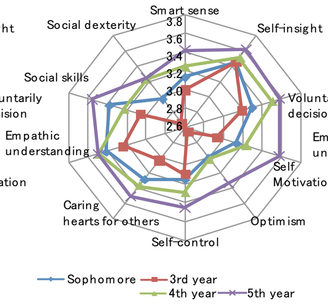


Figure 19: Changes in the same class (Graduated in the school year 2013)

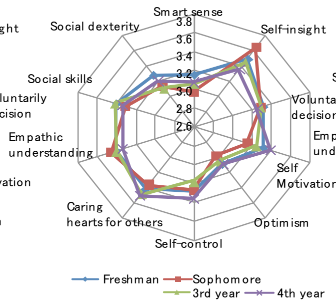


Figure 20: Changes in the same class (5th year in 2014)

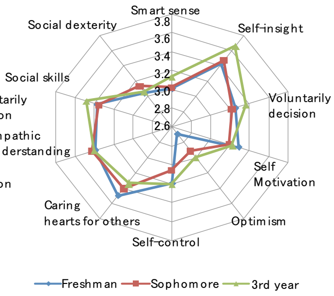


Figure 21: Changes in the same class (4th year in 2014)

year from 2010 to 2013. Scores over 3.0 indicates positive trends and scores under 3.0 indicates negative trends.

Results of the analysis are as follows. Almost the 4th year and 5th year results spread outward compared to other years, and 2nd and 3rd year results tend to fall near the center of the circle. Thus the EQ value tends to rise as the school year increases.

Changes in the EQ value in the same class are shown in Figure 18 - 21. Figure 18 and 19 show the changes in the value of EQ of the graduates. Figure 20 and 21 show changes in the value of EQ of the 5th and the 4th years in the school year in 2014. As shown in Figures 18 and 19, the outermost spread occurs at 4th and 5th years, Figure 18 is remarkable. We believe this shows that students have been able to master basic abilities and attitudes toward learning through this engineering education with a local community as classroom. The EQ in Figure20 and Figure21 are almost unchanged and tend to be not so smaller in the 3rd year. This is considered that they have been experienced our PBL approaches from entrance of our college.

Table4: Number of qualifier in our department and applicants in the Design Competition

year	category	Qualifier's number of our college	Number of qualifier	Number of applicants
2004	Interregional interchange symposium	1	12	19
	Manufacturing workshop	1	7	146
	Wooden house design	1	12	239
2007	Spatial design	1	20	153
2011	Spatial design	1	12	131
2012	Spatial design	1	13	133
	Environmental design	1	10	41
2013	Spatial design	3	20	115
2014	Spatial design	2	15	84
	Environmental design	2	11	92

In every question, the EQ value of Smart Sense, Social Dexterity and Optimism tend to be small, on the other hand, Caring Hearts for Others, Self-Insight, and Empathic Understanding tend to be high.

3. 4 The Design Competition

Students have been acquired professional skills on the work competency surely. In the Design Competition of National Institute of Technology, number of qualifier in our department has been increasing recently (Table4). Our students got the most-valuable award in the category of Spacial Design in 2014. It is considered that this is one of achievements of our program.

4 Problems

4.1 The Traditional Curriculum

The Aalborg PBL Model and the diagram of our AC department curriculum are shown in Figures 22 and 23. The Aalborg PBL Model is well known in the world as the project- organized problem-based learning (Kolmos, 2013) in the engineering education. It is the hybrid curriculum with courses and project. Every semester is set within a 'thematic framework' for sustainable development. The courses are almost traditional lectures. There are only 3 courses in the semester. Courses are developed and taught with reference to the theme of the semester (Kolmos, 2013). Some of the three parallel courses do support the project. Almost project work is carried out in groups and the same model is followed from the 1st semester until the completion of a master degree. The characteristic is that a project occupies one half of the full credits in the semester. The courses occupy the other half.

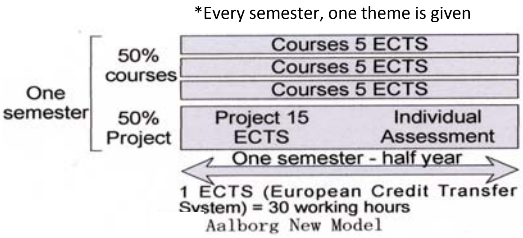


Figure22: The Aalborg PBL Model

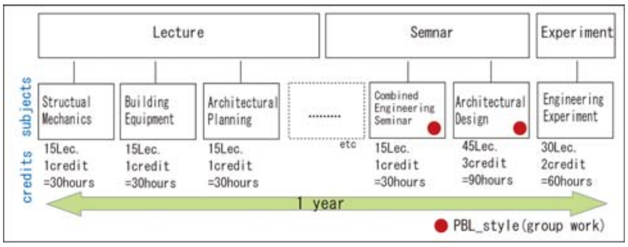


Figure23: The diagram of our AC Department curriculum of NIT, Kumamoto

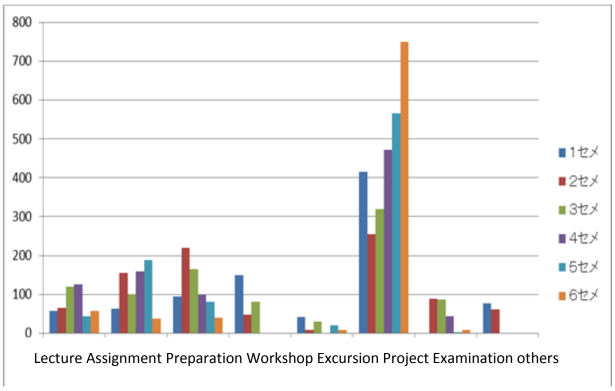


Figure24: Students' work load in each learning item(Department of Architecture, AAU)

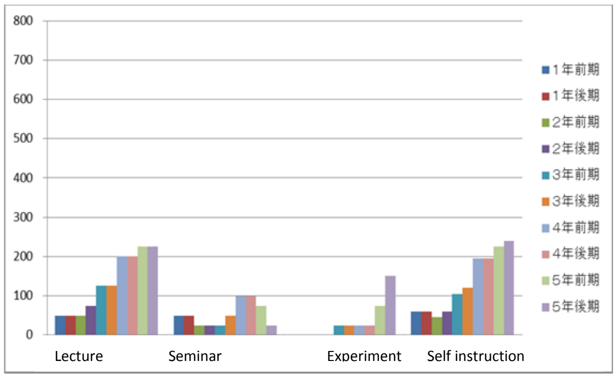


Figure25: Students' work load in each learning item(AC Department of NIT, Kumamoto)

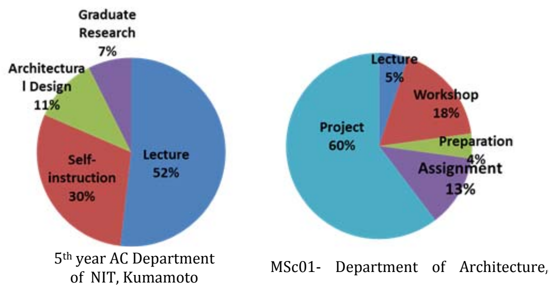


Figure26: The ratio of Students' work load in each learning item

Table5: Comparison of the main purpose of learning

Aalborg University	NIT, Kumamoto College
To secure continued professional development throughout the student's career via lifelong learning, i.e. "learning to learn"(Dahms, M.2012)	To ensure professional and technical knowledge
PBL Introduction, The Department of Development and Planning, Aalborg University, Sep. 1st 2012	Handbook for student of NIT, Kumamoto

Contrary to the Aalborg PBL Model, our AC curriculum is traditional. It is common to almost all engineering Japanese universities and our National Institute of Technology. There are many special subjects and they have almost no relevance to each other. Teaching is generally left to the professors. PBL method (group work) is only used in a few courses under the traditional curriculum (Figure 23). Most so-called PBL approaches in Japan are in almost the same situation.

4.2 Students' Work Load in Each Learning Item

The students' work load in each learning item of AAU (1st semester～6th semester) and our AC Department (1st year～5th year) are shown in Figure 24～25. The students' work load of the project of AAU is much remarkably. As semester promoting, the students' work load increases. The MSc01-Department of Architecture of AAU and the 5th year of our AC Department of the ratio of Students' work load in each learning item are shown in Figure 26. A 95% of the students' work load of AAU is student's independent or active work. On the other hand, our AC Department students' work load in student's independent or active work is 46%. About work load in lectures, the ratio of its share of our AC Department is 52%, on the other hand, it of AAU is only 5%.

4.3 The Purpose of Learning

Table 5 compares our college of purpose of learning with those of Aalborg University. The main purpose of learning of our college is to ensure professional and technical knowledge. The main purpose of Aalborg University is to secure continued professional development throughout the student's career via lifelong learning, i.e. "learning to learn" (Dahms, M., 2012). The project of the Aalborg Model is desired a new proposal that is carried out in people's surroundings development. It is attached importance to be innovative or creative. Contrary to this, our learning purpose is an understanding-level of Bloom's Taxonomy.

5 Conclusions

We have shown our characteristic learning methods, achievements and problems of our New Engineering Education; mainly the Architectural Design Subject in the AC Department of NIT, Kumamoto on the basis of our approaches for over 10 years. We understand that the educational effects are students' internally development, so we have tried to take EQ as an assessment of educational effect. As the result, it became clear the educational effects in our approaches.

On the other hand, there are a lot of problems. Our approaches of the Architectural Design Class are under the traditional curriculum. In the learning present situation are mixed in a traditional learning and PBL. This learning environment put too much load on students. And also educational development can't be expected further more. We have to improve our traditional curriculum to the students-cantered one as the Aalborg PBL model. Further practically investigation and discussing with a large number of our colleagues is necessary.

Acknowledgments

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Challenges of introducing PBL in engineering: lecturers' and students' perspectives

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Abstract

Problem-based learning (PBL) has become widely used across the professional education sector and is now emerging in engineering education as a viable teaching and learning strategy. PBL originated some 45 years ago in medical education at universities in McMaster (Canada), Maastricht (Netherlands) and Newcastle (Australia), and since then has gain popularity worldwide in many fields.

The PBL approach as presented in literature supports a shift from teacher-directed learning to facilitation of students' learning. Facilitation involves a different style of teaching compared to traditionally accepted styles, and from the experience of both students and lecturers, brings several challenges. A skilled PBL facilitator who is secure in his/her role can contribute significantly to the effectiveness of PBL groups' work and thus to students' learning.

This paper reports on a qualitative study of the experiences of academic staff and students at one institution, the German Malaysian Institute (GMI), in Malaysia. During interviews and focus groups, lecturers and students identified the challenges that lecturers face in effectively facilitating PBL. Analyses revealed two major themes that inhibit success: lecturers' and students' adaptation to PBL. These findings provide interesting insights into what is required to adapt to this mode of delivery.

Keywords: Problem Based Learning, engineering education, PBL challenges, PBL adaptation

1 Introduction

The dual factors of globalisation and industry's needs have changed the engineering education landscape. Among the many challenges confronting educators today is the divergence between the goals of curricula and the demands of the workplace (MOHE 2006; Galloway 2007) . Educational institutions need to provide graduates with the necessary sets of knowledge, skills and competencies to meet the demands of globalisation. Graduates are expected to be employable, ready for the workplace and equipped with a balance of technical knowledge and the relevant soft skills required by their potential employers(Jackson 2010; Pitman & Broomhall 2009).

PBL and its variants have been deemed appropriate for meeting the needs of both educators and industry in preparing engineers for the 21st century (van Barneveld et al. 2012). PBL was first introduced at McMaster Medical School in Canada, in 1969(Boud & Feletti 1998). This was followed by the development of PBL curricula at medical schools of the University of Limburg at Maastricht in Netherlands and the University of Newcastle in Australia (Du et al. 2009; Baden & Major 2004). From these initial efforts, PBL spread widely in some disciplines such as architecture and construction management, engineering, legal training, business and management, archaeology, information management, physics and others (Boud & Feletti 1998; Du et al. 2009). Specifically, PBL is being adopted increasingly as a learning and teaching strategy in engineering education worldwide, including in Malaysia, the context of this study (Yusof et al. 2004a).

While research suggests that PBL is an effective approach to promote learning, there are challenges when those delivering a curriculum change roles from a traditional lecturer to a facilitator (van Barneveld et al. 2012; Hasna 2008; Salimah & Zaitun 2004). However, the challenges and barriers of being a facilitator in PBL have not been fully addressed (Savin-Baden 2003). Furthermore, how lecturers manage these challenges in the engineering field remains largely under explored (van Barneveld et al. 2012). The study, reported in this paper, was designed to examine the challenges lecturers face in implementing PBL in engineering education in Malaysia.

2 Background

Evidence suggests that PBL has been at the core of significant developments in engineering education (Yusof et al. 2004b). PBL in engineering education was firstly implemented at Aalborg University in Denmark in 1974 (Kolmos et al. 2004). The traditional Aalborg model which is founded on problem-based project work is used in all study programmes within the Faculty of Humanities, the Faculty of Social Science, and the Faculty of Engineering and Science (Kolmos et al. 2004). The Aalborg model has grown to encompass all engineering institutions in Denmark who have developed their teaching on the basis of problem-based learning and project work (Kolmos 2006).

PBL has reportedly been successfully used in teaching a range of engineering courses including; civil engineering (Hadgraft, 1993), chemical engineering(Hadgraft, 2005; Khairiyah, Mimi, & Azila, 2004; Woods, 1996), microelectronic engineering (Ahmad 2006), engineering design (Hasna 2008), electrical and electronic engineering (Montero & Gonzalez 2009), computer network design (Linge & Parsons 2006), statistical engineering (Nopiah et al. 2008) and construction engineering (McIntyre 2002). The application of PBL into such a broad range of engineering disciplines demonstrates its applicability to engineering education.

Recent studies (Wan Muhd Zin et al. 2013; Masek & Yamin 2012; Montero & Gonzalez 2009; Hasna 2008) have documented the advantages in using PBL in engineering including; improvement in technical knowledge and skill in conducting searches (Edward 2004), development of a greater understanding of engineering science and core engineering fundamentals (Porter & Brodie 2001), development of engineering design skills (Linge & Parsons, 2006), development of problem-solving skills, enhanced communication skills, team-work, self-directed learning and lifelong learning (Montero & Gonzalez 2009; Wan Muhd Zin et al. 2013; Kolmos et al. 2004) and enhancing knowledge and critical thinking abilities (Masek & Yamin 2012). This supporting the concept above that PBL not only supports a range of engineering disciplines but also the disciplines' highly regarded attributes.

Despite wide-ranging support for the adoption of PBL in engineering (Hadgraft, 1998; Hasna, 2008; Perrenet et al., 2000) , the transition to PBL brings its own challenges (Hasna 2008; van Barneveld et al. 2012; Clancy 2005). The main challenge is the dissonance between theory and its application (Mills & Treagust 2003). This refers to the nature of engineering knowledge and practice compared to other disciplines, where PBL is widely adopted (e.g medicine). The knowledge required in engineering is sequential, meaning that if students miss essential topics, they will fail to learn later concepts (Perrenet et al. 2000). Further challenges include students' initial discomfort with their new roles in student-centred learning and inexperienced educators who are unfamiliar with their new roles as PBL facilitators (van

Barneveld et al. 2012; Salimah & Zaitun 2004). Some of the issues facilitators have to confront include: group conflicts (Hasna, 2008; Montero & Gonzalez, 2009), increasing workload (Hasna,2008), PBL assessment expectations (Edward 2004), being resource intensive (Edward 2004; Montero & Gonzalez 2009), time consuming (Edward 2004; Ahmad 2006), large number of engineering students (Salimah & Zaitun 2004); quality of PBL problem statements (Salimah & Zaitun, 2004), and depth versus breadth of engineering curricula (Montero & Gonzalez 2009). At present, there is little literature dealing with how engineering educators manage all these challenges. The authors believe this remains an under-explored area.

3 Purpose of Study

In response to the dearth of information regarding our understanding of how PBL implementation impacts engineering educators, a research project has been established which involves a qualitative study. This research project is part of a larger study by the first author for her higher degree research. The study reported in this paper was designed to examine the challenges lecturers face in implementing PBL in engineering education at the German-Malaysian Institute (GMI) in Malaysia. In this study, semi-structured interviews were conducted using a loose structure consisting of open ended questions that define the area to be explored, from which the interviewer or interviewee may diverge in order to pursue an idea in more detail (Britten 1995). For the students, semi-structured interviews were conducted in a focus group setting to explore participants' knowledge and experiences (Kitzinger 1995) and to experience the synergistic effect of group interactions that may result in the production of data that would otherwise remain hidden (Stewart et al. 2007). Specifically the interview questions used to direct the study in exploring the issues identified in this paper were:

<u>Interview with lecturers:</u>

What do you see as the most significant challenges/barriers in facilitating PBL effectively? Why?

<u>Focus group interview with students:</u>

What challenges do you think your lecturers face in facilitating PBL sessions? Why?

4 Data Collection, Sampling and Ethical Consideration

The study, undertaken at GMI was to investigate the challenges of delivering PBL courses as experienced by lecturers. The sampling plan was purposeful, where the respondents chosen had to have both sufficient background and experience in PBL to provide rich and deep descriptions of the phenomena being studied (Patton 2005). Twenty lecturers with teaching experiences ranging from two years to 20 years agreed to take part in individual interviews. Six focus groups were conducted (with five students in each group and all students enrolled in the same semester). The groups were kept small to allow for full participation by the students as well as to ensure in-depth discussions of the topic. All the interviews, which were audio-recorded, lasted 60-90 minutes. Approval for the study was obtained from the ethics committee of University of Newcastle (approval number H2014-0124). Ethical considerations of confidentiality, anonymity, and the ability of the participants to exercise their right to participate, withdraw or abstain from the study, were implemented throughout the entire research process.

5 Data Analysis

The analysis of data was undertaken using a framework of thematic analysis, as recommended by Braun & Clarke's (2006) in their step-by-step guidelines. These guidelines consist of familiarisation with data, generation of initial codes, immersion in the data, reviewing themes, defining and naming themes, and producing reports (Braun & Clarke 2006). The interviews and focus groups were transcribed and the analysis of the text was performed using the software package NVivo 10.0.

6 Results and Discussion

Analysis of the data yielded a number of themes, two of which provide the focus for this paper: lecturers' and students' adaptation to PBL and its corresponding subthemes, as shown in Table 1.

Themes	Subthemes
Lecturers' adaptation to PBL	• Transition to a new role • Lecturers' mind-set • Management of group dynamics
Students' adaptation to PBL	• Initial anxiety and struggle • Lack of knowledge, skills and attitude

Table 1: Challenges that lecturers' face in delivering PBL courses in engineering

6.1 Lecturers' adaptation to PBL

6.1.1 Transition to a new role

The majority of the lecturers (known as 'Technical Training Officers' (TTO)) interviewed described the challenges of transitioning to a new and unfamiliar role. Almost all of the TTOs interviewed explained that their own education and their teaching experiences to date were traditional and teacher-centric. Some were not prepared to make paradigm shifts to a teaching approach that was student-centred. Typical comments by those interviewed included:

> *TTOs may be resistant to change because PBL are different to their normal teaching. Since we are accustomed to traditional education, it is quite a challenge to depart from that system and adapt to PBL. (TTO 3)*
>
> *TTOs felt traditional lectures and practical work very well with technical education. They have practiced for such a long time and have successfully produced many good students. So why change?. (TTO 16)*
>
> *Some TTOs do not change their thinking from the old paradigm of teaching (still teach not facilitate), some misunderstood the role by simply supervise…even from far…and do not guide or coach in between the process (if needed). (TTO 10)*

However some interviewees articulated a positive experience about transition to PBL.

> *For me PBL is not that difficult. All this while, I've been doing some sort of student-centred learning in my class. I let students do their own work. I don't spoon-feed with all information needed. I encourage students to work in groups. Once they got stuck, I will guide them. (TTO 15)*

Some of the lecturers commented that they felt nervous about facilitating PBL modules, but they had become comfortable through the experience of implementing this approach.

> *It is not easy to change your role overnight. I feel anxious. It's a struggle for me not to be in control 100%, but to let students find the answers themselves. But after experiencing many PBL classes, I do enjoy the process and look forward to conduct PBL. (TTO 6)*

> *Initially, I was uncomfortable with PBL, but with more experience I'm getting better. On the positive notes, many of my colleagues don't know much about PBL, but still try their best to implement it in class. (TTO 9)*

From the students' perspectives, in taking a new role as a facilitator, it is very important for lecturers to be knowledgeable because in a PBL environment, students usually ask many questions.

> *When we research, we always come out with new information that needs clarification. In our class, students always ask many questions, sometimes beyond syllabus coverage, so TTO must be prepared and equipped with sufficient knowledge*. *(Student 3, Focus Group 1)*

> *For example, when we present in the class, TTO should not embarrass themselves by saying "Oooo, I see!… now I know why!. For me, it seems like TTO don't know much about the problem under research. (Student 2, Focus Group 4)*

Similarly, some students complained that TTOs did not provide guidance to problems.

> *In PBL, students need to find solutions on our own, but we still need confirmation from TTOs..… some TTOs don't answer our question directly.. maybe they don't know the answer... so they beat around the bush…. ended up… we are not sure if our answers are correct. (Student 1, Focus Group 6)*

Students also spoke about the quality of facilitation and sharing of knowledge:

> *I don't agree with some TTOs who leave us in the library to work totally on our own. Even though in PBL students must work independently, TTOs should monitor our progress, and be there in case we have questions to ask. (Student 4, Focus Group 2)*

> *We appreciate if TTOs can share their working experiences, examples of real life applications and other relevant knowledge. Some TTOs did that. (Student 2, Focus Group 4)*

In general, these comments reflect a concern of the lecturers as they shift from teacher-directed learning to facilitation of student learning. It is difficult to convince staff to shift paradigms and this is common in the early stage of implementation (Salimah & Zaitun 2004; Yusof et al. 2004). Normally, lecturers feel confident and satisfied with existing teaching practices and only few staff members feel the need for change (Kolmos 2006). Lecturers' comments suggest that as they become familiar with PBL, they are more comfortable and confident in teaching using this mode of instruction. The transition to the new role of facilitator also requires educators to equip themselves with both knowledge and facilitation skills (De Grave et al. 1999; Schmidt & Moust 1995). Proactively, those lecturers interviewed had implemented PBL, although some did not have the opportunity to attend any formal PBL training. The training of lecturers is an important consideration as the recent study by Mohd-Yusof, Hassan, Jamaludin, & Harun (2011)has established that facilitators who embrace the PBL philosophy, even without receiving extensive training, might yield more positive student outcomes than more experienced facilitators who did not facilitate through the full PBL process.

6.1.2 Lecturers' mind-set

The perspective of most of the lecturers interviewed was that lecturers must possess a positive mind-set to motivate them to implement PBL. They must be willing to accept changes. As one TTO commented:

> *PBL is all about TTOs' willingness! When there's a will, there's a way. It can be difficult at first, but TTOs must be positive to accept it. When you think positive, everything will fall in places.. it's all in your heart whether you want to embrace it or not!. (TTO 17)*

From another perspective, some TTOs have negative feelings about this approach because PBL increase lecturers' workload: thus it is a burden.

> *With PBL, we need to prepare so many things…… crafting problem statements, scaffolding student learning, change the assessment structure, prepare physical materials like mah-jong paper, manila cards, marker pens .. etc…so much work to do.. (TTO 5)*

The lack of confidence in PBL itself might also cause TTOs to have negative feelings about this approach.

> *TTOs need to have confidence in PBL and look at its benefits. From there they can convince the students to participate. PBL would not work unless TTO is convinced about using PBL, rather than they implement it because it was instructed by the management. (TTO 18)*

Some TTOs received incorrect information about PBL, demonstrating the importance of a well-structured implementation plan. For instance, there was resistance from some experienced TTOs because they considered that PBL was not suitable for engineering courses:

> *There are some difficulties in implementing PBL in my courses. The time is not enough to cover syllabus because my course involves almost 100% practical (hands-on). (TTO 13)*

> *Some complained … PBL may work for you, but it wouldn't work well for me… because my subjects involved real machineries …. It would be dangerous to let students operate the machines on their own. (TTO 3)*

Similarly, a TTO commented that he still preferred traditional methods over PBL. As with most innovations in teaching, there are those that are unconvinced of the benefits or unwilling to change, as evidenced in the following statement:

> *I conducted PBL a few times. It is OK. However, in my opinion, I still prefer lecture. I am completely sure of what to deliver and the expected learning outcomes. (TTO 9)*

In addition, certain TTO did not take the initiative to learn about PBL. They assumed that their implementation of the methodology was appropriate.

> *Some of my colleagues replace PBL session by giving tasks to student. For example, go study this chapter and present it in class. So where (does) that involve a problem statement? This is a totally wrong concept. (TTO 2)*

A lecturers' attitude is an important contributor to the successful implementation of PBL as explained by a TTO:

> *OK, some TTOs complained about lack of PBL training, but even during training these TTOs don't take it seriously. There are cases where some TTOs attended PBL trainings for many times and yet still do not take initiative to conduct PBL in their class. I know it because I was*

the one who gave them trainings few times. So the issue here is TTOs' willingness to implement PBL. (TTO 19)

Similarly, students commented that lecturers' attitude towards PBL is important. If lecturers commit to PBL wholeheartedly, students will gain the benefits of PBL and vice versa.

I always look forward to attend Network Ethics PBL class. She is the best TTO!. She will never provide us with answers easily, but will make us work hard for it.. .She is positive that we can solve the problems. (Students 2, Focus Group 3)

My Digital Electronic TTO will be in the class all the time checking our work. She explains the tasks clearly and encourages us to be creative when it comes to presenting findings. (Student 4, Focus Group 4)

I am not sure if TTOs take PBL seriously. Many TTOs just assign us problems and leave us to work independently. (Student 5, Focus Group 1)

All comments, documented above, clearly articulate that a positive mind-set is crucial in ensuring the effective implementation of PBL. A study by Glew (2003) attributes causes of PBL failure to a range of factors, including both insufficient guidance from the facilitators and also to the facilitators who do not practice the facilitation guidelines provided by curriculum designers. Facilitators need to become familiar with PBL processes, gain confidence in PBL and committed to its implementation. Only then can students experience fully the benefits of PBL

6.1.3 Managing Group Dynamics

Another challenge identified by most of the lecturers and students related to group issues. In the GMI model of PBL, students are encouraged to form their own groups of approximately four to five students. Students have different personalities, attitudes and attributes and inequalities in groups are inevitable. For example, there are inequalities in terms of students' participation levels, abilities, capacities and different levels of competencies. Therefore conflicts will arise. This was described explicitly as below:

Some students are 'free loading'. They did not focus in class, and take advantage of their group members. It happened either because they are weak students or maybe because of their negative attitudes. Sadly, these students sometimes get away with it because their group's performance is good. (TTO 4)

Alternatively, it may happen that one student dominates a discussion and other group members just follow because they don't want to create a scene or challenge the dominant student.

Some students dominate the discussion inappropriately,.. the more quiet members would simply not challenge them ..These dominant students sometimes speak on irrelevant issues and take group's time. Overall though, most groups can work well together. (TTO 2)

Lecturers identified another form of dominant student, one who motivates their group members positively. Their enthusiasm helps others to engage with the learning process by making productive contributions to group discussions.

Sometimes if there are some weaker students in the group, the good students can influence them in positive way. Help them to solve the tasks collaboratively. Usually, I can see during class presentation how the weak students improve. (TTO 1)

In addition, student absence is another challenge confronting lecturers. Absent members are likely to disrupt group activities since, in PBL, students divide work and everyone must complete their parts. One lecturer described her opinion about this:

> *Those absent students affect group work. To be fair, I always set ground rules. I will make sure the absent students complete tasks to the minimum standard and students must comply regardless of their wishes. No marks will be given if students did not complete their parts. (TTO 17)*

Students shared similar views about managing group dynamics. They like group work but at the same time there are some issues with group members as described in the following quotes:

> *Working in group is great. We can share opinions. Work can be completed faster. The disadvantage is that you are relying on other people to get work done on time. (Student 3, Focus Group 3)*
>
> *Group work is OK but some group member is like a boss, they give you most of the work …..some member depends on other people to do work for them. Some students are weak and some are good. (Student 2, Focus Group 2)*

Lecturers noted that group dynamics played a vital role in students' experience of PBL. Lecturers reinforced the need for receiving training in topics like dealing with difficult situations and how to engage quieter learners in group discussions. This view is supported by Hung (2011) who writes that the group dynamics issue is an extremely difficult management problem and requires sophisticated tutoring and group management skills, which are often not possessed by the first-time instructor. The findings also concurs with Salimah & Zaitun (2004) who found that lecturers feel they are inexperienced at facilitating group work and seek helpful tips to tackle unexpected situation. In fact, tutors who are perceived as being skilled in group dynamics are evaluated more highly than tutors who are not perceived as being so skilled (Schmidt & Moust 1995) .

6.2 Students' adaptation to PBL

The majority of lecturers and students interviewed commented that students' attitudes and their ensuing behaviours towards PBL implementation are barriers to success. This issue presented itself in two ways, these becoming two sub-themes of the study: (1) students' initial anxiety and struggle in adopting the new approach, and (2) a lack of knowledge, appropriate attitudes and skills to engage with PBL.

6.2.1 Students' initial anxiety and struggle

The significant majority of the lecturers interviewed reported difficulty transitioning students into more active roles associated with the change to PBL, as follows:

> *To have independent students in class is a challenge because they are more familiarised with teacher centred approach and mostly spoon-fed with information. (TTO 2)*
>
> *Students are so comfortable with traditional method all their life, so the initial PBL implementation is difficult. Students cannot adapt well to do tasks on their own. (TTO 7)*

Similarly another lecturer thought that PBL could lead to teaching experiences which disheartened lecturers if students did not engage fully with the PBL process. This was especially the case for lecturers who were trying to implement PBL as a new teaching method.

As a new TTO, I am very excited to try PBL. However, I noticed that with PBL, students don't really put effort in completing the tasks. They just do it for the sake of submitting the assignments without really understand it. When we ask them during class presentation, they cannot justify their answer. (TTO 9)

In addition, there are students who did not cope with learning in a PBL environment:

I received complaints that students found PBL are too stressful. Most of the courses follow PBL syllabus, therefore students have so many tasks to complete at one time. They become too overwhelmed with this. (TTO 12)

Interviews with students provided an insight into why the initial transition was a struggle and provided some suggestions.

PBL is very different from the conventional method I went through at school. At first I find it difficult. I felt lost. TTOs didn't help much. They just ask us to research more. To make it worse the group work is slow and inefficient. TTOs should guide what to do to finish the task. (Student 5, Focus Group 5)

Initially PBL is hard. But after going through the process, I like PBL. I think TTOs must first identify those students who are weak and require extra support. TTOs must know how to engage students in discussions, and let everyone participates. (Student 4, Focus Group 3)

These comments show students experience initial discomfort with PBL and that teachers need to have the capacities to help them to undergo a smooth transition from conventional methods to PBL. This finding is consistent with findings of van Barneveld et al. (2012) and Yusof et al. (2004) who highlighted that students struggle to adapt to PBL when they first encounter it. Students may at first react to the PBL practice with shock, denial, anger and resistance (Kolmos et al., 2007). Pepper (2010) stated that in the "early stages of PBL implementations…it is vital that students receive guidance about how and why they are expected to work in new ways" (p. 704). Students need to reassess their roles and modify their past study habits. Therefore, lecturers need to work to build confidence and guide students in their discussions before they were able to take responsibility for their own progress (Montero & Gonzalez, 2009), particularly with groups who have no experience of PBL.

6.2.2 Lack of knowledge, skills and attitude to cope with PBL process

A number of lecturers suggested that PBL was not always appropriate for the younger students, believing that PBL should not be used until the students had a good grasp of the course content and have developed sufficient foundational knowledge. Some of these responses include:

From my experience, PBL is not suitable for first year students. Most of them never experienced PBL at school. Students cannot solve the problem given. They keep on coming to us for answers. So, in my opinion PBL should not be used until the students had enough prior knowledge. I prefer to use it in Semester 3 or 4 as then they would be ready for it. (TTO 14)

My main concern is that first year students do not have skills to tackle engineering problems solving. They are not mature enough to handle ill-structured problems; therefore we need to craft a well-structured problem. (TTO 4)

Engineering involves lots of math and science. Students are used to memorise lots of formulas and focus on solving equations. So to learn technical with PBL is not easy. Students need time to learn, especially new students coming fresh from secondary school. (TTO 1)

Some students lack confidence and are afraid to try new approaches to learning. They are afraid of giving wrong answers. Some just not interested.

> *Students are afraid of making mistakes. If we say like this they will ask why in the book says differently? They just want answers that can be used in the exam. Even after doing so many PBL, some students still think TTOs answer is the best. (TTO 19)*

> *Sometimes, I feel so frustrated when listening to group presentations. Most of the students just reading off stuff they don't understand or mention words that they don't even know what it means… They simply copied and pasted information from the internet. (TTO 4)*

> *It's not about PBL. It's all about students' attitude. Some are just not ready for college/university life. (TTO 13)*

During interviews with students, similar issues were revealed, showing first year students' lacking knowledge, appropriate attitude and skill in coping with PBL

> *At school, we are used to be guided fully by teachers. Majority don't have the skills to find information on our own or how to analyse problems. TTOs must equip students with skills such as information searching. (Student 3, Focus Group 2)*

> *Initially, we don't have confidence, we don't know what to do with the problem given..how to complete the tasks. We are not confident to explore the problem ourselves. But I am sure with experience, we will improve. (Student 4, Focus Group 1)*

> *I don't understand what's so special about PBL. For me it's just like any other assignments. I do it just to get marks. (Student 2, Focus Group 1)*

The issues identified here, align with those presented in the literatures, where it is related that if the students lack the required background technical knowledge and lack the generic skills needed to undertake self-study, the objectives of PBL will not be fully achieved (Montero & Gonzalez 2009; Perrenet et al. 2000). Besides, there is evidence that students would like to learn in ways they are comfortable with, whilst taking less responsibility for their own learning (Salimah & Zaitun, 2004). Despite this, PBL can still be implemented earlier in the engineering programmes. However, a more structured approach is required with clearly defined problems and gradual moves toward open-ended problems (Hadgraft, 1999). This concurs with Edward (2004) who found that the level of technical knowledge of first-year students is insufficient to allow activities to be more than unstructured and unquantified exercises. In addition, Perrenet et al. (2000) suggests that in the early stages of an engineering curriculum, PBL is a possible strategy to be used to demonstrate the application context. Here teachers need to guide discussions because students are still unfamiliar with the method.

7 Conclusion

The study reported in this paper has identified a number of issues associated with the implementation of a PBL curriculum in engineering. The main issue revolved around the challenges lecturers face in implementing PBL, as identified by both lecturers and students. While transitioning to the instructional roles required by PBL, some lecturers are willing to embrace change, while others see it as a constraint. Nevertheless, it is interesting to note that most lecturers involved in this study did implement PBL even though some received little training. Reflections from the lecturers and students also established that PBL needs time to be fully adopted. It is expected that both lecturers and learners experiencing PBL for the first time will find it challenging because they need to adapt to the new way of learning. Lecturers need to be trained and mentored as they undergo the paradigm shift from a traditional mode of instruction to a PBL mode of instruction. Lecturers need to equip themselves with knowledge and facilitation skills, and have the commitment and willingness to embrace PBL.

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Design of virtual PBL cases for sustainability and employability

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Abstract

In a problem-based learning (PBL) environment, students take, as their point of departure, real life problems situated in a cultural context. This approach holds the potential to give engineering students a sense of what professional practice is like, and challenges engineers to find appropriate technology for cultural contexts and to face grand challenges like sustainable development. One way of bringing PBL into the classroom is by preparing case stories for which the students need to identify, analyse and attempt to solve potential problems and dilemmas that arise during the innovation process. This paper reports on the first phase of a project investigating how PBL principles can shape the design and methodology for open source educational material for a worldwide community to educate engineers for sustainability and employability. By taking our theoretical point of departure to be a synthesis of contending modes of engineering education and PBL principles, we suggest a set of design criteria and exemplify the case selection and overall design of an educational case by considering the implementation of energy and water supply systems at a school for physically disabled girls in a small village in Kenya. The conclusion is that the learning platform has to provide students with a) a case story that is exemplary and focused on a specific context; b) knowledge and possibilities that can be acted on and engaged in the case; c) a sense of the context and the different actors involved, through interviews, films and context-specific documents; d) a platform allowing collaboration through discussion, negotiation, decision-making and collaboration in a self-directed and interactive way around poorly structured, complex and dynamic problems; and e) assignments corresponding to those carried out by the case experts in real life. Last but not least, the learning platform should provide staff guidelines for facilitation but still acknowledge the need to tailor the facilitation to different educational contexts.

Keywords: Knowledge modes, hybrid learning, online learning, case design, sustainability

1 Introduction

Jamison *et al.* (2014) stress three grand challenges of our time that have to be taken into consideration in any approach to engineering education: the overarching sustainability challenge, the fact that science and technology permeate into ever more areas of our society and everyday lives, and the increasing complexity of techno-science due to the mixing of scientific and technological knowledge in new combinations. These challenges draw attention on the one hand to the need to address sustainability in engineering education, and on the other hand to the knowledge and skills required to handle what Hard and Jamison (2005) have characterised as the cultural appropriation of technology, implying that the engineer should relate to the context of use.

Problem-based learning (PBL) takes its point of departure in real life problems situated in a given cultural context, and offers a framework that Du *et al.* (2009), among others, have shown to be an effective framework for educating engineers and scientists in solving complex tasks. Furthermore, from an employability perspective, the problem-based learning process of identifying, analysing, clarifying and addressing problems corresponds to the challenges confronting engineers in their professional practice when they clarify design requirements and design, re-design, implement and maintain technological systems. This kind of system engineering approach provides a whole system perspective, which relates to understanding and learning for sustainability (Dowling & Hadgraft, 2012).

Following the experience-based roots of PBL, it would be best if students had the possibility of experiencing the context themselves and getting a sense of the cultural and structural setting. However, it is not at all easy to provide students with access to the relevant contextual settings. Public and private organisations can find it overwhelming to try to interact with a large number of different students with divers learning objectives and levels of competence. In cases of technology transfer to different cultural settings, it is, furthermore, difficult for students to travel and experience the problems that might occur.

One way to overcome this problem and bring real life problems more into the curriculum is to prepare case stories in which students are required to identify, analyse and attempt to solve potential problems and dilemmas that arise during the innovation process. This paper reports on the first phase of a project funded by the Grundfos foundation, where the design of such a case is the objective. The research question from this first phase is:

How do PBL principles shape the design and methodology for developing open source educational material that contributes to the education of engineers for sustainability and employability?

We will address this by clarifying our theoretical point of departure that is represented by contending modes of engineering education and a hybrid learning approach in which PBL principles are used to motivate the design criteria. From that point, we show how these principles have shaped the case selection and the overall design of an educational case that considers the implementation of energy and water supply systems at a school for physically disabled girls in a small village in Kenya.

2 Theoretical point of departure

The theoretical point of departure is an analysis of contending modes of engineering education (Jamison *et al.*, 2014); the purpose of the analysis is to combine academic, market and community driven knowledge modes (see table 1) into a hybrid learning mode.

The perception of engineering behind the hybrid learning mode combines the academic image of an engineer as an applied scientist, an expert or a consultant with the business image of an engineer as an entrepreneur and a manager of technological innovation processes and a community image of an engineer as a public servant, a change agent and, last but not least, a citizen. If the storyline is to hold students' attention and make a synthesis of these images of engineering, the case should embrace actors who either hold a legitimate position, such as a specialist, a product manager or a representative of a non-governmental organisation, or, maybe even more importantly, combine the different perspectives regardless of their given position.

Contending Modes of Engineering Education

	"Mode 1" Academic	"Mode 2" Market-driven	"Mode 3" Community-driven
Perception of engineering	(Applied) science	Technological innovation	Public service
Social role	Expert, consultant	Entrepreneur, manager	Change agent, citizen
Institutional perspective	The science university	The entrepreneurial university	The ecological university
Curriculum strategy	Emphasising "knowing" theoretical/scholarly book reading	Emphasising "acting" practical/instrumental company interaction	Emphasising "knowing, acting, being" contextual/transformative/situated learning

Table 1: Contending Modes of Engineering Education; adapted from Jamison *et al.* (2014).

Furthermore, the combination of the different knowledge modes should also be reflected in the way that the curriculum and the educational material is developed. The learning objectives should embrace and make room for what Barnett and Coate (2005) describe as the three aspects of the curriculum: knowing, acting and being, where "being" implies a more personal reflection on "how I as a person stand in relation to the world and the challenges posed". The educational material should therefore include:

- theoretical models or frames of reflection as well as links to relevant scientific articles (to know).
- open-ended problems, to be discovered by the students, calling for decision-making, action plans and implementation scenarios (to act).
- dilemmas calling for a normative stand in the problem identification and decision-making process (to let the "being" have an influence).

In sum, the three modes of knowledge when intertwined require a "sense of context" to allow a student to relate theory and practice, they require access to various perspectives on the actual case and they require educational material with which the students can interact in a self-directed way.

3 Design principles

To clarify the design principles based on the theoretical framework, we took as our point of departure the PBL principles that are common to all PBL models and that capture cognitive learning, content and the social dimension (Kolmos *et al.*, 2009).

Cognitive learning: Experiencing the problem in context

PBL is rooted in a constructivist and experiential view of learning in which learning, in the words of Kolb (1984), is created through the transformation of experience by reflective observation, abstract conceptualisation and active experimentation. Let us give an example related to the design of the educational material:

- Concrete experience: The students are able to access pictures, film and interviews that move beyond words to give them a sense of the context as well as the actors influencing the case.
- Reflective observation: The students internalise the concrete experiences and reflect on the problems/potential they have discovered; to facilitate this process students should be prompted to document the essence of what they have seen and heard.
- Abstract conceptualisation: The students relate the new experience to previous experiences and the generalisations to which these have led; to facilitate this, the students should be able to draw on texts, theoretical frameworks and scientific statements to supplement previous experiences of their own.
- Active experimentation: Based on the previous phases the students try out new solution strategies; to facilitate this the students are asked to do an assignment similar to the one carried out by the case actors e.g. formulating and analysing the problem, comparing it with previous experience, making acting plans for implementation etc.

The results of the actual experimentation lead to the next phase – it is a continuous process. When students are taking their own actions and reflecting, they have to reflect on their own choices and compare these with the choices made in the real life case. In this way they can challenge the decision made in real life, but at the same time they have to move forward from the decision taken by the project manager – a situation that might also happen in real life.

Content: Exemplary cases with theory/practice dialectics

Exemplarity implies competence to transfer in a positive way; in other words, previous experimental knowledge is transferred to encourage (and not to hinder) problem solving in new ways, in new situations, or in familiar situations with different content (Schunk, 2009). PBL cases or projects should therefore provide content and methods that make sense in other similar situations, together with the competence to transfer the knowledge to other contexts. In the design of a case, using a company context as the point of departure, exemplarity can be fostered on different levels:

- The organisational level: exemplary practices correspond to organisational, structural or cultural patterns and are followed by, for example, introducing models applied in product development or production teams.
- The inter-organisational level: exemplary practice corresponds to the way in which organisations interact with the environment e.g. in a product chain or a political or community perspective.
- The meta level: exemplary practice corresponds to different ways of developing competence to reflect on and, if necessary, change the organisational and inter-organisational patterns.

In selecting the case, examples at different levels should be considered, in order to make the case focused and to create awareness of the reach of the learning objectives compared to professional practice.

Furthermore, the context of exemplarity also stresses the need to combine theory and practice, which is also one of the basic principles in a problem-based learning environment (Kolmos *et al.*, 2009). To gain a sense of context and still to keep a theoretical frame of reference in the identification, analysis and solution requires an iterative process, where the students use theory to understand the context in question and get inspiration and guidance for potential change – but at the same time the theory that is chosen is informed by the context and the problems identified.

Theory represents a Mode 1 understanding of knowledge that can be found in more traditional learning environments, but here the educational material should create frames of understanding and, from a more pragmatic viewpoint, a "toolbox" for handling practical problems. Practice is situated in the market and the societal context of the other modes, and therefore the educational material should give the students the possibility of exploring in practice.

To experience the interaction between theory and practice, the educational design should be designed to include, but at the same time to distinguish between, generic knowledge platforms created in a Mode 1 perspective, and a contextual learning platform providing a Mode 2 and a Mode 3 perspective. In this way students get the chance to navigate across the different knowledge modes to combine theory and practice.

Collaborative learning – teams and participant directed learning

Jonassen (2010) presents a typology of problems, distinguishing between problems that are well structured or badly structured, simple or complex, static or dynamic. In situations in which the problems addressed are badly structured, complex and dynamic, such as problems to be addressed in the quest for sustainable development, it is likely that no one person would have the necessary breadth to address the problem. This call for collective learning adds to what Kolmos *et al.* (2009) characterise as the social approach to PBL. As noted by Katzenbach and Smith (1993, p. 9):

Teams outperform individuals acting alone or in larger organisational groupings, especially when performance requires multiple skills, judgements, and experiences… Real teams are deeply committed to theory purpose, goals and approach. High-performance team members are very committed to one another.

In a problem- and case-based learning environment, collaboration includes team learning, facilitator–student interaction, and interaction with case experts.

Team learning underpins learning as a social act in which students not only learn from each other but also learn to share knowledge and organise a collaborative learning process (Kolmos & de Graaff, 2014). Depending on the pedagogical model at the institution, the educational platform should encourage students to work on assignments in groups by, for example, providing facilitating questions for discussion and incentives for project management and team collaboration (such as asking the students to write a project application for funding or to reflect on the synergy of working in a group in relation to the problem at hand).

Together with teamwork, participant or self-directed learning is the other key principle in the social approach to PBL (Kolmos *et al.*, 2009); this calls for an interactive learning environment in which students can make their own choices based on their previous experience, personal interests and learning style and pace. Furthermore, the principle of self-directed learning has far-reaching implications for the staff–student interface. The teacher role is transformed into a facilitator role and, as noted by Schunk (2009, p. 469):

Facilitators arrange resources so that learning occur and, because they are resources, share their feelings and thoughts with students.

This implies that the facilitation is of a kind that is related to students' needs – it becomes "situated", as discussed by Kolmos *et al.* (2008). An online learning platform that can be used anywhere in the world cannot substitute for this kind of situated facilitation, but rather should support it by providing guidelines for facilitators that can be adapted to different educational contexts.

Whereas the facilitator has the important role of being close to the students, the case experts have the advantage of real life experience related to the case, and are therefore capable of providing the students with a sense of context and, maybe more importantly, with different perspectives on the context. For this reason the educational materials should provide the students with the opportunity to move from being what Dreyfus and Dreyfus (1980) characterise as novices, having access to non-situational instructions without the benefit of experience, to being competent, as they actually experience the situation of coping with a real life situation. Furthermore, as real life problems are often so complex that they call for interdisciplinary sources of knowledge, experts from different academic domains can be included, to provide students from different domains with a platform of knowledge from which to act.

4 Case selection

Many different case areas can be of relevance for students in engineering education. In figure 1, we have outlined five case areas, ranging from the organisational context to the product chain perspective, and at the same time we have emphasised the meta-level by an intertwined knowledge network. Each of the case areas covers both problem-based learning and sustainability aspects. These cases complement each other, as the organisational in-house cases focus on how the contextual considerations are embedded in the innovation and the production processes, whereas the implementation case focuses on the issues that are raised during the implementation process and, later on, in the maintenance of the technological system. From a life cycle perspective, the choice of a product could also be linked to the five case areas, and shows how learning and sustainability are inter-connected and create a need for trade-offs when all phases of a product's life cycle are considered.

We have chosen to start with case area four. First, the case should increase students' awareness of the importance of the context of use – in the innovation phase as well as in the implementation phase. Second, cultural diversity provides students with an understanding of the social construction of technology and the different perspectives that might have an influence on the decision-making processes.

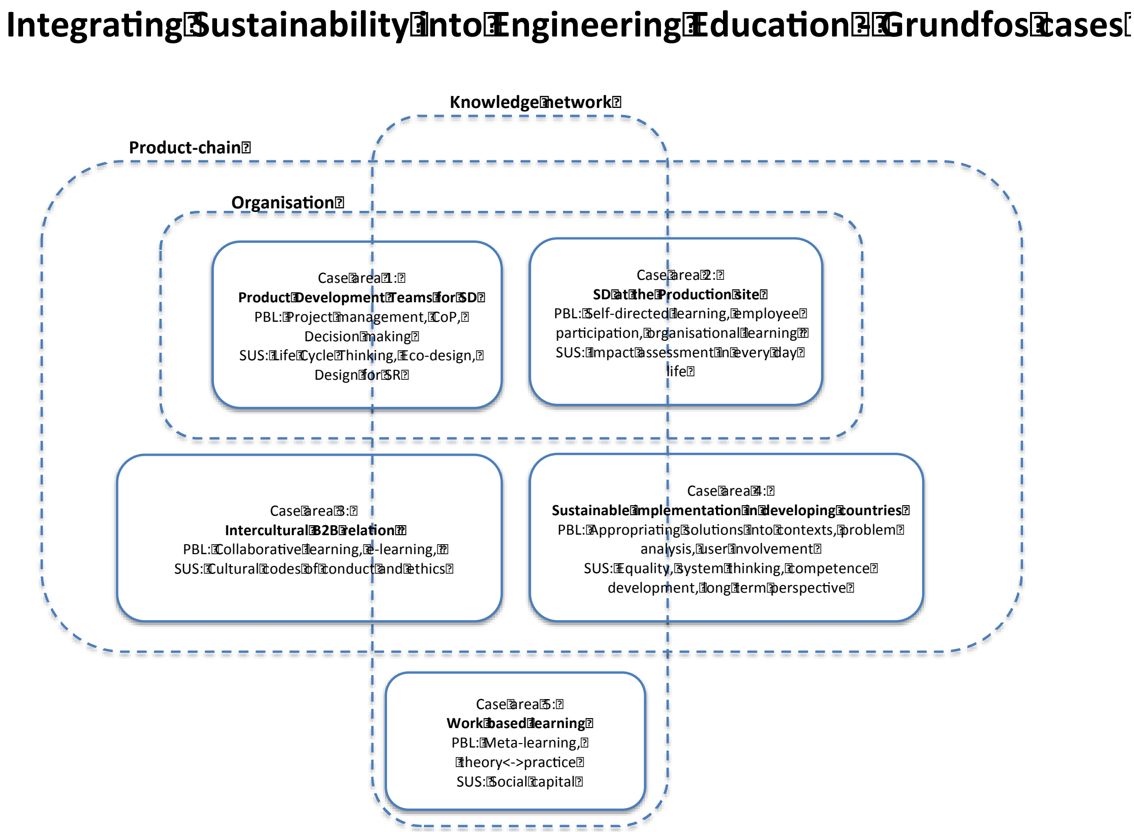

Figure 1: Examples of different types of cases depending on the contextual boundaries and focus areas related to PBL and sustainability respectively.

Furthermore, the cases should take their point of departure as a product type, should include a global perspective and should have a clear link to sustainability beyond the application of specialised tools such as Life Cycle Assessment. Engineers from engineering disciplines other than sustainability science should not become sustainability specialists; however, they should be systematic thinkers, capable of handling real life problems and being aware that sustainability is an important aspect to be considered in every innovation and implementation process.

Last but not least, it was important to find a case story for which the actors involved were interested in telling the story and saw its educational potential. We found this in the Shanzu project, which had been funded by the Grundfos foundation and had resulted in the implementation of energy and water supply systems at a school for physically disabled girls in a small village in Kenya. After having a meeting with the project manager and the technician from Grundfos, it became very clear that the project team's attitude to the project included professional interest, contextual curiosity and extraordinary personal engagement. Furthermore, the case included the different social roles of engineering, and different types of actors were represented (industry, public organisations, non-governmental organisations and privately funded educational organisations); the case is exemplary as it relates to typical phases in an engineering project; and it includes poorly structured problems that were complex (in terms of cultural diversity and context of use) and dynamic (due to infra-structural and unforeseen circumstances). In other words, the case was considered to be an optimal one for which to use a hybrid learning mode based on PBL.

5 Creating the case – the first phase

The case concept is not new in engineering education. There is a tradition for writing cases in the Harvard case-based model (with business studies), as shown by Andersen and Schiano (2014), and PBL universities like McMaster and Maastricht have also integrated cases into their educational practice. In a business context, case stories are also a well-known way to exemplify and visualise the activities of companies in a way that the target group can relate to. One example from Grundfos are the cases developed around the life-link project (Grundfos, 2015).

Case material like this provides insight into and information about a series of actions (typically telling the story in text accompanied by pictures), but for engineers to understand the process, the trade-offs during the process, the negotiations, and the different social constructions of technology carried by the different project participants, the material has to be more interactive. Students should be intertwined in a problem-based learning process – handling dilemmas, entering into negotiations and experiencing the fact that different problems emerge during chains of actions. This calls for students to interact with the context.

We are therefore thinking of cases as interactive learning objects. We will use interactive media such as:

- Sound-files with storylines accompanying pictures.
- Interviews with key persons.
- Video material providing a sense of “being there”.
- Documents elaborating on case details.
- Possibilities for uploading reflections on the case or documentation of casework.

From these interactive media the students can gain insights from case experts. The intertwining therefore relates to the intertwining of what we have called a student and a case expert thread, as illustrated in figure 2. The expert thread includes our first draft of possible learning objects in relation to the different phases of the project: problem identification, analysis and formulation, system design, implementation and potential follow-up projects. The student thread is related to a list of assignments prompting the “knowing”, “acting”, and “being” related to the phases mentioned above.

What will be essential for the cases in this project will be to point out the dilemmas, the negotiations, the uncertainties and the decision-making processes that characterise all engineering work, and to move the engineering challenges in the case to the students’ life world. What we typically experience in problem-based learning projects at Aalborg University is that when projects are carried out in partnership with external actors, students gain an understanding of engineering practice and become much more motivated for learning the technical content, as this also allows them to solve the problems they experienced. This is prompted by exercises.

In this way the learning in the case is fostered by the novices/students interacting with the experts/professional engineers. We will define a series of reflection points, at which the students will interact by giving a “before” reflection and an “after” reflection. The “before” reflection will be the students’ reflections on the problems and dilemmas in the case, and the “after” reflection will be the students' reflections on the professional engineers' solutions to the problems. It should be made possible for students to upload reflections to a blog or Facebook site, for example, to share their case experiences.

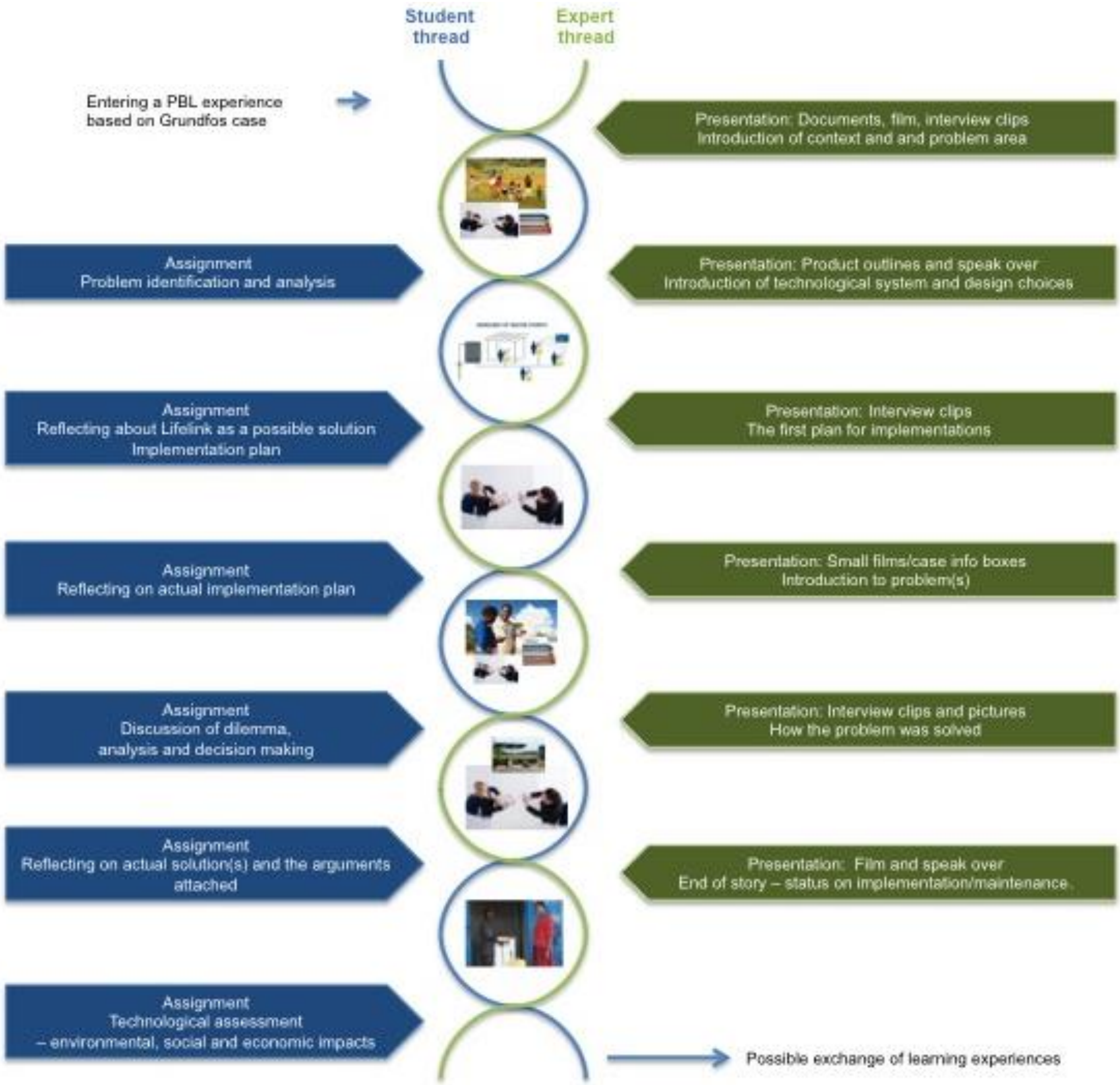

Figure 2: The learning process

Based on this overall conceptual model, we had several meetings with the project manager in charge of the Shanzu project; the purpose of the meetings was to:

- Create an overview of the case by collecting data consisting of documents, roadmaps, organisation diagrams, overview of involved partners, etc.
- Identify the different phases in the story related to the exemplary phases of problem-based learning: identifying, analysing, formulating, designing, implementing and assessing a technology – as an iterative process.

- Identify key persons who had been engaged in the project and influenced the implementation process in the specific cultural setting.

In the next phase the data collection will start in parallel with the design of the next phases and the development of specific learning objectives for each phase, short online overview-lectures, as well as recommended literature and links. The resources include documents, interviews, observations and AV-productions, in Denmark and in Kenya.

Figure 3 show a sketch of phase 1: Problem identification and analysis. As the figure shows, there are different elements to explore in the contextual knowledge platform brought about by the interaction with the case expert. Four different purposes have been distinguished: discovering the case, getting a sense of the case, sketching the case and reflecting on the case experts' responses to the challenges outlined after doing the assignments, after which the facilitator can "unlock" the solutions from the expert. This response from the case experts will be the starting point for the new phase and, one hopes, provide a frame of reference for lively discussions in class.

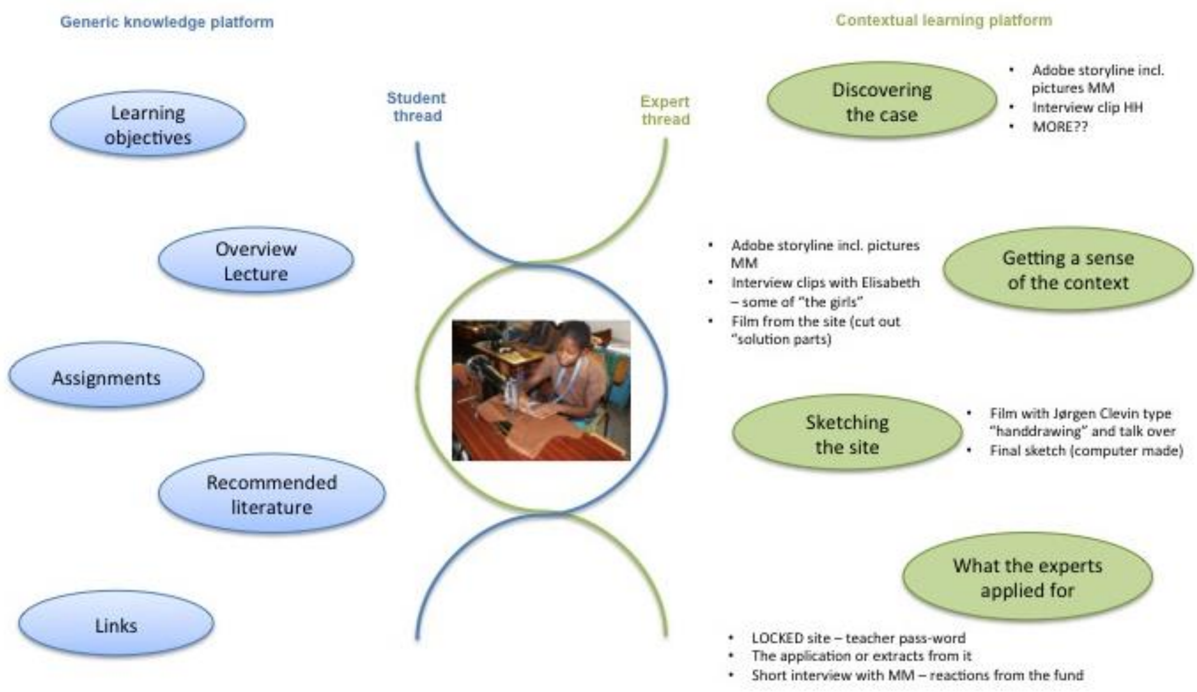

Figure 3: Sketch of the first phase: Problem identification and analysis

To secure the external validity of the educational platform, the material will be distributed to the sources to make sure that all partners approve their role and agree that the story aligns with their experiences. To further improve the prototype, the educational platform will be tested in an intercultural environment at Aalborg University. The educational platform will be released as open source material, but there will be a signing up procedure for staff using the cases; the Aalborg Centre will organise webinars for participants/developers/teachers. In this way, we hope that the educational platform can be used across the world, and that we will get representative feedback from the global community of engineering educators to develop the platform further.

6 Conclusion

It is not at all easy to provide students with access to relevant contextual settings and at the same time to ensure that the time to be invested by university partners and students is reasonable. In this paper we have tried to deal with this problem by preparing case stories for which students will identify, analyse and attempt to solve potential problems and future dilemmas during the innovation process, asking:

How do PBL principles shape the design and methodology for developing open source educational material that contributes to the education of engineers for sustainability and employability?

By taking as our theoretical point of departure a synthesis of contending modes of engineering education and PBL principles, we have suggested a set of design criteria, stating that the learning platform has to provide:

- a case story that is exemplary in terms of both sustainable development and professional practice
- a case story that is focused on a specific and delimited site that provides the students with a chance to get an overview without visiting
- knowledge that can be drawn on about related studies as well as scientific methods (a generic knowledge platform)
- possibilities for acting on the case, meaning that there should be a rich problem field and potential dilemmas to be resolved
- possibilities of engaging in the case, meaning that the students should get a sense of the context and the different actors/meanings involved, through interviews, films and context-specific documents (a contextual learning platform)
- a platform for collaboration through discussing, negotiating, deciding and collaborating in a self-directed and interactive way around badly structured, complex and dynamic problems
- assignments corresponding to those carried out by the case experts in real life
- staff guidelines for facilitation that can be adapted to different educational contexts.

The first case used for a pilot study is the so-called Shanzu project, which was funded by the Grundfos foundation, and resulted in the implementation of energy and water supply systems at a school for physically disabled girls in a small village in Kenya. This project was chosen because the attitude of the project team to the project included professional interest, contextual curiosity and extraordinary personal engagement, and the same was true when it came to sharing the insights they had gained throughout the project. The case was screened at meetings and it was concluded that it fulfilled the above criteria. The first phase underlines the importance of intertwining the students' process with the experience of the case experts and input from researchers (e.g. overview lectures). What will be essential for the cases in this project is to point out the dilemmas, the negotiations, the uncertainties and the decision-making processes that characterise all engineering work, to move the engineering challenges in the case to the students' life world.

This is what has made the engineers out there so engaged in the project, and this is what we hope will make engineering students from all over the world engaged in the many aspects of engineering in the twenty-first century.

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Quality of problems in problem-based learning and their role in the relation between achievement goal orientation and motivation

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Abstract

Assessing students' (N = 262) achievement goal orientation, study motivation and the ratings of the quality of two problems in a problem-based learning environment, this study examined the role of problem quality in the motivational process. We looked at the effects of problem characteristics (learning issues, familiarity, interest, collaborative learning, and critical reasoning) on students' self-determined motivation. The quality of the problems had an effect on autonomous (i.e., identified and intrinsic) motivation and not on controlled motivation. Furthermore, we investigated the relationship of prior differences in students' achievement goal orientation on students' intrinsic motivation and the mediating effect of problem quality. Structural equation modelling analysis supported a model in which a mastery-approach, performance-approach, and mastery-avoidance goal orientation had both a direct effect on intrinsic motivation and an indirect effect through the quality problems. A performance-avoidance goal orientation was only found to have a negative effect on intrinsic motivation. The importance of the quality of the problems was different for the two approach goal orientations, indicating that students high on mastery-approach goal orientation enjoyed interesting problems, whereas students high on performance-approach goal orientation enjoyed problems which resulted in learning issues. Interestingness of the problem and the way in which the problem resulted in learning issues were positively related to intrinsic motivation, whereas familiarity, critical reasoning, and collaborative learning demonstrated negative effects. In conclusion, students who endorse approach goals favour problems that are interesting and result in learning issues in order to enhance intrinsic motivation, whereas for students who endorse avoidance goals the influence of problems on their motivation is more complex.

Keywords: Problem-based learning; Quality of problems; Achievement goal orientation theory; Motivation; Self-determination.

1 Introduction

Student-centered learning environments, such as problem-based learning (PBL), are becoming more and more popular in education (e.g., Loyens & Rikers, 2011). PBL is a form of constructivist learning in which students are engaged in knowledge construction based on the problems presented.

Problems are descriptions of real-life, meaningful phenomena or situations in need of explanations. After students have read the problem, a PBL cycle generally consists of three phases: (1) an initial discussion phase in which potential explanations or hypotheses are generated based on prior knowledge and common sense, (2) a self-study phase, and (3) a report phase.

An important goal of PBL is to enhance students' intrinsic motivation (Norman & Schmidt, 1992). As problems form the starting point of the learning process, they are discussed with limited prior knowledge. Therefore, students cannot explain the problem completely and will experience a knowledge gap. The incongruence between prior knowledge and the knowledge that is needed to explain the problem will increase students' intrinsic motivation for self-study (Rotgans & Schmidt, 2014). Nevertheless, implementing a PBL environment is no guarantee for success: Motivational problems in PBL environments are sometimes reported and often, in discussions on the effectiveness of learning environments of PBL, individual differences in students are not sufficiently taken into account (Dolmans & Gijbels, 2013), although, prior differences in students' motivation might affect their subsequent motivation. Likewise, it is important to examine the characteristic of the problem as well. An important framework for understanding motivation in educational contexts stems from the achievement goal orientation theory (Dweck & Leggett, 1998). Someone's achievement goal orientation (i.e., mastery-approach, performance-approach, performance-avoidance, and mastery avoidance goal orientation) determines for what reason an individual engages in a certain activity and by that it determines the quality of motivation. In the current study, therefore, we investigates the relationship of prior differences in students' achievement goal orientation on students' self-determined study motivation in a PBL setting, taking into account the possible mediating effect of the quality of the problem.

In PBL, the learning process starts with challenging and meaningful problem descriptions (Barrows, 1996). Problems are supposed to trigger the learning process and therefore, high demands are placed upon the quality of the problem. Quality of problems has been shown to be related to group functioning and achievement (e.g., Hurk, Dolmans, Wolfhagen, & Van der Vleuten, 2001). Moreover, previous research demonstrated that problems play a significant greater role in students learning process compared to tutor functioning and students' prior knowledge (e.g., Van Berkel & Schmidt, 2000). However, hardly anything is known how motivation is triggered by means of the quality of problems. PBL theory and views of PBL experts and students (e.g., Schmidt & Moust, 2000; Sockalingam & Schmidt, 2011) have indicated that high quality problems engage students in discussion, are familiar, assure self-directed learning, are of interest, and adapt to prior knowledge. A factor analysis by Sockalingam, Rotgans, and Schmidt (2012) combining the different characteristics found in previous studies, revealed that the quality of a problem is determined by the extent to which a problem 1) generates the intended learning issues, 2) is familiar to students, 3) triggers interest, 4) promotes collaborative learning, and 5) stimulates critical reasoning.

The first phase of the PBL-cycle, the initial problem discussion, results in the formulation of learning issues (i.e., questions for further self-study). The formulation of learning issues might be associated with autonomous motivation, because it allows for students to determine to a certain extent what they study during the self-study phase. In line with this view, the quality of learning issues predicts the quality of self-study and the depth of reporting (Van den Hurk et al., 2001).

Familiarity will likely make the subject matter more relevant and meaningful for students and therefore increase students' motivation (Assor, Kaplan, & Roth, 2002). In an experiment by Soppe, Schmidt, and Bruysten (2005), rating of problem quality was higher for a familiar version compared to an unfamiliar version of a problem. Hmelo-Silver (2004) mentions the importance of the resonation with students' experiences and argues that this might result in intrinsic motivation.

In PBL, activation of prior knowledge, elaboration during the discussion, and exploring alternatives are suggested to trigger student's interest and self-directed learning (Gijselaers & Schmidt, 1990). The relation between interest and intrinsic motivation is well established (Deci & Ryan, 2000) and in PBL, higher ratings of topic interest have been associated with autonomous motivation and engagement in class (Wijnia, Loyens, Derous, & Schmidt, 2014).

In the initial discussion phase, students tackle problems in small collaborative groups. Problems are aimed at triggering a brainstorm and a group discussion (Schmidt & Moust, 2000). Collaborative learning could help students to feel more connected to their peers, and as a result positively influence autonomous motivation (Deci & Ryan, 2000). Students have indicated that collaborative learning was one of the motivating elements of a PBL environment (Wijnia, Loyens, & Derous, 2011).

Barrows and Tamblyn (1980) held that the objective of PBL is to transfer and develop critical reasoning skills and therefore, students need to identify the problem and find different perspectives or paradigms to interpret the problem. Research indeed demonstrate that the improvement in cognitive thinking is higher in PBL environments compared to lecture-based learning environments (Tiwari, Lai, So, & Yuen, 2006). A critical thinker is willing to spend time and effort on reflecting on own and others' ideas and by that enhancing intrinsic motivation (Garcia & Pintrich, 1992).

2 Current study

In PBL, the quality of problems plays a significant role in students' learning process (Gijselaers & Schmidt, 1990) and by that in their motivation to study. Although intrinsic motivation is the most optimal type of motivation, not all extrinsic reasons for studying are harmful. Deci and Ryan (1985, 2000) proposed the self-determination theory (SDT) in which motivation is viewed as a multi-dimensional construct. From lower to higher self-determination, there are: *external, introjected-avoid, introjected-approach, identified,* and *intrinsic motivation* (Assor, Van Steenkiste, & Kaplan, 2009). External and introjected motivation are considered to be controlled forms of motivation. External motivation by means of an external source (e.g., rewards, external expectations). Introjected by means of inner pressure to avoid low self-worth and feelings of shame (i.e., introjected-avoid) or attain high self-worth by excerpting certain behaviour to feel proud (i.e., introjected-approach). Identified and intrinsic motivation are both autonomous forms of motivation in which activities are performed freely. Intrinsic motivation refers to activities that are carried out for their own sake, whereas identified motivation represents a means to an end (Deci & Ryan, 2000). Research have indicated that students' autonomous motivation is more likely to lead to higher grades and less procrastination (e.g., Soenens & Vansteenkiste, 2005) compared to students' controlled motivation. Studying based on an interesting and familiar problem that promotes critical reasoning and collaborative learning, and result in learning issues makes study activities more challenging, enjoyable or beneficial for personal goals. These study activities will likely be performed freely. Therefore, according to the SDT (Deci & Ryan, 2000) problems that meet these criteria are more likely to result in autonomous motivation for studying, either identified or intrinsic motivation. We does not expect an effect of quality of problems on the less self-determined forms of motivation (i.e., external; introjected-avoidance, and introjected-approach motivation). These types of controlled motivation pertains to feeling pressured to perform a certain activity, such as studying. Problems either of high or low quality are not aimed to pressure students.

Hypothesis 1: The quality of problems is related to motivation such that problems that generate learning issues, are familiar, trigger interest, promote collaborative learning, and stimulate critical reasoning will result in identified and intrinsic motivation.

Someone's achievement goal orientation (GO) determines for what reason an individual engages in a certain activity and by that it determines the quality of motivation (Dweck & Leggett, 1988). GO refers to one's dispositional goal preferences in achievement situation. Four classes of GOs are usually distinguished (Elliot & McGregor, 2001). Individuals high on *mastery-approach* (MAP) GO tend to focus on mastering a task and self-improvement. Individuals high on *performance-approach* (PAP) GO tend to focus on looking competent, whereas individuals high on *performance-avoidance* (PAV) GO tend to focus on preventing looking incompetent compared to others. Individuals high on *mastery-avoidance* (MAV) GO tend to focus on preventing incompetency for themselves Variations in ones' GO have been linked to different types of motivation (e.g., Ntoumanis, 2001). Results of these studies have clearly demonstrated that a MAP GO results in autonomous motivation, whereas a PAP GO results in controlled motivation. PAV and MAV GO are detrimental for intrinsic motivation (e.g., Elliot & McGregor, 2001). Individuals high on PAV are concerned with the pressure of others and low on self-determination. Individuals high on MAV are not concerned with others but rather by inner pressure to avoid feelings of shame or to behave in such a way that they can be proud of themselves. They might even have some form of autonomous motivation, although, the behaviour is not enjoyable in itself (i.e., identified motivation)

Peoples' GO might result in finding value in certain tasks and activities (Pintrich, 2003) and it is well known that certain task characteristics are important in predicting motivation (e.g., Eccles, 2005). Therefore, it could be assumed that the relationship between GO and motivation might be (partially) explained by the effect of goals on the perception of a task. We therefore, propose that the quality of problems will likely mediate the effects of GO on autonomous motivation (identified and intrinsic). Students with a MAP goal, compared to students with a MAV, PAP, or PAV goal, are more likely to experience tasks as interesting and more relevant for their life (Harackiewicz, Barron, Tauer, Carter, & Elliot, 2000). Furthermore, people high on MAP GO focus on increasing competencies and learning, and deep processing of information (Dweck & Leggett, 1988). Critical reasoning but also collaborative learning could be helpful to think more in-depth and learn more about a topic by discussing and elaborating on certain ideas. Therefore, it might be assumed that for individuals high on MAP GO problems that trigger interest, promote collaborative learning and stimulate critical reasoning result in intrinsic motivation and to a lesser extent identified motivation. For students high on PAP, high grades are important to outperform others and for them problems in itself are not the means to this end. In general PAP is not related to either identified or intrinsic motivation (e.g., Ntoumanis, 2001). However, it could be argued that clear learning issues provide students high on PAP with guidelines how to obtain high grades and familiarity indicates that the problem is not to difficult. Therefore, we propose that for students high on PAP familiar problems resulting in the intended learning issues will have an effect on their identified motivation and maybe even on their intrinsic motivation because they might enjoy the activity as it will help them with their aim of getting a high grade. For individuals high on PAV GO the quality of problems will not influence autonomous motivation because they are usually low on self-determination (Elliot & McGregor, 2001). People high on MAV are focused on preventing incompetency (Elliot & McGregor, 2001). This prevention is based on inner pressure but at the same time there is some autonomous regulation of their actions (i.e., identified motivation) to prevent incompetency. For people high on MAV, identified motivation might be fostered by the quality of problems. However, it is hard to make predictions about the different characteristics that might mediate the relation between MAV and identified motivation.

Hypothesis 2: The quality of problems will mediate the effects of achievement goal orientation on a) identified and b) intrinsic motivation, such that interestingness, collaborative learning, and critical reasoning will partly mediate the relation between MAP GO and intrinsic and identified motivation and familiarity and the generation of learning issues will partly mediate the relation between PAP GO and intrinsic and identified motivation.

3 Method

The sample consisted of all first-year psychology students from one academic year of a large University (*N* = 262 students). Mean age was 19 years and 78% of the students were women. PBL is the dominant educational method at the psychology department of the University. Students meet two times a week in groups of 10-12 guided by a tutor. In the first meeting, students read the problem, analyse, discuss the problem and formulate learning issues (i.e., initial discussion). In between meetings, students study the topic related to the problem (i.e., self-study). During the second meeting, students report and discuss their findings.

3.1 Problems

The problems were part of a regular course (i.e., 'differences between people') in the first semester. The first one was titled: "*The link between genes and personality"* and the second one*"(In)stability of behaviour"*. The next story is part of the problem "(In)stability of behaviour":

"In a study of the stability of impulsiveness as a characteristic, Seymour Epstein (1979) had students observe other students for a period of 14 days. The first group spent a lot of time in the near the observed students. (This concerned women that shared the same dorms and went to the same classes at Smith College.) The observers had to register the behaviour of the students they researched on a number of relevant characteristics. This assessment took place on the basis of the frequency that the behaviour was being observed. For example: "She actively looked for the company of others: (a) never, (b) once or twice, or (c) three or more times."

If the frequency or impulsive behaviour correlated on two consecutive days, it got coefficients of 0.30. If the behavioural frequency was spread over the seven uneven days and did that correlate with the average observed frequency of the seven even days, he would find correlations of about 0.90."

3.2 Measures

At the start of the academic year, we measured students' GO. All students rated two problems during two standard PBL meetings, one problem after reading the problem and the other problem after the initial discussion. Finally, after rating the problem, students' motivation for studying was measured. All items were assessed on a 5-point Likert scale

3.2.1 Problem quality rating scale

The quality of the problems were assessed by means of the problem quality rating-scale (PQRS; Sockalingam et al., 2012). The PQRS consists of 32 items (see Appendix A for the items). We conducted a confirmatory factor analysis to investigate the measurement model for quality of problems. Based on the study by Sockalingam et al. (2012), for the latent constructs (learning issues, familiarity, interest, collaborative learning, and critical reasoning) we created 14 parcels that served as indicators of the latent variables (see Appendix A). Results indicated that the five factor model fit the data well, $\chi^2(67) = 115.3$, $p < .01$; RMSEA = .05; SRMR =.05; CFI = .96. However, one parcel did not contribute significantly to its' underlying construct. Therefore, we removed the parcel '*the problem encourages multiple perspectives'* that was used as one of the indicators of 'critical reasoning'. The improved model $\chi^2(56) = 73{,}93$, $p = .05$; RMSEA = .04; CFI = .99. All factor loadings were statistically significant, >.50.

3.2.2 Self-determined Study Motivation

Students' study motivation (i.e., intrinsic, identified, introjected-approach, introjected-avoidance, and external motivation) were assessed by means of by the Academic Self-regulation Questionnaire (SRQ-A; Assor et al., 2009; VanSteenkiste, Sierens, Soenens, Luyckx, & Lens, 2009), asking students why they study. Item examples: '*because others oblige me to do so'* (external); '*because I would feel ashamed if I did not study'* (introjected-avoidance); '*because I want to prove that I'm able to study'* (introjected-approach); *'because this is an important life goal to me'* (identified)*;* and '*because it is fun'* (intrinsic). We conducted a confirmatory factor analysis to investigate the measurement model for study motivations in which the items served as indicators of the latent variables (intrinsic, identified, introjected-approach, introjected-avoidance, and external motivation). Results indicated that the five-factor model fit the data well, $\chi^2(109) = 220.9$, $p < .01$; RMSEA = .06; CFI = .94. All factor loadings were statistically significant, > .50.

3.2.3 Achievement Goal Orientation

Students' GO was assessed by means of VandeWalle's (1997) and Baranik, Barron, and Finney (2007). GO questionnaires. Item examples: *'I often look for opportunities to develop new skills and knowledge'* (MAP); *I enjoy it when others are aware of how well I'm doing'* (PAP); *I prefer to avoid situations where I might perform poorly'* (PAV); *I try to avoid being incompetent in performing tasks and skills'* (MAV). We conducted a confirmatory factor analysis to investigate the measurement model for GO in which the items served as indicators of the latent variables (MAP, PAP, PAV, and MAV GO). Results indicated that the four-factor model fit the data well, $\chi^2(113) = 190.0$, $p < .01$; RMSEA = .05; CFI = .93. All factor loadings were statistically significant, >.50.

4 Results

Descriptive statistics and intercorrelations of variables used are given in Table 1. Partly supporting Hypothesis 1, familiarity, $r = .16$, $p < .05$, interest, $r = .20$, $p < .01$, and critical reasoning, $r = .15$, $p < .05$, were positively related to identified motivation. Only interest was related to intrinsic motivation, $r = .26$, $p < .01$. No significant relationships were found between problem characteristics and introjected-approach, introjected-avoidance, and external motivation (i.e., controlled motivation). So, interesting problems result in intrinsic and identified motivation (i.e., autonomous motivation). Problems which are familiar to students and result in critical reasoning have also an effect on autonomous motivation but only for the identified and not for the intrinsic component.

We tested our hypothesized models for identified and intrinsic motivation with structural equation modelling. The model for the direct and indirect effects of GO on identified motivation through the mediating role of problem characteristics, provided a good fit to the data, $\chi^2(96) = 133.9$, $p = .01$;

RMSEA = .04; SRMR = .04, CFI = .98, with significant path coefficients between GO and identified motivation and between GO and several problem characteristics. However, none of the path coefficients between the problem characteristics and identified motivation was significant. Thus, it appears that the effects of GO on identified motivation are not mediated by the quality of problems (Hypothesis 2a not supported).

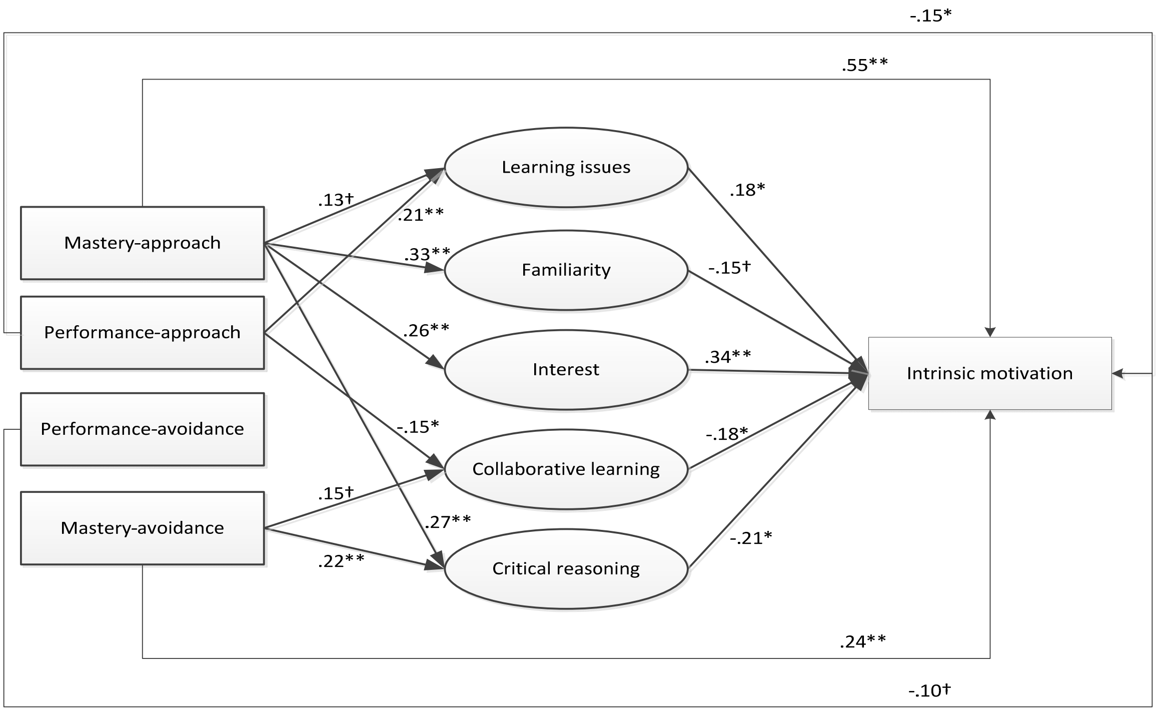

Figure 1. Partial mediation model for intrinsic motivation. Only significant path coefficients are depicted. Rectangles indicate observed variables and ovals latent variables (for the parcels constructing the latent variable standardized path coefficients were above .50, $p < .01$). $^{\dagger}p < .10$. $^{*}p < .05$. $^{**}p < .01$

Our hypothesized model for the direct and indirect effects of GO on intrinsic motivation, provided a good fit to the data, $\chi^2(96) = 130.5$, p = .01; RMSEA = .06; SRMR = .04, CFI = .98 , with significant path coefficients between GO and intrinsic motivation, between GO and the problem characteristics, and between the problem characteristics and intrinsic motivation (see Figure 1 for the path coefficients). Thus, it appears that the effect of GO on intrinsic motivation is partly mediated by the quality of problems (Hypothesis 2b supported).

5 Discussion

An important goal of PBL is to enhance students' intrinsic motivation. In the present study we investigated the influences of problem characteristics on the quality of motivation in a PBL context and we argued that students' achievement goal orientation would play an important role in this motivational process.

Regarding the quality of problems, a clear relationship was found between interesting problems and intrinsic motivation. Interesting problems result in study activities for its' own sake; the topic of the problem is exciting and enjoyable and students experience a knowledge gap they really want to 'fill up'. This relation between interest and intrinsic motivation is well established (Deci & Ryan, 2000).

However, a remarkable finding in our study was that this link only holds for students who scored high on MAP GO and not for other students. Their intrinsic motivation was elicited when problems resulted in the intended learning issues (PAP GO). Although it has been argued and proved that a PAP GO does not likely result in intrinsic motivation (Dweck & Leggett, 1988), certain task characteristics might foster intrinsic motivation for students with PAP goals but only when the result of the task is clear and the task is helpful in achieving their goal. People high on PAP GO want to show how good they are (Elliot & McGregor, 2001) and it seems that learning issues derived from high quality problems are helpful in achieving this goal. For students who want to avoid looking incompetent compared to others (PAV GO) or want to avoid incompetency (MAV GO) the quality of problems did not influence their intrinsic motivation.

Besides interest and resulting in learning issues, critical reasoning, familiarity and collaborative learning are also considered to be characteristics of high quality problems (e.g., Socklingham et al., 2012; Soppe et al., 2005). However, in our study familiarity, critical reasoning and collaborative learning had a negative effect on intrinsic motivation. An explanation for this finding might be that familiarity, critical reasoning, and collaborative learning does not have a direct effect on intrinsic motivation but that they enhance interest and influence intrinsic motivation through the interestingness of the problem. In line with this explanation, Gijselaers and Schmidt (1990) argued that elaboration during the discussion (part of collaborative learning) triggers students interest and Soppe et al. (2005) demonstrated that a familiar version of a problem was rated as more interesting. Therefore, future research should shed light on the relation between the different characteristics of high quality problems in enhancing intrinsic motivation and how they influence each other. Furthermore, it might be that the characteristics of problems will have a different role in the enhancement of intrinsic motivation depending on the phase of PBL. For example, several studies indicate that the level of interest may be higher after group discussion compared to after reading the problem (e.g., Gijselaers & Schmidt, 1990) or after the report phase (Schmidt, 1993)

In conclusion, intrinsic motivation in PBL could be enhanced through the interestingness of the problem and the extent to which a problem results in learning issues. These two characteristics of high quality problems are beneficial for students' intrinsic motivation, although this is especially true for students with approach goals. Students who want to improve their competencies enjoy problems that are interesting and stimulate critical reasoning, whereas students who want to show their competencies enjoy problems that result in learning issues. Unfortunately, for students who want to avoid showing bad competencies or want to avoid showing incompetency the quality of problems is hardly a factor influencing intrinsic motivation. Therefore, problem developers in PBL must taken into account that problems fulfil the requirements of interestingness and that they result in the intended learning issues. However, at the same time they should realise that this does not benefit all students.

Table 1: *Descriptives and intercorrelations of the variables*

Variables	α	*M(SD)*	1	2	3	4	5	6	7	8	9	10	11	12	13
Achievement goal orientation															
1 Mastery approach	.79	3.52 (0.53)													
2 Performance approach	.81	3.11 (0.70)	.15*												
3 Performance avoidance	.83	2.89 (0.79)	-.04	.21**											
4 Mastery avoidance	.63	3.34 (0.62)	.13	.26**	.52**										
Quality of problems															
5 Learning issues	.83	3.30 (0.51)	.18*	.07	.10	.01									
6 Familiarity	.72	2.96 (0.53)	.29**	.09	.06	-.01	.48**								
7 Interesting	.88	3.41 (0.61)	.25**	.10	.01	.09	.44**	.43**							
8 Collaborative learning	.72	3.22 (0.63)	.08	-.05	.10	.07	.48**	.32**	.29*						
9 Critical reasoning	.57	3.45 (0.51)	.29**	.11	.05	.14	.39**	.42**	.64**	.38**					
Motivation															
10 External	.88	2.31 (0.96)	-.15	.24**	.13	.09	-.03	.01	.04	.10	.04				
11 Introjected avoidance	.79	2.61 (0.89)	.00	.31**	.16*	.16*	.00	.08	.03	.06	.07	.63**			
12 Introjected approach	.69	3.45 (0.84)	.18*	.31**	.13	.21**	-.01	.01	.08	.05	.09	.29**	.44**		
13 Identified	.74	4.18 (0.47)	.44**	.15*	-.04	.17*	.07	.16*	.20**	.12	.15*	-.09	.07	.33**	
14 Intrinsic	.84	3.93 (0.64)	.51**	.04	-.03	.19*	.10	.06	.26**	-.06	.12	-.28**	-.16*	.05	.50**

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Appendix A. Items of the PQRS

	Parcels		Items
Problem characteristic 1: Learning issues			
1	Clarity of the problem	1	I was/is clear about what the problem required my PBL group and me to do
		2	The problem was/is clearly stated
2	Clue or keywords in the problem	3	The problem provided/provides sufficient clues/hints
		4	The problem contained/contains sufficient keywords
3	Structured approach to the problem	5	I was able to identify the key learning issues from the problem*
		6	I was able to come up with a satisfactory list of topics to explore on based on the problem*
		7	I had a logical approach to the problem*
Problem characteristic 2: Familiarity			
4	Familiarity with content	1	I was familiar with the content of the problem even before I started to work on it
		2	I have personally experienced one or more situations described in the problem
		3	I could relate to the content of the problem based on my experiences
5	Relates to general knowledge	4	The problem fits well with my prior knowledge
		5	The subject matter of the problem reflects real life issues
6	Relates to subject-domain knowledge	6	I have done a similar topic as in the problem before
		7	I have sufficient basic knowledge to understand the topic of the problem
Problem characteristic 3: Interest			
7	Triggers personal interest	1	The problem was not interesting
		2	I'm curious to find the answer for this problem
8	Engages in self-directed learning	3	The problem stimulates me to find out more information on the topic
		4	The problem stimulates me to work hard
9	Captivates attention	5	The problem is engaging
		6	The problem captivates my attention
Problem characteristic 4: Collaborative learning			
10	Triggers brainstorm	1	The problem triggered a sufficient level of brainstorm*
		2	We brainstormed over the problem on what we needed to find out*
11	Triggers discussion	3	Everyone in the PBL group participated in the discussion*
		4	The problem stimulated us to discuss*
12	Encourages group work	5	There were many different viewpoints regarding the solution*
		6	Our PBL group worked efficiently*
Problem characteristic 5: Critical reasoning			
13	Stimulates thinking and reasoning	1	The problem has triggered lots of questions in my mind
		2	I have/had enough ideas to respond to and understand the problem
		3	The problem stimulates/have stimulated me to think and reason statement
14	Encourages multiple perspectives**	4	The problem had more than one right answer*
		5	There were many different viewpoints regarding the solution*
		6	Group members had diverse opinions on the problem*

* Items only measured after the initial discussion

**Parcel removed after factor analysis

PBL Implementation of Computer Simulation in the Teaching of Strategic Management at Duy Tan University

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Abstract

Strategic Management is an important but difficult subject for business students at most universities. One reason is due to the complexity of its materials while another is the methodology being used to help students integrate business, accounting, finance and information systems knowledge to successfully complete the course. For years, computer simulations have been used to create a sense of reality to real-world practices for Strategic Management at many schools. Its effectiveness, however, is still in question. At Duy Tan University, we have run into the very same question due to the following reasons: Firstly, students complained that the simulation required a large volume of knowledge integration, making it hard for them to grasp the materials. Secondly, they complained that the computerized results presented might not have been objective, and some groups, who did not do much work but understood how the system worked, still won the game. Thirdly, a big question was raised as to whether they should consider the simulated game a problem or a project or simply, an experience. Last but not least, since the software is English-based, many students ran into problems understanding the game, and so, many of them feel uncomfortable with the use of computer simulation. As much as computer simulations have been praised as an innovative component in the Active Learning approach of many PBL-based programs, the above problems did show that the computer simulations themselves do not transform the nature or quality of our teaching. It is our specific teaching and learning settings and methodologies which make the difference. Through a series of observations and surveys over the years, our staff members have created a number of PBL-based tactics with the use of computer simulations in business and finance coursework, and those will be very much the focus of this paper.

Keywords: PBL standards, computer simulation, PBL implementation, strategic management, Duy Tan University

1 Introduction

The teaching of Business Administration coursework in general sometimes appears to be vague and obscure to many people because of the many theories and concepts involved. Indeed, people sometimes question about what a college graduate in Business Administration actually get out of his or her four years of study apart from some presentation skills and a bunch of finance, human resource and marketing theories (Pfeffer & Fong, 2002). The usual answer would be that a business graduate will possess an effective business mindset and strategic market viewpoints. Is that always true or it is more of an illusion for the majority of the business graduates? Frankly speaking, while it is true that some business graduates do actually develop an effective business mindset, the rest of them are likely to have no clear direction when they just get out of college (Bailey & Ford, 1996). The reason has to do with the fact that the college settings and class sizes usually do not allow for the development of real-world skillset in business for the majority of the students. How to fix this dilemma has become a constant challenge at many business schools (Pfeffer & Sutton, 2000). In this paper, we would discuss about the use of computer simulation in the Strategic Management course as part of our PBL effort at Duy Tan University to create more of a real-world study environment for our students and to help them develop essential business skillset. Coincidentally, Strategic Management seems to be the right course to test our effectiveness in teaching business because it integrates the knowledge of many fields in Business Administration like Accounting, Finance, Marketing, Human Resource, Information Systems, etc. (Knotts & Keys, 1997) However, the reality of computer-simulation deployment at our school has showed a series of shortcomings in terms of students' preparedness, their trust for the simulation results, their English skills required to understand the English-based simulation instructions and results, and their integration of different business knowledge for decision-making in the simulation. This paper, as a result, set out to determine whether by putting together a series of PBL-based tactics of team member assignment through skill screening, grading based on business scenario interpretation, English training for simulation and flexibility in the use of Vietnamese and international accounting/financial conventions will make a difference in helping students develop more of an integrative business mindset for Strategic Management.

2 Shortcomings of Computer Simulations at DTU

At Duy Tan University, computer simulations have been used long before in certain chosen classes of Marketing, Financial Modeling, Hospitality Management, and Logistics. They were, however, not adopted on a large scale basis mostly because of the off-limit per-user license fees as well as the lack of qualified instructors to help run those simulations. The benefits of computer simulations were also in question by our students and instructors for a number of reasons:

- The lack of sufficient information and training for the computer simulations usually makes the students (and even some instructors) unprepared and confused when they start running the simulations.
- Most students do not trust that computer simulations actually simulate real-world activities of the market. Students generally believe that the simulations follow some numeric formulas (Knotts & Keys, 1997), and if anyone can recognize those formulas, it will be easy for them to win the simulations.
- Almost all computer simulations used (at Duy Tan University) are English-based, and this presents certain difficulties to students who are not proficient in English.
- Almost all computer simulations (at Duy Tan University) adopt Western or American conventions in accounting, finance, and budgeting so that our Vietnamese students usually have to spend more time learning those new conventions.

3 Proposed PBL-based Solutions & their Match-Up with PBL Standards

Given the shortcomings identified above, when we started with the new simulation of Strategic Innovation Simulation (by Willy C. Shih and Clayton Christensen) (Shih, et al., 2008) for our Strategic Management course, certain PBL-based approaches were adopted to help improve on the effectiveness in the use of our computer simulations:

• A preliminary test of skills and knowledge in accounting, finance, marketing and human resource is designed to assess students' capability. While students will not be eliminated from the course if they fail the test, the test serves as a reminder to them that they need to review on previous business skills and knowledge learned before. In addition, the test results serve as the basis for instructors to assign team members so that the overall capabilities of different teams in the class are on the same par.

• Grading for the simulation is not entirely based on the simulation results but rather also on the explanations of why students make certain decisions in the simulation and how they interpret the subsequent simulation results in their reports and final presentation (30 minutes). This helps relieve the pressure and tension posed by the former approach that if students could not understand how the simulation worked, they would fail the class.

• A vocabulary of prevalent terms and keywords used in the simulation is provided to students on the school's eLearning platform to help with problems in their English proficiency. Video-based instructions and online support staff for English used in the simulation are also provided.

• Students are allowed to process the simulation results for either international or Vietnamese accounting/financial convention in their reports. Also, in order to encourage students to learn new accounting/financial conventions, bonus points are provided to teams which adopt international conventions in their reports. While this effort is beneficial to the students, it requires our use of additional teaching assistants in validating the report results under different conventions.

Still, how can we be sure that those efforts above are really PBL-based approach? By matching up those efforts with the PBL standards, we will be able to evaluate the correlations amongst them, as followed:

Table 1: Correlations between the PBL Efforts for Computer Simulation and PBL Standards

PBL Standards	**PBL Efforts for Computer Simulation**			
	Preliminary test of business skills and knowledge for review and team assignment	Grading based on logical business decisions and explanations/ interpretations	Direct and indirect support for English use in simulation	Acceptance of different accounting/ financial conventions and Incentives for learning of new conventions
1. Is organized around an open-ended driving question or challenge				
2. Creates a need to know essential content and skills				
3. Requires inquiry to learn and/or create something new				
4. Requires critical thinking, problem solving, collaboration, and				

various forms of communication, often known as "21st Century Skills"				
5. Allows some degree of student voice and choice				
6. Incorporates feedback and revision				
7. Results in a publicly presented product or performance				
	Strong correlation		Good correlation	

4 Research Methodology & Result Analysis

4.1 Research Methodology

Strategic Management purports to teach students how to achieve the SMART (Specific-Measurable-Attainable-Relevant-Time-based) objectives. An overview of the improved process that we used for the computer simulation of Strategic Management will provide a better idea of how we set out to attain our objectives. Based on the efforts listed in the previous section, the instructors were required to provide lectures about the essentials of Strategic Management. After that, a preliminary multiple-choice test was delivered to our students to assess their skills and knowledge in Accounting, Finance, Marketing and Human Resource. The instructors would then grade the students' tests and assign team members based on the ranges of their test scores. One ideal team would consist of 4-6 students from different majors. Next, the team leader received the game simulation manual from the instructor and the team was provided with enough time to discuss and ask questions related to the simulated challenges. Instructors and supporting staff would always be available to answer their questions about the course contents and the simulated game. The students should also be informed that their grade would be marked based on their simulation performance as well as the write-up interpretations of the simulated business scenarios which they ran into. For the simulation performance, if there was a tie result amongst two or more than two teams, the higher grades would be assigned to the faster ones. At the end of the course, members of different team are invited to present in class their chosen strategies under certain business scenarios as well as their choice of accounting/financial conventions for the final write-up. Final deliverables include a final write-up and a board presentation accompanied by a 10K report (if some international accounting convention was used) or a series of quarter-end financial reports (if the Vietnamese accounting convention was adopted).

In order to assess and validate the effects of our PBL-based modification efforts for the implementation of the computer simulation for Strategic Management, a post-course survey was designed for students who took Strategic Management with the new simulation settings. The survey adopts a five-point Likert scale, with the scale being in put in a reversed order with 5 coming first as Strongly Agree and 1 coming last as Strongly Disagree. The reason for the use of a reverse Likert scale is because with the use of the standard Likert scale and given the many statements in the survey, students tend to scan fast through the statements and most of the times, providing quick answers as either Agree or not, which mostly would be Neutral rather than Disagree. By reversing the scale, students would be caught by surprise and they would have to think twice before providing their answers. In addition, if they agreed or disagreed with a certain statement, they would truly show the strength of their agreement or disagreement.

The focus of the survey results would be on:

(1) MEAN VALUES, and

(2) STANDARD DEVIATIONS

of answers for each question.

The mean values would provide a relative answer as to whether a certain PBL effort has been effective or not and/or whether our PBL effort does synchronize with the corresponding PBL standards as indicated before. On the other hand, the standard deviations would offer a clear view of how much spread out the students' feedbacks are on some specific aspect. This is indeed very important because the course of Strategic Management is being taught to a wide variety of business and hospitality students in various majors like Business Administration, Accountancy, Finance, Banking, Marketing, Hotel Management, Tour Management, and Restaurant Management. This is not to mention of the fact that the quality and capability of this big group of students are quite varied.

Table 2: Post-course Survey Questionnaire

<table>
<tr><td colspan="2">Duy Tan University
PSU-MGT 403 - Strategic Management</td><td colspan="5">Academic Year and Semester:</td></tr>
<tr><td>Team's Name:</td><td>Student's Name:</td><td colspan="5">Student's Major:</td></tr>
<tr><td colspan="7">5: Strongly Agree - 4: Agree - 3: Neutral - 2: Disagree - 1: Strongly Disagree Tick one</td></tr>
<tr><td colspan="2"></td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td></tr>
<tr><td colspan="2">1. The preliminary test did emphasize the Accounting materials necessary for the computer simulation in the course.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">2. The preliminary test did emphasize the Finance materials necessary for the computer simulation in the course.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">3. The preliminary test did emphasize the Marketing materials necessary for the computer simulation in the course.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">4. The preliminary test did emphasize the Human Resource materials necessary for the computer simulation in the course.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">5. The preliminary test did emphasize the Information Systems materials necessary for the computer simulation in the course.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">6. The preliminary test did create a need to review on materials learned before.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">7. The team assignment by the instructor was satisfying, bringing together people with supplemental skills and knowledge.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">8. The grade distribution for performance in the computer simulation was adequate.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">9. The grade distribution for the regular and final reports was adequate.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">10. The grade distribution for the final executive presentation was adequate.</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

11. The overall grade distribution did encourage the team to spend more time to learn about the simulation and to interpret results after each simulation session.					
12. In every simulation decision and report write-up, our team worked closely together.					
13. The computer simulation required significant proficiency in English.					
14. The online vocabulary and online support staff for computer simulation were adequate.					
15. Our team did try to learn international conventions in accounting and finance.					
16. Our team adopted international conventions in accounting and finance for the report write-up.					

A sample of 120 students, who took Strategic Management with the new simulation settings were surveyed. Out of those 120 students, 35 students are Business Administration and Marketing majors, 23 are Accounting majors, 26 students are Finance and Banking majors, 27 students are Hotel Management majors and 9 students are Tour Management majors. The survey was carried out at the end of the fall semester 2014, and it required a total of around 120 working hours of 3 instructors and 7 teaching assistants.

4.2 Results Analysis & Discussion

Table 3: Numeric Results from the Survey

	5	4	3	2	1	N	MEAN	STANDARD DEVIATION
Question 1.	23	15	24	45	13	120	2.92	1.31
Question 2.	34	27	39	12	8	120	3.56	1.19
Question 3.	36	43	19	12	10	120	3.69	1.24
Question 4.	12	16	32	34	26	120	2.62	1.24
Question 5.	24	37	31	21	7	120	3.42	1.16
Question 6.	37	32	20	23	8	120	3.56	1.29
Question 7.	24	23	33	21	19	120	3.10	1.34
Question 8.	33	27	16	14	30	120	3.16	1.56
Question 9.	46	32	20	15	7	120	3.79	1.24
Question 10.	37	23	21	21	18	120	3.33	1.45
Question 11.	23	45	23	17	12	120	3.42	1.23

Question 12.	26	36	17	14	27	120	3.17	1.47
Question 13.	13	35	26	15	31	120	2.87	1.37
Question 14.	15	21	24	28	32	120	2.66	1.37
Question 15.	68	29	11	8	4	120	4.24	1.08
Question 16.	21	24	28	26	21	120	2.98	1.35

The survey results revealed certain interesting findings about our PBL efforts in redesigning the computer simulation settings for Strategic Management:

• First of all, it appeared that the preliminary test of business skills and knowledge has served as a strong reminder for students to review on materials of previous business courses with around 57.5% of the students Agreed or Strongly Agreed that they had done certain review. Answers to Question 1 to 5 indicated that the preliminary test had properly touched upon materials in Finance, Information Systems and especially, Marketing as required for the computer simulation. Test items for Accounting and Human Resource, on the other hand, were not very relevant as 58 out 120 students Disagreed or Strongly Disagreed about the relevance of questions for Accounting, and another 60 out of 120 has the same viewpoint for questions about Human Resource. This probably has to do with the fact that our questions for Accounting mostly focused on the Vietnamese accounting convention taught before while the computer simulation for Strategic Management indeed did not have much to do with Human Resource aspects.

• The effectiveness of our team member assignment based on the results of the preliminary test was not recognized because up to 60.83% of the students were either Neutral or Disagreed or Strongly Disagreed about whether our team assignment actually brought about integrative and supplemental skills and knowledge for the team. The general neutrality in Question 7 signified that either there was not much gap in the capability of our sampled students or there was problem in our team assignment criteria based on preliminary grading.

• With respect to our move to emphasize on the explanation and interpretation of business decisions in the simulation rather than the simulation performance per se, there was generally a consensus on the new grading percentiles for the regular and final reports, the final executive presentation, and the team performance in the simulation with the overall Agreement and Strong Agreement rates of 65%, 50% and 50%, respectively. One thing which should be pointed out is that answers to Question 8 about the grading structure for team performance in the simulation have a very high standard deviation of up to 1.56, with 33 students (out of 120) Strong Agreed with the new grade distribution for simulation performance while at the same time there were also 30 students who showed Strong Disagreement.

• 56.67% of the students Agreed or Strongly Agreed that the overall grade distribution encouraged them to learn more about the simulation while 51.67% confirmed that they had to work closely together for every simulation decision and write-up. This indicated our success in bringing the students together for collaboration and search for new knowledge according to the PBL standards, even only to a certain extent.

• An average Likert point of 2.87 (out of 5) for Question 13 signified a less-than-neutral response to the importance of English proficiency in using the simulation. However, we should keep in mind that up to 35 (out of 120) students still Agreed that English proficiency is required for the simulation. That means while most students were comfortable with our English-based simulation, there were still many who were not. And to our disappointment, the online vocabulary features and online support staff were not as effective as expected with up to 70% of the students expressing their Neutrality, Disagreement or Strong Disagreement about the value of such support.

• The contrast between the answers to Question 15 and 16 raised certain concern in our PBL effort. While up to 80.83% of the students stated that they did attempt to learn international accounting and financial conventions for the simulation, only 37.5% actually adopted those new conventions for their simulation reports. So, giving students a high level of freedom is not necessary a good thing. The fact that most students still choose to stick to Vietnamese accounting and financial convention also signified the failure of our bonus points as an encouragement for students to learn and try new conventions.

It should be said that the nature of our computer simulation for Strategic Management mostly deals with financial budgeting for different Marketing tactics and quality control activities. As a result, it does not deal that much with in-depth Finance and Human Resource issues. The simulation actually has much to do with different book-keeping accounting activities; thus, the low perceived relevance by our students for Accounting test items in our preliminary tests indicated our failure in tackling the right aspects of Accounting for the simulation. Sampled case studies on the making of the 10K reports (for the international accounting convention) and the quarter-end financial reports (for the Vietnamese accounting convention) should be provided to our students to better prepare them for later processing of the simulation results. On the other hand, for the Human Resource aspect of our simulation, an issue was raised by students as to whether team members holding a specific role might assume the decision-making responsibility for that role. Right now, even though one member may be designated as the CEO, another as the CFO, another as the COO, etc., most of the budgeting or quality control activities are done jointly by the whole team or by any one (or two) team members alone, thus losing the whole meaning of labour allocation in Human Resource. There is no easy answer to this, and future studies should look more into ways for better Human Resource settings in our simulation. While the preliminary test has helped greatly our students' review and integration of past knowledge for the simulation, it did not help much with the optimal assignment of students to teams as expected. Still, it is important that instructors take charge of the team member assignment; otherwise, good students may try to team up together, leaving average and below-average students to one another.

Perhaps, the biggest success amongst our PBL-based approaches was with the development of the new grade distribution which did not put so much emphasis on the performance in the simulation alone. Rather, the relevance of interpretations about certain business scenarios that students get themselves into as well as the quality of the final reports, the 10K or quarter-end reports, and the board presentations also add up to a sizable grade percentile, which did give most students more motivation in their learning of the simulation as well as Strategic Management. The fact that students also have to stick together on every aspect of the simulation and related deliverables also signified our success in helping them learn from each other and develop more or less of an integrative business mindset individually. While teams who do well on the simulation alone may not be so happy with this approach, it is suggested that some additional bonus points to the teams will settle the issue, and at the same time, keeping everyone happy in our learning process. The bonus-point approach can also be adopted to encourage students to improve on their English for the simulation as well as for the whole course. Specifically, bonus points should be given out to teams who can write their reports in English or do their board presentations in English. Of course, bonus points may not always work as it was the case with our incentives for students to choose international accounting conventions instead of the Vietnamese one.

5 Conclusion

The mixed results of our PBL-based approaches indicated that there are still certain shortcomings in our PBL efforts for the redesign of simulation settings in the course of Strategic Management. Still, more or less, some efforts like preliminary test of business skills and knowledge or the redesign of the grade distribution have appeared to encourage students to learn new things and seriously engage them in critical thinking, problem solving, teamwork, and public presentation. Further studies should look into more effective ways to help improve students' English proficiency, redesign team assignment criteria and set up effective incentives for the adoption of new knowledge and approaches to serve the ultimate goal of better implementation of our computer simulations. Inquiries into differences between students of different majors may also be needed to accommodate for better learning of Strategic Management materials from various business perspectives. In addition, since our current simulation game is some Western-designed software (Abdullah, et al., 2013), it is not specifically suitable Asian or Vietnamese students. This may be considered as a challenge as well as an appealing opportunity for Vietnamese software companies. Vietnamese computer simulations for Vietnamese students will definitely be an attainable dream. One last thing to point out is that Strategic Management and its computer simulations are always very much human-related, which requires continuous improvement of interpersonal skills on the part of both our students and instructors. Thus, this strongly reminds our instructors and students about the importance of communication in the simulation implementation rather than technology aspects of the simulated games.

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Transforming Models, Mindsets and Metrics for Engineering, Engineering Education and Development

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Abstract

Engineering is vital for innovation, sustainable social and economic development, and addressing global issues such as poverty reduction, climate change mitigation and adaptation. Many countries around the world, however, are reporting an increasing shortage of engineers, in both numbers and quality, especially in some fields. These shortages constrain development, especially in developing countries -developed countries can solve shortages by immigration, with a consequent brain-drain impact on developing countries, which is neither a good engineering or ethical solution. This policy-oriented paper examines the need for better metrics, models, mindsets and solutions to this major challenge, with particular reference to the need for the transformation of engineering education toward a student-centred, problem- and project-based learning approach, focusing on graduate attributes and professional competencies. There is also an urgent need for better metrics to facilitate understanding and evidence-based policy on engineering education, innovation and transformation, and how engineering and engineering education link to technological innovation and development. Problem- and project-based learning, learning by doing, rather than the traditional learning by lecture and formulae, which turns many students off, appeals to students, attracts them to engineering and enhances their employability. This is evidenced by the experience of PBL institutions, universities with Engineers Without Borders groups and employers around the world looking for problem-solving graduates. Much of this evidence is anecdotal, however, and more refined data and metrics are required for evidence-based policy. This paper explores these issues, and also reflects on their roots in the mainstream models and mindsets that underpin traditional notions of teacher and subject-lead education and science-lead innovation, and the need to update these models and mindsets to mirror actual and changing realities and needs.

Keywords: Engineering education, transformation, metrics, PBL, development

1 Introduction

Engineering knowledge and application drives innovation, social and economic development. Our physical infrastructure is designed, built and maintained by engineers, and most innovations derive from engineering (Metcalf, 2009). Engineering defines us, and engineering knowledge, design, tools and infrastructure has changed and continues to change the world and the way we live in it. Despite this, engineering and engineers are generally poorly understood and routinely confused in the media. Engineering is also generally overlooked in economic development and theory. Engineering is often unmentioned in the study, models of and policy relating to ‘science’, ‘science and technology’, or the more recent ‘science, technology and innovation’ (STI), and associated statistics, indicators and metrics. Although engineering is generally regarded as a part of science, it is mainly engineers who create, apply and innovate technology – engineers do “rocket science”. Significant change in knowledge production, dissemination and application has taken place over the last 50 years, driven by engineering. Engineering is the most radical profession, in terms of technological, social, economic and cultural change, and yet is perhaps also the most conservative. Engineering education has changed very little over this period. This is a major factor in the decline of interest, enrolment and retention of young people in engineering, reported shortages of engineers in many countries and brain drain from developing countries. Change is in the wind, however, with the move toward a focus on graduate attributes and professional competencies by the Washington Accord and International Engineering Alliance. Graduate attributes and professional competencies focus particularly on a problem-solving approach ideally suited to engineering as a problem-solving profession (Washington Accord).

There has been increasing discussion and calls for the need for innovation and the transformation of engineering education, focusing on student-centred, problem-based learning (PBL)(Kolmos, Krogh and Fink, 2004; de Graaf and Kolmos, 2007; Du, de Graaf and Kolmos, 2009). PBL is also important in the promotion of engineering for innovation and humanitarian development, where engineering is a major solution in addressing global issues such as poverty reduction, climate change mitigation and adaptation. With a focus on relevance and need, PBL and humanitarian engineering are crucial in the promotion of interest, enrolment, employability, mobility and the retention of students and young engineers around the world, and help reduce the brain drain of engineers from developing countries. This paper examines and discusses the above issues, looking first at the history and background of engineering and engineering education – at models of how things are and mindsets that need to be transformed, and at current statistics, indicators and metrics that also need transformation to facilitate the transformation of engineering education. The paper explores en passant engineering education, innovation and transformation, with particular reference to the important role of active problem- and project-based, student-centred learning.

2 Engineering and development

Engineering is closely linked to human, social, cultural and economic development. The history of humanity - the way we live, interact with nature and each other, and the world today is the history of engineering. Much of the direction, pace, shape and framing of human, social and economic development relates to engineering and the design, use and innovation of tools and technology. Engineering is one of the oldest professions in the development of knowledge, technology and infrastructure. Engineers built the ancient world, and underpinned the Stone, Bronze, Iron, Steam and Information Ages and associated civilisations, and the change from one Age to another was due to engineering, technology and innovation. Engineering drove the first Industrial Revolution, and the five major waves of technological innovation over the last 200 years, from iron and water power to steam power, steel and electrification, oil and automobiles and mass production, to electronics and computers. These 'Kondratiev waves' of innovation, industrial development and surges in the world economy, periods of alternating sectoral growth, initially of around fifty years duration but decreasing with increasingly rapid knowledge change, are also identified as part of the 'Schumpeter-Freeman-Perez' model of innovation and change (Gibbons et al, 1994; Nowotny et al, 2001). Engineering is driving the sixth wave of new knowledge in ICT, biotechnology, nanotechnology and new materials, and will drive the seventh wave of sustainable development, climate change mitigation and adaptation. It is important to note that all waves of technological innovation and development are accompanied by new modes of knowledge generation, dissemination and application, which require new approaches to learning and education (Beanland and Hadgraft, 2014).

Within these broader waves of revolutionary technological, industrial, social and economic development, engineering has played a central role in the incremental development of infrastructure in transportation, communications, buildings, water supply, sanitation, energy generation, distribution and use. These technological, industrial, social and economic revolutions spread around the world, initially in periods of exploration and colonisation, later in trade and development - the concept of “development” and “developed” countries has been closely identified with the development of technology, industry and infrastructure. Although many “developed” countries now have large tertiary service sectors as well as secondary industry, and primary resource sectors, much of the service sector is built and depends upon engineering and technology, as do the primary and secondary sectors. The concept of development remains largely linked to the development of industry and infrastructure and standard of living, although continues to be measured by such indicators as Gross Domestic Product, GDP per capita and, more recently, by the Human Development Index (HDI). Given the role of engineering in development and, conversely, the link between underdevelopment and the lack of engineering and technology, engineering metrics can be seen to be as important an indicator of development as GDP, growth and other economic data (Stewart, 1977). Engineering and associated metrics are also vital in sustainable, limits to growth, development.

3 Development of engineering education

Engineering education is also very much a part of human development and history, and indeed of the direction and pace of historical change. Engineering and engineering education is at the heart of the development of civilisation – the Stone, Bronze, Iron, Steam and Information Ages could not have developed without the development of engineering and transmission of engineering knowledge. The development of engineering education, as part of the emerging profession of engineering, began over 150,000 years ago, with the transfer of the understanding and skills of tool and weapon making. Military engineering was soon followed by civil engineering and the development of early infrastructure. Engineering education developed from what was essentially the informal transmission of knowledge in an early form of apprentice-mentor relationship, with the development of engineering knowledge, formalised crafts and guilds and associated training. Simple, often patriarchal forms of engineering education developed into various types of vocational technical schools in the Middle Ages, particularly during the Renaissance and the scientific revolution of the 16^{th} and 17^{th} Centuries. Leonardo da Vinci, for example, held the official title of ‘Ingegnere Generale’, and produced notebooks recording how things worked, and communicating this to others. Galileo Galilei developed the scientific approach in the understanding of the natural world and analysis of practical problems with mathematical representation, structural analysis and design. These were landmark activities in the development of engineering and engineering education.

The 1700s and 1800s were a crucial period in the development of engineering, particularly the Iron and Steam Ages - the second wave of innovation and industrial revolution. Early interest in the development of engineering education began in the early 1700s in Germany, Czech and France – that developed a formal system of engineering education after the Revolution, under Napoleon’s influence, and engineering education has retained a strong theoretical and military character. At the beginning of the 1800s the French model influenced the development of polytechnic engineering education institutions around the world, especially in Germany. In the early 1800s polytechnics were established in Berlin, by Wilhelm von Humboldt, establishing the university model we see today, In Germany, polytechnic schools were accorded the same legal foundations as universities. In Russia, schools of technology were opened based on the model of military engineering education. The first technical institutes appeared at the same time in the USA. In England, after the early years of the Industrial Revolution, engineering education continued to be based on the model of apprenticeship with a working engineer. Many famous engineers, including

Newcomem and Stephenson, had little formal or theoretical training, yet developed technologies that powered the Industrial Revolution and changed the world. Practical activity preceded scientific understanding in many fields, – steam engines preceded thermodynamics. England tried to maintain technological lead by prohibiting the export of engineering goods and services in the early 1800s, which was one reason why countries in Europe developed their engineering education systems based on French and German models, with a foundation in science and mathematics. Through the 1800s and into the 1900s, however, engineering and engineering education changed. England was obliged to change toward a science and university-based system due to fears of lagging behind the European model in terms of international competitiveness. This foreshadowed the rise of the 'engineering sciences' and closer connection between engineering, science and mathematics.

Toward the later 1800s, most of the industrialising countries had established engineering education systems, based on the liberal, student-centred model introduced by Wilhelm von Humboldt at the University of Berlin. This, combined theory and practice, with a focus on scientific research. The "Humboldt model" influenced the development of universities in France and elsewhere. Over time, emphasis on the practical gave way to theory, largely on professional grounds and the desire to emulate science. This has lead to a negative impact on the interest and enrolment of young people in engineering, and need for educational approaches based on problem-based learning, projects and real-world needs – a return to the theory and practice of von Humboldt. In the 1900s the professionalisation of engineering continued with the development of learned societies and the accreditation of engineers. Universities and professional societies facilitated education, research and the flow of information. This activity continues with the development of international accords, standards and accreditation, and the mutual recognition of engineering qualifications and professional competencies. These include the Washington Accord (established 1989), wider International Engineering Alliance and associated agreements.

Educational practices change slowly and evolve to match cognitive and professional paradigms, requirements and expectations. In engineering education, "engineering science", following the Humboldt model, is the dominant paradigm. Changes in knowledge and technology production, dissemination and application have lead to calls for change in associated learning approaches - toward cognitive, knowledge- and problem-based learning. Engineering is a problem-based profession, and needs a problem-based approach to learning (UNESCO, 2010). Emerging needs in terms of changing knowledge production, dissemination and application, cognitive and professional paradigms for the next generation of engineers are reflected in the twelve graduate attributes and professional competencies as identified in the Washington Accord (Washington Accord):

1 Engineering knowledge
2 Problem analysis
3 Design and development of solutions
4 Investigation
5 Modern tool usage
6 The engineer and society
7 Environment and society
8 Ethics
9 Individual and team member
10 Communications

11 Project management and finance
12 Life-long learning

As is evident, less than half of these criteria relate to the "old" engineering curricula, with the majority relating to contemporary and emerging needs of professional practice. All are ideally suited to problem- and project-based learning, as originally advocated by von Humboldt, before practice gave way to theory.

As noted above - the waves of technological innovation and industrial revolution were reflected in transformation in engineering education and epistemologically in changing knowledge production, dissemination and application. The first major wave of technological change in the early 1800s (based on iron and water power) was reflected in a craft mentor-based hands-on approach. The second wave in the later 1800s (steam) was reflected apprenticeships and trades. The third wave in the later 1800s and early 1900s (steel) was reflected in the development of technical schools, colleges and universities. The fourth wave in the early/mid 1900s (oil) reflected an increasing science, theory and hands-off approach. The fifth wave, post 1950s (ICTs) reflects the significant changes in knowledge and technology, as does the sixth wave, based on changes in knowledge production, dissemination and application from the 1980s and the convergence of science and engineering based on interdisciplinarity, networking and a problem-solving, systems approach, with an increasing focus on applications. These changes relate to what has been typified as the change in knowledge production from "Mode 1" (academic/disciplinary) toward "Mode 2" (problem-based/interdisciplinary) (Gibbons et al 1994 and 2001; Etzkowitz and Leydesdorff, 2000). Changes from theory to practice, individual to teamwork, with converging bodies of knowledge, professional practice and employment, need to be reflected by change in science and engineering education toward project- and problem-based, student-centred learning. These changes will be needed in the transition to a seventh wave, based on cleaner/greener technology for climate change mitigation and adaptation, where a focus on practice, teamwork, converging knowledge, applications and innovation will be necessary.

4 Models of engineering, science, technology and innovation

Early models of engineering, science, technology and innovation were based on technological determinism - the view that technology drives social and cultural development. More sophisticated models followed, based around science, technology and society, stimulated by the publication of Thomas Kuhn's "The Structure of Scientific Revolutions" in 1962 and the concept of scientific paradigms and paradigm change (Kuhn, 1962). This also stimulated interest in science determinism and the linear model of innovation. Other models of science, technology and innovation followed, based on systems theory. The linear model of innovation and technological change posits that innovation derives from basic research in a linear fashion through applied research and engineering to technology and innovation, emphasising basic research in "technology push" or "market pull" versions. Later models of innovation derive from Actor-Network Theory (Latour, 1987), and the social shaping of technology (Mackenzie and Wajcman, 1985). Contemporary models of innovation include open innovation and user innovation – relating to openness to internal and external ideas, products, processes and services, and to user-developed ideas, products, processes and services.

The linear model became the popular view on innovation, due largely to its simplicity, and the support of the science lobby. The origins of the model are unclear (Edgerton, 2004), although many accredit the emphasis in 1945 of Vannevar Bush, head of the U.S. Office of Scientific Research and Development during

WW2, on the role of basic science in technological development and wartime success, underpinned by statistics reinforcing the conception of a linear model. The linear model became the paradigm for S&T policy and postwar economic development, as illustrated in the Marshall Plan and later the work on "science and technology" indicators by OECD and UNESCO, despite some critique. Chief among these were that the linear model overlooks engineering in innovation, for example, in not differentiating data on science and engineering. The linear model gives a misleading picture of science, engineering and technology, overlooking the role of engineering in development, and in S&T policy.

An accurate model representative of actual and changing modes of knowledge production, application and innovation is required, based on a systems conception of science and engineering, research, education, applications and innovation, encompassing government, universities and industry. The limitations of such an approach should also be recognised - many developing countries, for example, lack such a system at national level, and a model of knowledge transfer, application and innovation is more appropriate. Science and engineering education needs to be based on such a model, as does understanding of the role of engineering in development. There is a particular need to emphasise the contribution of engineering to innovation and development, to underline the weakness of the linear model. There is a need to develop engineering studies and policy to facilitate this, and to support research to facilitate understanding of innovation and technology transfer. In developing countries there is a particular need to put engineering on the development agenda by focusing on the important role that engineering and engineering education plays in development. Engineering education needs to respond to the seventh wave of sustainable 'green' engineering and technology, with a focus on environmental, eco-engineering and associated design, manufacturing and infrastructure.

Public and policy interest in engineering will result from a better understanding of the contribution of engineering to development, facilitated by information, case studies and advocacy. The efficacy of such an approach is demonstrated by the success of such activities as the Daimler-UNESCO Mondialogo Engineering Award and growth of Engineers Without Borders groups around the world – which are attractive to students concerned about such issues (UNESCO, 2010). As noted, engineering has changed the world, but is professionally conservative and slow to change. To attract young people, engineering education needs to put fun back with the fundamentals. Curricula and pedagogy needs to be transformed from the traditional, formulaic approach, that turns students off, to active, project and problem-based learning, combining just-in-time theory and hands-on applications, that turns them on.

5 Innovation and the transformation of engineering education

One of the main goals of innovation and the transformation in engineering education is to respond to rapid change in knowledge production, dissemination and application, and the need to move from the traditional engineering curricula and pedagogy toward a cognitive, knowledge-based approach. This approach emphasises experience, problem-solving and insight, with a more just-in-time, hands-on approach, as exemplified by project and problem-based learning. This also responds to the changing need for engineers to be better attuned to change in terms of synthesis, awareness, ethics, social responsibility, experience, practice, applications, lifelong and distance learning, continued professional development, adaptability, flexibility and interdisciplinarity. There is also the need for relevance regarding pressing global issues and challenges – including poverty reduction, sustainability (environmental, social, economic and cultural), climate change mitigation and adaptation. These needs are reflected in the graduate attributes and professional competencies of the Washington Accord.

Engineers are problem-solving innovators, and need to innovate in engineering education for a curricula focused on project and problem-based learning, with reference to real world, relevant issues and problems, cleaner and greener engineering and technology appropriate to social, economic, environmental and cultural context. Curricula needs to reflect formal and informal learning trends, especially the use of ICTs for student-centred learning, with a focus on learning facilitation rather than lecturing. There should be a focus on the assessment of graduate attributes, and the facilitation of student interaction. The focus on real world issues and problems also promotes engineering as essential, exciting and a rewarding career (Beanland, 2012). It is interesting to note that other professions, such as medicine, have transformed toward ‘patient-based’ learning, when there was no enrolment need to do so, wheras engineering has enrolment and retention issues that clearly need to be addressed.

Innovation and transformation is a socio-political and technical process, and may encounter barriers and resistance to change - culturally, universities and academics have a focus on research rather than education, are conservative, resist change, with space for lecturing, rather than learning. Universities see staff performance in terms of papers published and grants gained, have higher rewards for researchers than effective educators. University leaders rarely see the need for transformation. Barriers and resistance may relate to accreditation authorities, tending also to the conservative, slow to change, possibly averse to promoting an output-oriented, graduate attribute and professional competency approach. This may not the case, however, as some accreditation authorities lead and are instrumental and noteworthy champions of transformation, as with many members of the Washington Accord. Despite the rhetoric of excellence, quality, innovation and creativity by some universities, there are real concerns regarding declining standards in some areas (Hill, 2012).

5.1 Transformative action

There is an increasingly need to transform engineering education to address the shortages of engineers reported in many countries, to move with changing modes of knowledge production, dissemination and application, and in recognition of changing needs for engineers, in terms of knowledge, learning, graduate attributes and professional competencies. These include a problem-solving, problem-based learning approach and link to global issues. There is a related need to promote information, metrics, examples of good practice and advocacy on the need to transform engineering education. These need to be targeted at engineers, engineering organisations, accreditation bodies, universities, decision takers, policy makers and governments, and emphasise the need for change, facilitate support and enlist champions for change and transformation. ‘Transformative actions’ are vitally important for change, and areas of transformative action that are crucial for change in engineering education can be identified (UNESCO Report, 2010; Beanland and Hadgraft, 2014). In engineering (and also in science and technology) these relate particularly to:

Knowledge systems
Data, metrics and information
Ethical issues, social and cultural context
Engineering education and educators

Engineering profession and institutions
Engineering industry, employers and associations
Government ministries, departments, policy makers and decision takers

Transformative actions need guidelines, and this includes the need to develop and disseminate a better understanding of the knowledge system of engineering (knowledge production, dissemination, application). This underlines the need better understand engineering and develop engineering studies and input to policy. This requires data, metrics and information on engineering, to support evidence-based advocacy for change. This needs to be targeted at engineering (and science) educators, the engineering profession, institutions and industry, policy makers and politicians. Particular guidelines for transformative actions include the development and use of:

Washington Accord graduate attributes as objectives for education and assessment
Curricula based on WA graduate attributes for student goals and professional competencies
Student-centred, problem-based learning and ICTs to motivate and engage, especially first year
Student learning rooms, environments, e-portfolios, staff as learning facilitators
Projects focused on real-world needs to develop design skills, teamwork, communication
University-industry cooperation for project activity, experience, staff exchange

Addressing barriers and resistance to change requires various strategies. The university and academic focus on research needs more emphasis and reward for educational activity, and pedagogical change can be encouraged with information, metrics and advocacy. A particular issue relates to the belief that learning is by lecture, and problem-based learning takes more time and effort than lecturing. Such perceptions can be challenged by research, metrics and information on learning approach and outcomes presented at such conferences as IJCLEE2015. PBL graduates, for example, are sought after by industry for their experience, initiative and innovativeness. Many universities are realising and addressing the need for student learning space. Some accreditation authorities may be conservative and reluctant to change, although many recognise the importance of the graduate attributes and professional competencies and are champions of change. Engineers and engineering educators can facilitate change by recognising, supporting and promoting the transformation of engineering education to universities and government through example, research, metrics, information and advocacy. They can work with accreditation authorities and universities to implement Washington Accord graduate attributes and professional competencies, and with industry on projects, professional experience and staff exchange to facilitate transformation.

6 Metrics of engineering and engineering education

In order to understand engineering and transform engineering education, also to promote public awareness, formulate and implement policy and manage engineering, we need good information, data, indicators and metrics on EST. Metrics are vital in understanding and advocating evidence-based policy and practice - “No data, no visibility; no visibility, no priority” (Huyer and Westholm, 2007). Metrics and indicators relate to needs as well as numbers - how many engineers, scientists, technologists and technicians do countries need, in what fields and at what levels, and how do we best educate engineers to address these needs? What engineers will be needed in ten and twenty years time, who need an education from now? Despite their importance, there has been little interest in engineering metrics and indicators - “No international engineering data of the very detailed kind have ever been published; the only (and usually still rather scarce) information available is for R&D expenditures and personnel in the higher education and private non-profit sectors" (Westholm, 2010; UNESCO 2010). Considering the importance of engineering in the knowledge society and economy, it is surprising that better data is not available on one of the most important drivers of social and economic development.

Metrics and indicators on engineering are part of a wider set of data and statistics on engineering, science, technology and innovation. Many richer, OECD, countries produce their own information on EST, often in some detail (for example, the US National Science Foundation). This information contributes to data collection at the international level, where the main collectors are the OECD (a leader with a long-term interest in the field, for OECD member and non-member countries), the World Bank, Eurostat (for the EU), UNESCO (at the global level, mainly following the OECD data collection methodology) and the ILO (for labour and employment data). OECD gathers data widely on issues relating to economic development, and began collecting data on 'science and technology' in the 1960s. OECD data collection in this field relates particularly to human resources (recently work includes the careers of doctoral holders), research and development, and innovation. Human resource guidelines are covered in the OECD Canberra Manual, R&D in the Frascati Manual and innovation in the Oslo Manual (OECD). UNESCO began collecting data on science and technology in the 1960s. OECD and World Bank data is collected and "cleaned" to address possible inaccuracies and irregularities, whereas UNESCO is obliged to use data directly, as submitted by Member States.

The collection of statistical data is based on various classifications – the UN Systems of National Accounts (SNA), the International Standard Classification for Education (ISCED), the International Standard Classification for Occupations (ISCO) and the International Standard Classification of all Industrial Activities (ISIC). Data is collected with a focus on subject – for example, human resources and numbers of graduates, investment and expenditure, number of papers published, copyrights and patents issued. Metrics and indicators relate to information that is requested or required at national and international level (to provide internationally comparable data). Statistics of science and technology relate to numbers that are readily available and measurable, and are not necessarily indicators that give the best picture of engineering, science or technology. How good the information and data is, and how good a picture it presents of EST and engineering education, depends on the metrics and indicators used, and the quality and quantity of data collected. There are also issues with the methodology of data collection – engineering and science may be defined and measured differently in different countries.

In terms of human resources, for example, engineers and scientists are often defined differently in different countries, and usually aggregated together in data and statistics – so that it is not possible to examine and compare data relating to engineering and engineers in general, or the various branches of engineering. For research and development, the quality of the data depends on the definition of R&D, which is mainly carried out in richer, OECD countries, and measured by such indicators as investment (public and private), number of papers published and patents issued. The data on innovation similarly depends on definition, and the measurement of innovation at the formal level relates particularly to intellectual property (IP), patents and copyrights issued, which focuses attention on richer, OECD countries, although much innovation takes place in engineering (Metcalfe, 2009), at the informal, non-measured level, in developed and developing countries. The conventional view of engineering, science, technology and innovation emphasises knowledge production, application and dissemination in terms of what can be measured in patents and papers, rather than reality, and paints a poor picture of engineering, especially in developing countries.

6.1 Better metrics

The above discussion illustrates how the statistics, indicators and metrics for engineering are in serious need of refining. The data for engineering is collected under guidelines developed by OECD, and is collected and analysed at such an overall level as to be of limited usefulness in answering many of the questions relating to engineering raised above. Better definition, indicators and metrics of engineering is clearly required, with better disaggregation of data regarding engineers and engineering, branches and levels of engineering. Better definition and measurement of research and development are also required, especially regarding development (rather than research), and better definition and measurement of innovation, especially at the informal level in developed and developing countries. Better indicators and metrics of engineering and innovation that will provide a better understanding of the role of engineering in development, what sort and how many engineers will be needed in the future.

The data combine "scientists and engineers", without disaggregating into science and engineering, or the various fields of science and engineering, and focus on R&D without specifying the division of research and development and the respective roles of science and engineering. Data on patents, scientific publications and innovation are presented without reference to the origin of patents and papers in science or engineering (and publishing papers may be less of a career priority for engineers than scientists), what constitutes innovation, who does it and where it takes place. These indicators and metrics are of limited use in analysing the need for, types and numbers of engineers required at national and international levels, how they are educated and how this reflects Washington Accord graduate attributes and professional competences. Indicators and metrics need to be refined and in some cases redefined to allow better disaggregation between engineering and science and the various fields of engineering and engineering employment (eg industry, teaching, research). This will facilitate a better understanding of the role of engineers in R&D, patenting, publishing and innovation, the contribution of engineers and engineering to international trade, the role of engineering in development and associated policy and planning. It will also help dramatically in providing better data for engineering education policy, planning and transformation.

7 Concluding remarks

There is a need to recognise the changing context of knowledge production and application, and changing needs for engineering and engineering education in terms of learning, graduate attributes and professional competencies, as indicated in the Washington Accord, and the development of new models, metrics and mindsets for engineering. These include a problem-solving, problem-based learning approach and link to global issues, such as the need for poverty reduction, sustainability and climate change mitigation and adaptation. There is also a need to develop and promote information, metrics, evidence-based examples of good practice, and to enlist champions for advocacy regarding the transformation of engineering education, focusing on engineering organisations, accreditation bodies and universities, with the goal of facilitating government and private sector support.

Transformation and change in engineering education is required to attract and retain young people, address reported shortages of engineers around the world, reduce brain drain from developing countries and to keep pace with changing needs for engineers, changing modes of knowledge production and application and changing global needs. These include the increasing need for sustainability, climate change mitigation and adaptation, and humanitarian engineering to reduce poverty and promote social and economic development – challenges that concern and appeal to many young people and attract them to engineering. The transformation of engineering education needs to be student-centred, focusing on graduate attributes, professional competencies and relevance. This transformation will benefit students and engineering, and also universities, industry and the wider public. Student-centred, problem- and project-based learning has been shown to facilitate such transformation at universities around the world (including Aalborg University, Olin College and Singapore University of Technology), with many other universities taking an increasing interest. Accreditation authorities and governments need to recognise, support and help facilitate the output-oriented, graduate-attributes approach and transformation of engineering education.

In conclusion, it is mindful to consider the consequences of failure in addressing the need for transformation in engineering education - continued and increasing shortages of engineers around the world, continued brain drain and impact on social and economic development, especially in developing countries - a world of increasing borders without engineers. This is the backdrop against which engineering education needs to transform itself to interest, promote enrolment and retention of young people, reflecting changing knowledge, production, dissemination and application, changing societal and economic conditions and needs, changing models and mindsets of engineering.

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Integration of three instructional design models within the organization of PBL activities

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Abstract

This work is aimed at defining a method to design courses based on Project Based Learning methodology. This proposal is specially focused on those academic contexts in which instructors are starting to use this methodology and students are not used to dealing with ill-structured projects, and consequently they could find important difficulties in its implementation. To reach this goal, this method is based on several instructional design models, learning theories and PBL principles. In particular, the method faces three fundamental issues in active learning and especially in PBL: Students' Motivation, Supporting Students' Work and Autonomous Working. Engaging instructors to follow these models when they are designing the course facilitates the subsequent success during the course implementation. The method has been put into practice in three courses, where first results seem to be satisfactory according to a survey conducted by the University. Results of this survey over for the last six years have been analysed. Besides the description of the method, we present a collaborative online tool that supports it.

Keywords: Instructional design, course design, students' motivation, PBL support

1 Introduction

Project Based Learning (PBL) has spread across countries and disciplines over the last decades. In particular it has demonstrated to be appropriate to engineering studies. Probably, for this reason every year more and more teachers join this methodology. Nevertheless, in some experiences PBL is used in an intuitive way based on the teaching experience of instructors, but unfortunately without considering basic principles or formal methods. Consequently, expected results are not achieved. According to our experience, the better results in PBL are achieved when some instructional design methods, developed by experts, are taken into account to organize the PBL course or activity.

This problem appears to be especially important with freshman students, who do not have large experience with facing ill-structured problems. Just to illustrate, we can describe the recent case of Programming Workshop taught at Universidad Politécnica de Madrid during the first semester in two degrees: Computer Science Engineering and Software Engineering. This workshop lasts one semester. Students have to solve a programming project while they are following a first programming course. Results were disappointing. As far as teachers' opinion in concerned, they seem to have a clear idea about the main drawback they found: "The main problem was the lack of knowledge about programming language and programming practice. This workshop takes place in the same semester than Fundamentals of Programming. Although the workshop starts later, students follow both courses simultaneously during the second half of the semester. An additional problem is organization. Students do not plan adequately their time and do not organize tasks among team members. On the other hand, students enjoyed developing a project and they end up learning about programming".

But, not only happens this problem in first semesters. In some academic contexts, even more experimented students are not used to dealing with this kind of problems, therefore they feel lost and end up rejecting the methodology. We had a similar experience in the course Operating Systems, taught during the fifth semester. Precisely, this is the course where we put into practice the method described in this paper and where we obtained the results presented in section 3. Jonassen summarize this issue in (Jonassen, 1997), "we cannot assume that learners are naturally skilled in problem solving, especially complex and ill-structured problems such as those required in most PBL programs". Based in our experience, this issue is related to some of the most important drawbacks in PBL implementation.

There is a significant number of instructional design theories focused on organizing different issues of PBL activities that turn out helpful to overcome the difficulties above mentioned. In particular we highlight in this paper three models that work separately on three different aspects of instructional process: ARCS Motivational Model (Keller et al., 1982), Supporting PBL (Jonassen, 1999) and Autonomous Work (Rué, 2009). ARCS model was developed by J. Keller, who proposes to work on four areas to foster student motivation: capture the attention, demonstrate the relevance, create student confidence and facilitate students' satisfaction. D. Jonassen theories about supporting students' work on constructivist learning environments are used to design the support that instructors will provide to students during the learning process. Finally, J. Rué proposal helps us to organize the autonomous and directed work of students.

The aim of this paper is to describe a method to design courses (or activities) based en PBL methodology. This method leads instructors to design PBL courses by following several instructional design models, learning theories and PBL principles. This way, students will have more chance to achieve success in the project development and learning process. From our point of view, this method could be especially helpful in academic contexts in which instructors are starting to use PBL and students are not skilled in dealing with complex projects.

The method, described in detail in section 2, is divided into three phases: Definition of the problem, Support of student's work and Organization of the course. Definition phase is mainly based on principles and characteristics of PBL, some learning theories and suggestions to design ill-structured problems. In Support phase we establish some relationships among the three instructional design models, then, leaned on these links, we propose a set of steps to design the course or activity. The third phase, Organization is not object of this paper, since it was described in previous works (Garcia et al., 2009). Anyway, we will link it with the present work in order to provide a general vision of the complete process.

Once the content of the course has been configured, every aspect of it (documents, references, planning etc.) can be incorporated into an online tool developed at the Computer Science School (Universidad Politecnica de Madrid). This tool is of use to both instructor and students (Garcia et al., 2014).

This process has been used to organize two courses: Operating Systems and Real Time Systems, both of them taught in the Computer Engineering degree. Some surveys reveal significant improvement in student opinion about subject organization, interest, learning and results. Likewise, it has been use to organize a first-year course, Programming Workshop, that is being taught during the spring semester in 2015.

This paper is structured as follows: Section 2 presents the description of the process, the steps and the theories in which it is based. It also includes an introduction to the online tool PBLT. Section 3 shows the main results obtained in some courses where this method was applied. Finally, in Sections 4 we present the main conclusions and future works.

2 Method

2.1 Introduction

There are a large number of proposals to design PBL activities. For instance, (Edutopia, 2012) specifies seven steps: Introducing the Driving Question; Introducing the Culminating Challenge; Developing Subject Matter Expertise; Doing the Culminating Challenge; Debriefing the Culminating Challenge; Responding to the Driving Question; Summative Assessment. L. M. Nelson (Nelson, 1999) focuses attention on collaborative problem solving issues, pointing out the organization of collaborative work. We find particularly interesting the process proposed by (Jonassen, 1997) to design ill-structured problems, which consists of seven steps: (1) Articulate the problem; (2) Introduce problem constraints; (3) Locate, select and develop cases for learners; (4) Support knowledge base construction; (5) Support argument construction; (6) Assess problem solutions.

Based on these ideas, we have divided the process into three general phases: Definition, Supporting and Organising. The goal of the first one is to develop the definition of the project, following the main PBL principles and meeting the characteristics of good problems. This definition includes not only the goals, but also other information that helps to articulate the project. Subsequently, Support phase is dedicated to prepare different learning activities and materials focused on facilitating project success. Finally, Organization phase assists in planning the teaching-learning activities throughout the semester. Each phase is based on several learning theories and tries to coordinate them in order to establish a general process to design courses based on PBL. Figure 1 displays these phases, which will be discussed in more detail in next sections.

2.2 Definition

The goal of this phase is to obtain the first project definition, which includes the basic information about objectives, restrictions, resources etc. Nevertheless, we start by gathering some previous information: Learning Outcomes of the course, Professional Activities that are carried out in professional contexts related to the course matter and the Topic that we want our students to face. Regarding Professional Activities, (Jonassen, 1999) suggests that it is recommended to engage learners in solving authentic problems, where “authentic means that learners should engage in activities which present the same type of cognitive challenges as those in real world.

Then, the first Project Proposal is written, which specifies the topic, the main goals and the work that must be developed. This proposal is prepared based on PBL principles formulated by Barrows (Barrows, 1996), summarized in (Kolmos, 2012) and increased in (De Graaff et al., 2003), which are recapped here: the use of problems as a starting-point for the acquisition and integration of new knowledge; new information acquired through self-directed learning; student-centered; learning in small groups; teachers acting as facilitators and guides rather than informants; activity-based learning, requiring activities involving research, decision-making and writing; inter-disciplinary learning, extending beyond traditional subject-related boundaries and methods; exemplary practice, ensuring that the benefits for the students are exemplary in terms of the objectives.

Then, we check if this proposal meets the Characteristics of a good problem, such as they are formulated in (Kolmos et al., 2009): It is engaging and oriented to the real-world; It is ill-structured and complex; It generates multiple hypotheses; It requires team effort; It is consistent with desired learning outcomes; It builds upon previous knowledge/experiences; It promotes development of higher order cognitive skills. According to these characteristics and PBL principles we would wonder if some changes are necessary in our proposal to improve it and make it more suitable for a PBL activity.

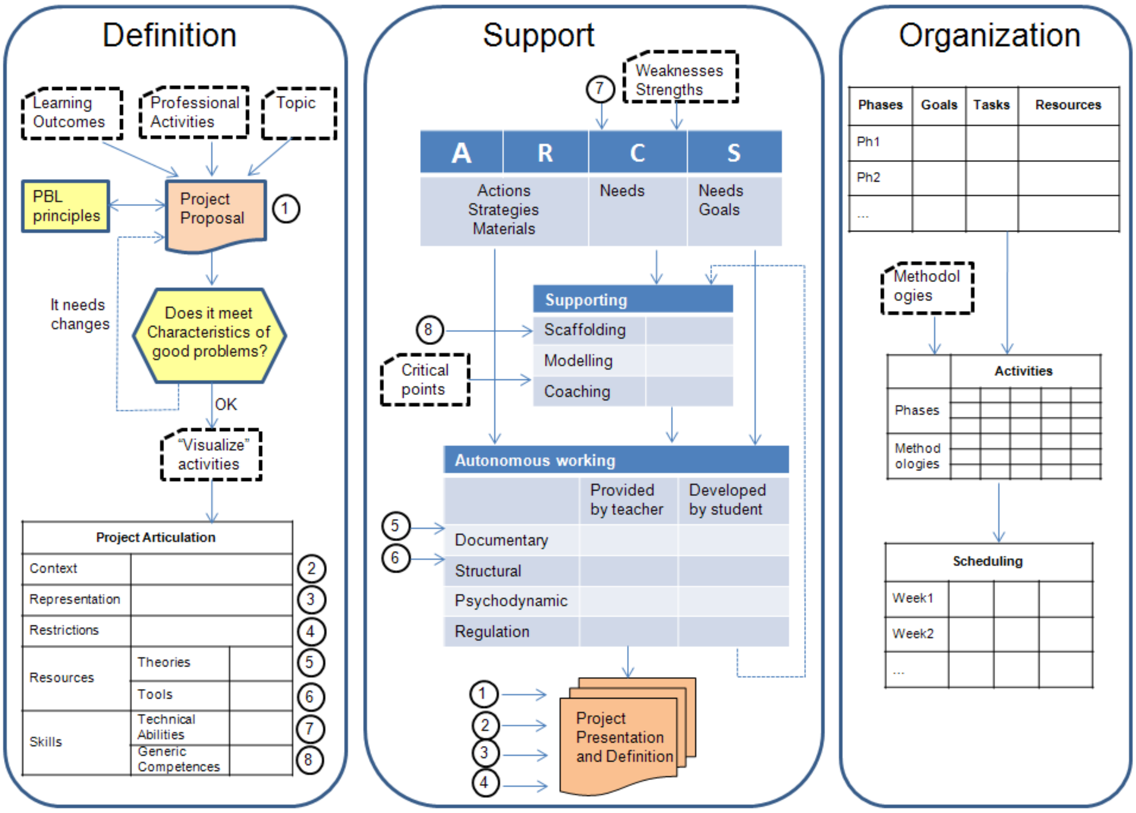


Figure 1: Schema of the method.

Once we have confirmed the Project Proposal is in tune with these characteristics and principles we move on to articulate the problem, according to (Jonassen, 1999). Nevertheless, before tackling this task, we find particularly helpful to "visualize" the activities that students will have to carry out when they will face the solution of the project. Sometimes, teachers prefer to implement an almost complete project, similar to the project that will be developed by students. In both cases, the aim is to have an accurate idea about the student's work, its needs, difficulties and other issues that could help us to configure the project.

Project Articulation consists of five sections. First we describe the context of the project. The relationship of the problem with the social and professional context is an important issue for students to understand the relevance. According to (Jonassen, 1997), a representation or model of the problem can help students to understand the start point and the goals. Restrictions in the development as well as resources that will be needed, both theoretical ground and tools, are included in project articulation. Finally, we describe the skills that students will have to put into practice to develop the project. We distinguish between two kinds of skills. On the one hand technical abilities are those related to the specific discipline of the course. For instance, testing programs is an important technical skill in computer engineering. On the other hand Generic Competences are those that are transversal to every discipline, such as Team Working, Problem

Solving or Written Communication. Regarding the later, we propose to include not only those competences that are required by the activities of the project, but also other competences that are specific goals of the degree curriculum.

We dealt with this problem in previous works (Perez-Martinez et al., 2014). In that work we proposed a method to integrate generic competences into curriculum in order to meet EHEE directions. The method consists in developing a map of generic competences according to some precedence relationship. Once the map is configured, it is projected into the semesters, so that a set of competences is attached to each semester. Afterwards, one or two competences are assigned to each subject. This way every subject is in charge of developing and assessing one or two generic competences specified in the curriculum. Competences are introduced into curses throughout the design of learning activities coordinated with the activities planned in the course. Including this issue in our method, we contribute to develop generic competences and consequently to integrate these skills into the curriculum. According to our experience, PBL is a suitable methodology to improve this kind of competences, such as teamwork, problem solving, analysis and synthesis or oral communication.

Numbers specified in Definition phase are used to identify those parts that will be used in other places. In Support phase, these numbers together with an arrow indicate where this information coming from Definition phase is used.

2.3 Support

Initially, we gather some information about the main weaknesses and strengths of students who are going to develop the project. This information can be obtained from students who have followed the course in previous years or from previous courses in the curriculum. Weaknesses and strengths are important in designing the PBL support, in order to provide more assistance in those issues where student have more deficiencies.

ARCS model (Keller, 1982) is focused on promoting and maintaining student's motivation in the learning process. It proposes four steps: Attention, Relevance, Confidence and Satisfaction. First, Keller describes several ways for grabbing students' attention, using surprising and stimulating curiosity. Next, he introduces the relevance of the problem in order to increase learner's motivation. Confidence helps students to understand their likelihood for success. If they feel they cannot meet the objectives or that the cost (time and effort) is too high, their motivation will decrease. Finally, Keller suggests several ideas to make students find satisfaction from their learning (Keller, 2010).

According to this model we enumerate and describe the actions, strategies and materials that we propose to use to catch student's attention. Similarly we describe the same elements to highlight and communicate to students the relevance of their project. Next, we think about students' confidence. In particular, we try to identify what are the needs of the students to gain confidence. At this point, information gathered about technical abilities and weaknesses provide important clues. Applying ARCS model finishes by identifying how we can promote students' satisfaction. What do our students need to feel satisfaction with the project? Based on this question we established some goals about this issue.

Before dealing with supporting strategies, we analyse the critical points of the project. We identify two types of critical points. First, those tasks or phases in which students find more difficulties, due to its complexity or the student's lack of experience. Second, some points can be cornerstones of the project, and consequently the viability or success of the project could depend on them.

Subsequently, we design the supporting material according to Jonassen model (Jonassen, 1999). This author identifies three types of supporting: scaffolding, modelling and coaching. Modelling is focused on the expert's performance. Behavioral modelling demonstrates how to perform the activities identified in the activity structure, it provides learners with an example of the desired performance. Cognitive modelling articulates the reasoning, decision making and argumentation that learners should use while engaged in each step of the activity. Coaching is focused on the learner's performance, it consists in accompanying, instructing and training a person to support him while achieving a specific personal or professional competence result or goal. Finally, Scaffolding is focused on the nature of task and the environment. It provides temporary frameworks to support learning and student performance beyond the learner's capacities.

In our case, first we propose to think about the points of the project (phases, tasks, activities etc.) in which students will need specific support. Most of these points can be identified by analysing the information elaborated about confidence needs, generic competences and critical points. Then, for each one of these points, we think about the most appropriate type of support (Scaffolding, Modelling or Coaching). The questions that we try to solve at this step is: What do our students need to overcome these points of the project?

Next step consists in organising the contents of the course, documents, tools, activities, tasks etc. In particular, we want to determine which contents will be provided by the teacher and which contents are responsibility of students through autonomous work. (Rué, 2009) classifies these issues into four classes: Documentary (Theories and information needed), Structural (Ideas, rules and tools to act or work), Psychodynamic (It is focused on the relationship among people, members of a group, related to the work) and Regulation (Information necessary to direct and asses or self-asses the work). For every item that we place in one of these classes we can decide if this item will be provided by the teacher or should be developed by the own students. We will place in the column "developed by teachers" those things that we know student cannot do by himself (or in groups) or we do not want them to spend time on it. On the other hand, those things that students can do with some help of the teacher, they can do with some help of their mates or he can do by himself, will be placed in the column "Developed by the own students".

To integrate this model into our method, we propose to elaborate the table of Autonomous Working taking into account some information compiled in previous steps: actions, strategies and materials for caching attention and showing relevance; needs and goals to achieve student's satisfaction, all the materials described in supporting section, including any type (Scaffolding, Modelling and Coaching). Moreover, theoretical ground and tools that are needed in the project must be considered in this section. For each one of these items included in this table we think over the responsibilities of teacher and students. That means, we decide which facilities will be provided by teacher or which activities will be carried out by teacher. On the other hand, we define those materials and activities for which student will be responsible by themselves. This organization is made according to Rué's criteria. Once the table has been completed we suggest reviewing it in other to detect possible lacks in some of the sections. For instance, in some cases Structural and Regulation areas tend to have less items and we could consider to add new activities of facilities that could be useful to reinforce this issues.

To conclude the Support section, we deal with project presentation, which not only consist of those documents that will be handed out to students, but also activities carried out to engage students into the project and make them understand their work and responsibilities. At this step we find relevant some advices presented by (Ertmer, 2005) focused on how to present a project to students: Getting students thinking about the problem before the unit begins, planting seeds of curiosity weeks in advance; To “hook” students through the use of engaging opening scenario; Program activities to ease students into their new roles and responsibilities; Short problems used to introduce students to the problem-based method; Create “messing about” activities that help students to understand the specific sub-issues embedded within the problem. These actions are more effective than starting “cold” by researching an unfamiliar topic

In addition to this project presentation, we include a detailed definition of the project, so that students know the kind of work they have to develop, constraints, final goals, resources provided by teachers, working rules etc. Most of this information is elaborated from the information included in the table Autonomous Work. In this way, the final project definition, this that will be given to students, takes into account the elements elaborated in previous steps. These elements have been pondered according to instructional design theories and advisability in our project.

2.4 Organization

This phase consists in planning and organizing the learning activities that will take place throughout the semester, so that we obtain a complete scheduling of the course. Although this process was presented in previous works (Garcia et al., 2009) we will summarize briefly it in order to provide a complete view of the method. This phase suggests seven steps to design an educational plan. It establishes relationships between every project phase and the educational methodologies which can be used in the course (cooperative learning, laboratory, tutoring, etc). These relationships are established by means of the learning activities required in each phase (study, reflection, debate, testing, information management and tutoring). It helps to determine which methodology is the most appropriate for each phase of the project and establishes a relation between the work carried out in each phase and the learning activities required to complete it. In conclusion, we chose the most appropriate learning activities for each phase of the project. Finally, we place these learning activities in the semester schedule.

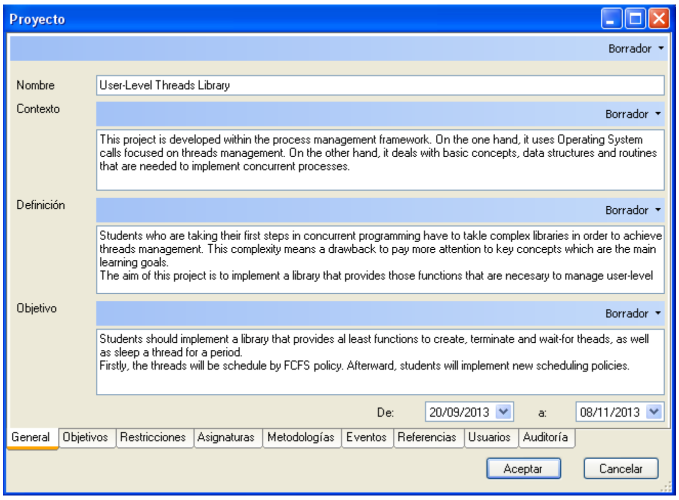
2.5 The tool PBLT

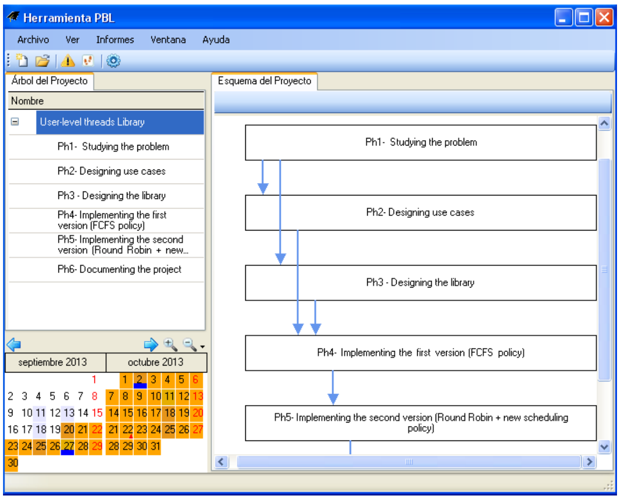
In order to facilitate the use of this process, a cooperative tool that supports it has been developed at Computer Science School (Universidad Politécnica de Madrid), called PBLT. This tool consists of two parts. Firstly teachers use it to design course contents, taking into account the main principles of PBL methodology. Afterwards, once the course has been designed, teachers generate different instances of the course, so that every team of students is attached to an instance. Then, students use the same tool to organize their own project development, including aspects as planning, tasking, meetings or resource management. The most significant features of PBLT are: to integrate the activities of both teachers (design) and students (develop) in the same tool; to offer a collaborative environment for both, teachers’ team and students’ team; to allow different levels of depth in the project specification, in such a way that teachers can design a project at the desired level between well- and ill-structured; to take into account specific issues of academic contexts, like courses or lessons; to allow remote work.

Although this tool was originally presented in (Garcia et al., 2014), we describe briefly some features in order to show the support that this tool provides to the method described in this paper and the relationship between them. Figure 2 shows the windows through which teacher fills up the project definition and supporting materials, such as we have discussed in the first two phases of the method: Definition and Support. Moreover, it displays the graphic that represents the set of phases into which the project is divided and a calendar with important dates. This information is proved to students, who elaborate their own scheduling chronogram, shown in the last window.

3 Results

The method described has been used to organize two courses over the last two years, Operating Systems (OS) and Real Time Systems (RTS), and we have observed important changes in student opinion throughout final course surveys. At the end of the term, students have to fill a survey elaborated by the UPM, which consists of 17 questions about the teachers and the subject. For this study we have analysed 4 items: I7-"I have improved my starting level, regarding the competences established in the course"; I11-"The teacher assistance is effective to learn"; I15-"The teacher achieves to arouse interest in the different topics studied during the learning activity"; I16-"The teacher facilitated my learning, and thanks to his/her help I improved my knowledge, skills or the way to face some topics". This survey follows a Likert scale of 6 points (1=strongly disagree, 6=absolutely agree).





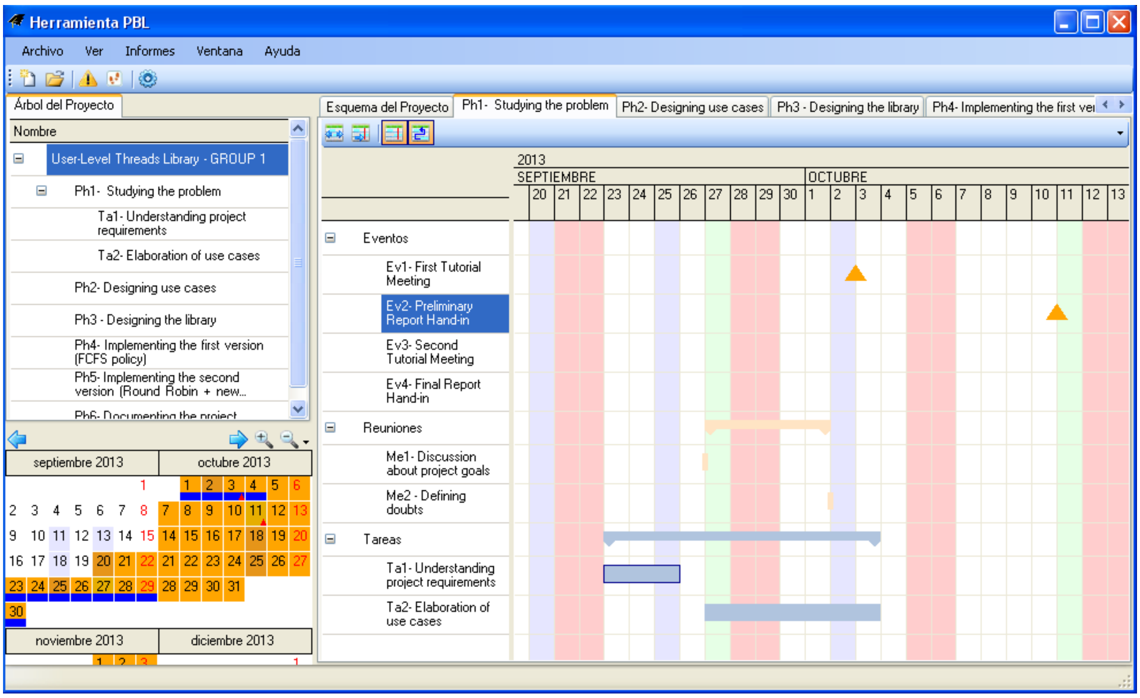


Figure 2: Examples of windows in PBLT.

Table 1 displays the results of the four questions selected for this study. Columns show the mean and standard deviation obtained for the last 6 years in the Operating Systems course. In the years 2014 and 2013 the method described in this article was used in order to organize the teaching-learning activities. Previous years implemented PBL activities without a specific design of motivation and support. In the year 2012 worse results were obtained. Teachers in charge of these course explained that the part of the course dedicated to theory was organized following Cooperative Learning methodology (in particular the jigsaw technique) and it was not well received by students. This fact could influence on the general opinion of students about the course. Then we have established three groupings, OS2014-13, OS2012 and OS2011-10-09 in order to analyse significant differences.

First exploratory analysis of data was carried out in each of the groups. This analysis includes the sample size, the minimum and maximum values, the mean, the variance, as well as Kolmogorov-Smirnov and Shapiro-Wilk tests to check if each of the variables follow the normal distribution. Statistics of the three grouping can be observed in Table 2.

Table 1: UPM survey

	OS 2014 N=15	OS 2013 N=14	OS 2012 N=24	OS 2011 N=22	OS 2010 N=27	OS 2009 N=38
I7	5,07 (0,77)	5,14 (0,83)	4,25 (1,09)	4,77 (1,04)	4,60 (0,69)	4,55 (1,04)
I11	5,07(0,68)	5,36 (0,61)	3,58 (1,47)	4,33 (1,13)	4,70 (1,01)	5,08 (0,81)
I15	4,8 (1,17)	4,64 (0,61)	3,54 (0,96)	4,43 (0,95)	4,33 (1,05)	4,24 (0,91)
I16	4,73 (1,18)	4,79 (0,67)	3,65 (1,13)	4,29 (1,12)	4,44 (1,07)	4,27 (0,89)

Table 2: Statistics of groupings

Item	Group	N	Mean	Stand. Dev.	Stand. Error
I7	OS2014-13	29	5,10	,817	,152
	OS2012	24	4,25	1,113	,227
	OS2011-10-09	85	4,62	,963	,104
I11	OS2014-13	29	5,21	,675	,125
	OS2012	24	3,58	1,501	,306
	OS2011-10-09	86	4,78	1,011	,109
I15	OS2014-13	29	4,72	,960	,178
	OS2012	24	3,54	,977	,199
	OS2011-10-09	85	4,32	,978	,106
I16	OS2014-13	29	4,76	,988	,183
	OS2012	24	3,67	1,129	,231
	OS2011-10-09	85	4,33	1,016	,110

Therefore, we established the equality of means as null hypothesis and run t-Student test. Table 3 shows the results obtained for items I7, I11, I15 and I16 from the groups OS2014-13 and OS2012. In a similar way, Table 4 displays the results obtained from the groups OS2014-13 and OS2011-10-09. We can reject the null hypothesis (equality of means) for every item between groupings OS2014-13 and OS2011-10-09 with values $t=3,215$, $t=5,228$, $t=4,428$ and $t=3,755$ respectively, and p-value $p< 0,05$ for I7 and $p<0,01$ for the remaining items. Nevertheless, as we have explained, this results can be influenced by the unsatisfactorily results of the cooperative learning sessions. On the other hand, if we compare groupings OS2014-13 and OS 2011-10-09, significant differences are obtained only in two items, I7 and I11, with p-value $p=,018$ and $p=,036$. In item I15, although p-value is really close to 0,05 we cannot reject the null hypothesis. In item I16, p-value is equal to 0,05.

Therefore we can determine that, in the courses in which the method was applied, students have a better opinion about having "improved their starting level, regarding the competences established in the course" and considering that "the teacher assistance is effective to learn".

Table 3: t-student for equality of means between OS2014-13 and OS2012

Item	**t**	**gl**	**Sig.**	**Mean Difference**	**Stand. Error.**	**95% Confidence interval upper**	**95% Confidence interval lower**
I7	3,215	51	,002	,853	,265	,321	1,386
I11	5,228	51	,000	1,624	,311	1,000	2,247
I15	4,428	51	,000	1,182	,267	,646	1,719
I16	3,755	51	,000	1,092	,291	,508	1,676

Table 4: t-student for equality of means between OS2014-13 and OS2011-10-09

Item	**t**	**gl**	**Sig.**	**Mean Difference**	**Stand. Error**	**95% Confidence interval upper**	**95% Confidence interval lower**
I7	2,402	112	,018	,480	,200	,084	,876
I11	2,123	113	,036	,428	,202	,028	,827
I15	1,941	112	,055	,406	,209	-,008	,821
I16	1,977	112	,050	,429	,217	-,001	,859

As far as the items I15 and I16 are concerned, I15-"The teacher achieves to arouse interest in the different topics studied during the learning activity"; I16-"The teacher facilitated my learning, and thanks to his/her help I improved my knowledge, skills or the way to face some topics", although we cannot reject the equality of means in one of the groupings, differences are really close to be significant. These results could be influenced by the number of samples.

This semester, the course Programming Workshop is being taught during the spring semester in 2015. Besides organizing the course by following the method described in this paper we are developing an experiment which consists in two tests, Teamwork Questionnaire and Achievement Goal Questionnaire in order to analyze correlations between the method, teamwork competence and motivation of students. At the end of the term we will offer these results.

4 Conclusions and future works

To sum up, we have described a method to design courses based on PBL. This method is based on three instructional design models and follows several learning theories. We have applied this method to two courses and it is being applied to a third course taught in spring semester. Results obtained from students' opinion seem to be satisfactory, since students who followed those courses designed by using this method have a better opinion about their learning level and teacher assistance. Improvements in arousing students' interest are really close to be significant. New experiments with a larger number of samples will help us to clarify this issue.

The method appears to be useful to help students to overcome the main difficulties when they are facing complex and ill-structured projects. Teachers pay more attention to analyze the support needed by students to overcome these difficulties and improve their motivation. At the end of the current semester we will analyze the results in Programming Workshop. Moreover, more experiments to analyze the effects of the method are needed.

We believe that nowadays it is important to develop some tools that facilitate the use of the method, engaging more instructors to use it. In this regard we are testing a first version of the tool PBLT and working on some improvements.

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Design education in cooperation with industry and practitioners

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Abstract

The European Commission is asking for new strategies to bridge the gap between industry and academia, especially in the current context of economic crisis, which particularly influences labour insertion of new graduates. This paper describes how Mondragon University's strategic design master fosters university-industry cooperation through Real Life Learning Labs. Real Life Learning Labs are collaborative frameworks where multidisciplinary students work on real assignments under the mentorship of researchers and industry professionals. In order to discuss the contributions of this approach, first, the groundwork which enables the collaboration between students, university's researchers and practitioners is presented. Second, one experience developed within the strategic design master is described. Finally, results of the experience are discussed. The results show that this collaborative framework allows integration of students within a professional environment. In addition, enterprises seed the ground for new ideas, while experimenting with innovative design approaches and having limited expenditure of resources.

Keywords: design education, strategic design, industrial design, university-industry collaboration

1 Introduction

The current economic crisis is an issue that concerns highly qualified graduates. Labour insertion of new graduates has dramatically decreased since the beginning of the crises. In this context, the European Commission is asking for new strategies to bridge the gap between industry and academia. The collaboration between the industry and academia seeks, on the one hand, to improve the competitiveness of the industry, and on the other hand, to enrich the training for the students before entering the labour market (European Commission, 2012).

Mondragon University is well known for its proximity to industry, having collaboration between industry and university researchers. The constant contact with industry and business has clearly contributed on the definition, development and implementation of the university's study programs and teaching methods in design.

Mondragon University places a big effort on the various forms of collaboration with industry as part of the learning process of its students. According to Fink (2002, p. 32):

"The Project Based Learning (PBL) process as such calls for a high degree of cooperation between industry and university. This cooperation will be stimulating not only for the student in the learning process but also for the companies involved".

This way, the PBL model was incorporated as the framework for the development of a real assignment aligned with a company, following principles such as problem-orientation, project work, interdisciplinarity, participant directed learning and team work.

PBL model pursues an alternative and innovative approach to education, providing students with an active role in the development and acquisition of knowledge and higher academic standards (Barge, 2010). In addition, PBL model is a learner-centred approach that empowers students to conduct research, integrating theory and practice in the development of a viable solution to a particular problem (Savery, 2006). Thus, if the framework of the project is real and close to the industry, it enables the learner to have a more clear vision of the conducted research and the generated solutions.

In current PBL processes, the educator acts as an initiator and facilitator in the collaborative process of knowledge transfer and development (Sjoer, Nørgaard, Goossens, 2012). However, when integrating industry practitioners in the PBL model, the role of university lecturers and researchers must be redefined. In particular, if we want to achieve long term cooperation between industry and university (Fink, 2002). Some emerging cases, (Fink, 2002; Iriarte et al., 2013) show the potential benefits and positive impact of these long term collaborations. Nevertheless, in order to promote such collaborations, more practical cases must be developed and subsequently analysed, to identify the proper collaboration and training methods and framework.

This paper presents a case where the PBL model was implemented in collaboration with industry. This way, the authors aim to show an experimental case in the field of industrial design, which could be used as a preliminary guide on how to build long term university-industry collaboration frameworks.

2 Objectives

This paper describes and discusses how Mondragon University's strategic design master fosters university-industry cooperation through Real Life Learning Labs (RLLL). RLLL integrate students within a professional environment, where learning and teaching is combined with practical work experience and exposure to the needs of industry (EURL3A, 2015).

The objective of integrating RLLL in PBL model is threefold: (i) to bring students closer to the industry, (ii) to promote the potential of strategic design discipline, and (iii) to support companies in their innovation processes. The achievement of these objectives will enable the transformation of educational practices in PBL model, fostering university-industry long term collaboration. The case study presented in this paper suggests a preliminary groundwork to accomplish these objectives.

3 University-industry collaboration through the PBL model and Real Life Learning Labs

The university-industry collaboration through the PBL model and Real Life Learning Labs is conducted within the strategic design master. The master, which is an industrial design program of two years, developed over the past five years with much work done on active learning methods and PBL model aligned with industry (Iriarte et al, 2013; Iriarte et al, 2014). The projects developed in the master program focuses on the development of technical and transversal competences, engaging student teams in search of a possible solution to a real problem. Teams of four students put into practice what has been learned during the semester courses on one integral project.

In the collaborative framework multidisciplinary students (engineering, architecture, business administration, marketing and business entrepreneurship) work on a real strategic design assignment under mentorship of university lecturers and industry professionals. Projects are carried out through collaboration between students of the master degree and companies. RLLL provide a dynamic integration of practice and theory.

Among all the experiences carried out over the past five years, this communication presents one of them. The case has been chosen for its impact on the company, due to the good reception of generated solutions. Next, the method and framework used in the case study is described.

3.1 Method and framework

In the projects students followed a general design process. Even if the purpose of PBL approaches and design approaches are different -learning on the one hand, and design outcomes (products, services, spaces, interfaces, etc.) on the other-, similarities between both approaches are evident. On the one hand, PBL is focused around the investigation, explanation and resolution of problems (Barrows, 2000; Torp and Sage, 2002). On the other hand, the general design process focuses on exploration, ideation and development of design outcomes (Brown, 2009). Both approaches tend to explore solutions to complex problem scenarios. In addition, students (as designers do), ask the key questions and tend to solve them exploring facts that will guide towards possible solutions. Both approaches include a reflection phase for evaluating the followed process and the achieved results. Finally, in both processes the proposed solutions are tested for validating the hypothesis. As a result, the design process is proposed as the conducting process for the PBL practical experimentation.

The methodology used for the development of the case studies is composed of three phases: exploration, ideation and development. The phases are a simplified version of Mondragon University's Design Innovation Center's design methodology (DBZ, 2014) adapted for its implementation in the PBL project. Figure 1 shows the methodology that was followed, highlighting the performed phases by the students.

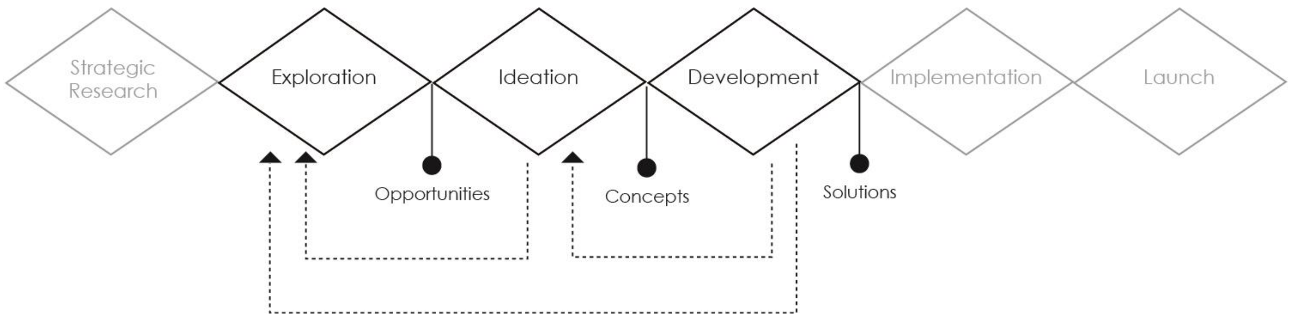

Figure 1: Adapted design methodology in the PBL.

As follows, the case study is presented. The objective, project approach and case development are detailed.

3.2 Case study

This case study is developed together with a small-medium industrial company with two business areas: prototypes and manufacture of products on one side and checking fixtures on the other. The company operates in the automation and health sector, and it is specialized on the pre-launch phase of product development. Its offer focuses on guiding and giving support to a diverse variety of companies on the design and development phase of their products.

The project collaboration starts with the company's wish to ideate, develop and introduce its own product to the market in order to develop a new business activity. In this context, the company gets in contact with the university to show its willingness to collaborate on this exploratory project. Mondragon University identifies second year strategic design master students as the most suitable student group to develop the project. Students in that semester develop and acquire the competences related to brand and product strategy, trend analysis and new product economics, among others.

On the one hand, the aim of the project is to give support to the company on the exploration and identification of new product development opportunity areas. On the other hand, the collaboration aims to give strategic design master students the opportunity to collaborate and initiate on a real new product development process.

The project has duration of 17 weeks and it is divided in 3 main workshops, according to the phases of the methodology that has been described in the previous section. Figure 2 shows the structure of the PBL project placing the workshops throughout the project.

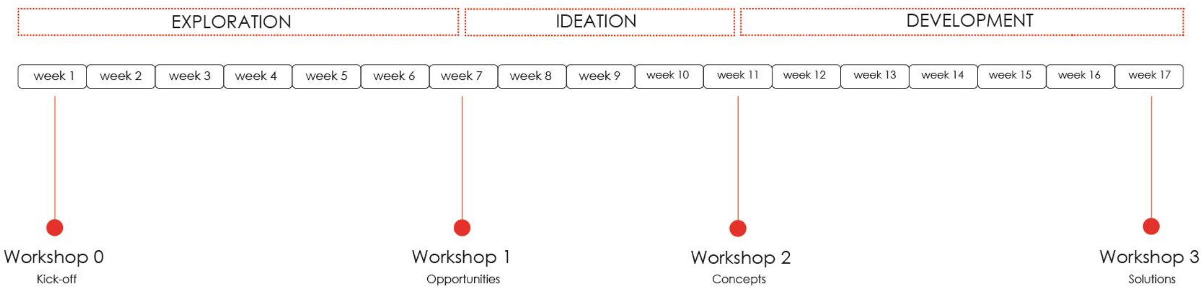

Figure 2: Structure of the PBL project.

Throughout the PBL project strategic design master students work in collaboration with industry professionals: (i) identifying new product development opportunities for the company, (ii) generating new product ideas and (iii) developing the ideas into solutions. In the workshops, along the process, the company provides feedback to students, sharing the company's vision and providing their expertise on specific topics.

Industry professionals, lecturers and students participate in each of the workshops. The student teams get technical guidance from the lecturers of all the courses of the semester, and an additional support of two mentor professors, who contribute to the development of transversal competences of project management, teamwork and communication. As follows, the workshops are described:

Workshop 0: Kick off. Industry professionals and university lecturers collaboratively define the focus of the project, defining the expected outcome from the company and from the academic point of view. The project's kick off is done in the company's headquarters. The company's business manager makes a presentation to the university lecturers and students. The focus of the presentation is to share the company`s vision, challenges and strategy. Furthermore, there is a guided tour around the company where manufacturing facilities are shown to students, as well as the company's capabilities in terms of manufacturing materials and processes.

Workshop 2: Opportunities. Students present the new product development opportunities that have been identified in the exploration phase. Broad analysis is presented by each of the student team, covering company analysis, market and future trend analysis, and user research. As a result of the research analysis, each of the student teams present a design brief that serves as a starting point for generating new solutions.

Workshop 3: Concepts. Student teams present to the company three different product concepts that respond to the previously identified opportunities. At the end of the workshop, discussion teams are set up putting together lecturers, industry professionals and students. In these discussions, the concepts are evaluated and future design directions are redefined if needed.

Workshop 4: Solutions. As the final result of the project, students present a detailed product concept, where, not only technical aspects are defined but business related topics as well: detailed definition of product development (materials, manufacturing processes, etc.), product's brand for commercialization, business model as well as a viability plan, among others.

4 Results and discussion

Once the project is finished, and after workshop 4, semi structured interviews (Rubin and Rubin, 2004) are conducted to the three involved parties: lecturers, industry professionals and students. The focus of the interviews is the collaborative framework that was enabled for the development of the project and the resultant product solutions. As follows, the main outcomes and learnings arising from the presented case are shown.

Industry professionals, lecturers and students indicate that the collaboration has provided advantages for both students and the company. In particular, the project has stimulated the development of technical and transversal competences of students, enabling them to have a more clear vision of the conducted learning process thanks to the realism of the a proposed problem scenario. Stimulating the development of these competences is considered essential in higher technical education (Zubizarreta and Altuna, 2010), and demonstrates value for active learning methods. In addition, the results of the project has added value to the company's business and has operated as an idea generation laboratory in an open innovation set up having limited expenditure of resources, in terms of time and money. Finally, the project has worked as seeding ground for research projects of the university. This has been considered by the participating lecturers as an enabler for future long term university-industry long term collaboration.

Furthermore, thanks to the good reception of the results among the involved industry professional, the project has supported the promotion of the strategic design master's students among the companies in the area. It is expected that this will help in the labour insertion of new graduates.

5 Conclusions

This case has brought students closer to the industry, has promoted strategic design discipline and has supported the participant company in its innovation processes. The framework has enabled an open setting where lecturers, industry professional and students work together on strategic design PBL projects. In this practical case, it has been shown how RLLL seed the ground for new ideas for companies while promoting innovative collaboration on learning processes. As Fink (2002) indicates this is important in order to continue the maintenance and development of the professional competences.

However, these kind of collaborations are still incipient. The authors believe it is necessary to further analyse, from a pedagogical point of view, the inclusion of industry professionals on design learning processes. The authors consider relevant for future research to define further when and how to include companies on design learning processes. This paper has suggested a preliminary guide based on workshops, framed in PBL methods and RLLL. In this sense, the authors suggest a progressive introduction of industry professionals in design education, intensifying the collaboration by the time the students develop more technical and transversal competences, and gets closer to the labour insertion.

In addition, it is also necessary to provide lecturers with methods and tools which enable them co-design academic projects in collaboration with industry. Finally, some other issues linked to Industrial and Intellectual property between industry and students should also be investigated searching for reliable long term collaborations.

So far, five editions of PBL projects have been carried out with 9 companies, involving 36 teams of 75 students in total. It is expected that further analysis of these experimentations will help to build a strong framework for sustainable university-industry collaboration.

6 Acknowledgments

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Students and Staff Perceptions of Project/Design Based Learning in an Engineering Curriculum

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Abstract

This paper focuses on the students and staff perceptions of project/design-based learning in an engineering curriculum. Engineering at Deakin University has used project/design based learning as one of its engineering learning principles for further development in learning and teaching. It is required to improve the learning and teaching process as a holistic approach from the perspective of students' and staff over the entire degree program. Engaging students are an important aspect of the project/design based learning model which it helps students to be self-directed active learners. A project/design based learning environment helps a curriculum to practice career related skills for students, such as practical learning, problem solving, collaborative teamwork, innovative creative designs, active learning, and engagement with real-world assignments. The focus of this paper is to analyse the impact of project/design-based learning in an engineering curriculum. From the quantitative and qualitative analysis performed, the results are analysed and presented from a students' and staff perspective about project/design based learning within the curriculum. This paper is also concerned with enhancing staff and students engagement through project/design based learning. The feedback was sought from students on project/design-based learning. Additional feedback is also needed from staff members who teach and perform research in engineering design. The survey results shows more than 50% of students and 75% of staff views on project/design based learning proven that the impact of project/design based learning is helps to enhance of student and staff interaction in the School of Engineering at Deakin University.

Keywords: Students perceptions, Staff perceptions, Project/Design based learning

1 Introduction

Design based learning education is a form of project/problem based learning in which students gain knowledge while designing a solution (object or artifact or report) meaningful to the students. It involves collecting information, identifying a problem, suggesting ideas to solve it and evaluating the solutions given. Once students have chosen the problem to focus on, they design a solution to solve it. Finally, the students receive feedback on the effectiveness of their design both from the facilitator and from other participants. Design-based learning (DBL) is especially used in scientific and engineering disciplines (Dopplet, 2008). It is inspiring for students and staff members to understand the project oriented design based learning approach and to implement it in all engineering design courses and programs. The Design-Based Learning program is a cutting-edge, inquiry-based curriculum that engages students in simulations and understanding of essential questions. Engineering science and technology are at the core of its challenging multi-disciplinary curriculum Engineering at Deakin University has used project/design-based learning as one of its engineering learning principles for further development in teaching and learning. This research intends to encapsulate the perspectives of students and staff about a particular approach. The focus of this paper is to analyse student and staff perceptions of project/design based learning in an engineering curriculum.

2 Project/Design Based Learning in Engineering

Project Based Learning is perceived to be a student centred approach to learning (Frank, Lavy, & Elata, 2003; Kubiatko & Vaculová, 2011). It is predominantly task oriented with facilitators often setting the projects. Students need to produce a solution to solve a project and are required to produce an outcome in the form of a report guided by the facilitators (Kolmos, 1996; Graff, 2007). Teaching is considered as an input that directs the learning process. The problem is open ended and the focus is on the application and assimilation of previously acquired knowledge.

Design based learning (DBL) is one type of project-based learning which involves students engaged in the process of developing, building, and evaluating a product they have designed (Dopplet, 2008). In engineering science classrooms, DBL opens new possibilities for learning science. Working and completing design based activities can make students feel proud of their achievements, as well as building up their confidence as thinkers, designers, and that will benefit them through their education and life. Design based learning encourages a thriving learning context for students' active participation and construction of knowledge instead of passively learning about engineering science from textbooks and lectures (Doppelt & Schunn, 2008). Overall, design based learning supports encouraging evidence that this project/problem based learning that which increases students' science content knowledge and engagement working on the design challenge, enables students to transfer knowledge into another task, learn through collaboration, and develop students' positive attitudes towards engineering design education.

At Deakin University, the engineering program involves Design-Based Learning, or DBL projects at different levels of course structure. It engages students in real-world assignments. It starts right from the first year of engineering. In the DBL projects students will work in a group of approximately four to six students on absorbing innovative issues. In this way, students will gain an idea of the field of work and students will learn to work in a team and try to solve problems by using technical and psychological knowledge. This is important, because in the future students will often cooperate with people from other disciplines. Students will often be the bridge builder between (technical) specialists, the consumer and society.

3 Methodology

When considering the significance of students' learning outcomes and the teaching requirements of staff in design education, this research intends to encapsulate the perspectives of students and staff about a particular approach. Engineering at Deakin University has used project/design-based learning as one of its engineering learning principles for further development in teaching and learning. The qualitative and quantitative paper based survey method is used to obtain students' perspectives. Face-to-face interviews are used to obtain the perspectives of staff on the design based learning approach. Data collected from these surveys and interviews are from the experience of students and staff on project/design-based learning. The research consultation process obtained ethics approval from the higher degree research ethics committee of the School of Engineering at Deakin University. The views of students' on project/design based learning in this research come from senior level undergraduate engineering student. The perspective of staff comes from staff members who are teaching and practicing project/design based learning. From the quantitative and qualitative analysis performed, the results are analysed and presented from a students and staff perspective about design based learning within the curriculum. The paper-based survey is given to more than 50 students in their classroom and around 26 of them responded to the survey. The face-to-face interview is conducted with 18 staff members. The collected data were analysed and converted to quantitative and qualitative data form.

4 Project Oriented Design Based Learning Model

The new learning and teaching model Project Oriented Design Based Learning (PODBL) is focused on curriculum renewal to practice innovation and creativity for students who are learning to solve design problems through projects in engineering education. Studying engineering not only involves learning scientific knowledge and technological skills, it also involves learning the language, established practices, beliefs, and professional values of engineering culture that makes a student an engineer. Problem solving is one of the important skills for students therefore the goal of all engineering programs is to teach problem solving skills to educate students as professionals. Industry is looking for professionals with design knowledge, combined with creative and innovative interdisciplinary thinking.

The PODBL model focuses on skills such as innovation and creativity in the engineering discipline through investigation of various design projects in engineering, the perceptions of students on design based learning, and the views of staff on design based learning, in addition to industry requirements for design education. The new learning and teaching model, Project Oriented Design Based Learning is applicable to motivate students and teach engineering design so more practical experience is gained so academic and industry needs are met. Chandrasekaran et al (Chandrasekaran et al, 2013; Chandrasekaran et al, 2013, 2013) (Chandrasekaran et al, 2013; Joordens et al, 2012) intended that Project Oriented Design Based Learning has been established to have a positive effect on students' content knowledge and development of skills such as innovation and creativity, which increases their motivation and engagement.

Chandrasekaran et al (Chandrasekaran et al, 2012; Chandrasekaran et al, 2013) proposed that the learning space that exists in the PODBL model has been specifically designed for engineering students who work in teams on PODBL projects. The students need well-developed generic attributes, including the skills associated with oral and written communication, working in teams, locating and evaluating information and project management. This emphasis on generic attributes is reflected in the accreditation requirements of Engineers Australia, the professional engineering body in Australia.

PODBL indicates that students learn through real engineering design activities while driven by a project that has a defined deliverable that is presented to them by industry partners or academic staff. Figure 1 shows PODBL process. The PODBL cycle involves seven main steps. The steps are illustrated in Figure 1. Steps 1-4 and step 7 take place in a combination of both cloud and located learning, and Steps 5 and 6 are performed through located learning. There are many versions of project based learning as well as design based learning. This new learning and teaching model is a unique combination of the two. In our version, participants work in PODBL teams of four to six members with a facilitator. The same group meets regularly throughout the trimester to work on a series of design activities. The learning and teaching delivery is a combination of cloud and located learning activities. Cloud learning (online learning) enables students to evidence their achievement. Units contain integrated short, accessible, highly visual, media-rich, interactive learning experiences rebuilt for the mobile screen, with integrated learning resources created by Deakin and other worldly universities and premium providers. Cloud learning will require students to be generators of content, collaborators in solving real world problems, and evidence their achievements in professional and personal digital portfolios. With premium cloud learning experiences in place, students who come to campus will have the opportunity to engage with teaching staff and peers in opportunities for rich interpersonal interaction through large and small team activities.

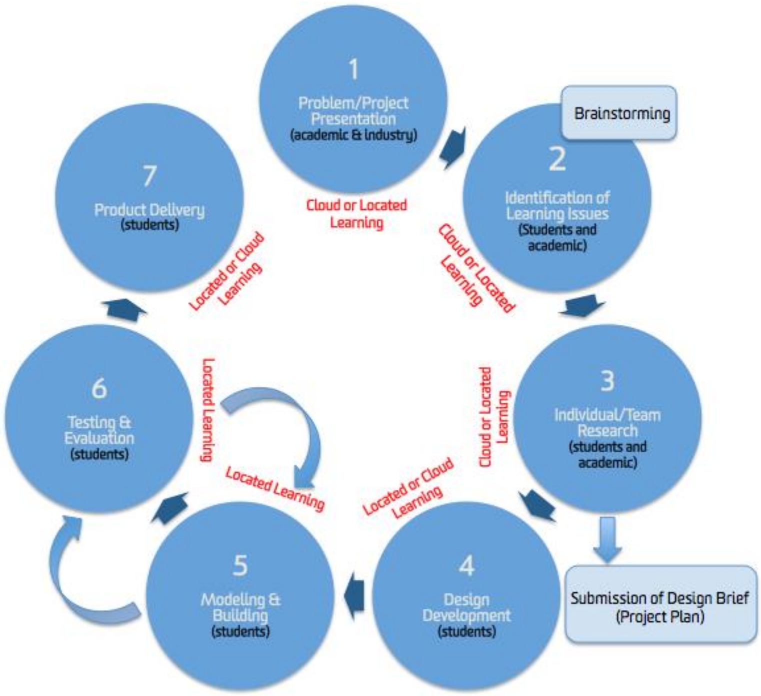

Figure 1: PODBL process

PODBL is a teaching and learning approach (TLA) that is based on engineering design activities undertaken during a project. PODBL encourages independent learning and a deep approach to learning. The Project Oriented Design Based Learning (PODBL) approach is encouraging in enhancing the student/staff interaction in engineering education. The PODBL is based on five learning principles such as research-based learning, student driven learning, outcome based learning, analytical thinking and collaborative based learning. These five learning principles are all constructively aligned and underpinned by constant engagement between students, staff, community and industry. Thus PODBL allows current students, staff, and industry perceptions to remodel pedagogy without distracting from the curriculum.

4.1 Student Engagement through PODBL

Engaging students is an important aspect of the learning and teaching process because it enhances students to be self-directed active learners. To measure student engagement and the experiences of staff in the learning and teaching process, engineering at Deakin has used design based learning as one of its engineering learning principles. All engineering curriculum has the responsibility of educating students in their engineering disciplines. Students have responsibility for the quality of learning and teaching. In each learning process, a student learns at their own pace and in their own learning style to achieve educational objectives. Through a chosen learning career path, students obtain a great opportunity to gain self-knowledge that helps them attain their full potential. The role of students in the Project Oriented Design Based Learning approach is as follows:

- Ability to observe and react in a professional environment (self-directed).
- Identify and solve problems with interactive knowledge.
- Getting involved with the practical application of knowledge.
- Being creative and innovative in solving design problems.

- Be aware of industry graduate expectations and be career focused.
- Seek support and guidance from staff members.
- Contribute engineering knowledge to the needs of society.
- Adapt to new values, customs, and learning styles in a working environment.

The ongoing personal and professional development helps students sustain life-long learning skills such as critical thinking, self-directed learning, interpersonal skills, self-confidence, creativity and innovation.

4.2 Staff Engagement through PODBL

The Excellent learning and student engagement is a positive experience and also a result from quality teaching. Over many decades, researchers believe students will engage more deeply and learn more thoroughly when their teachers care about them to educate, learn, communicate and be innovative in the classroom. Academics need the perspectives of students' to analyse their experience in practicing and learning a particular approach. It also helps teachers to understand the level of expectation of students in their area of expertise. A teacher must ensure that course design, program structure, teaching and learning assessment should help learners to learn. The role of staff in PODBL is as follows:

- Developing and presenting consistent and creative resources for student learning.
- Implementing Project Oriented Design Based Learning approach to learning and teaching engineering course units.
- Communicating with students to meet their objectives and expectations for self-directed learning.
- Enhancing learning outcomes and teaching methods by actively engaging students.
- Inspiring and motivating students through project driven design based learning.

5 Results

The questions covered here are designed to determine the perspectives of students and staff on project/design based learning through their own level of experience in learning and teaching engineering design from undergraduate engineering.

Table 1: Students perceptions about project/design based learning in the curriculum

Students Perceptions on project/design based learning in the Curriculum	%
No answer	37
Practical learning, demos in classes, more practical less theory	26
Learning through projects, design techniques	7
Integrate with teaching (individual DBL units)	15
Labs, practical's, tutorials, more assessments based on practical's	15

Table 1 indicates the perceptions of final year students about project/design based learning in their curriculum, 26% of students experiencing project/design based learning as practical learning, and demos in their classroom. More than 50% of all students believed project/design based learning was learning through industry related projects or learning through projects, design techniques. When students were asked about the influence of project/design based learning in their future career, about 55% of final year students believed the influence of project/design based learning does help in the engineering curriculum (Table 2).

In addition, Table 3 shows that 55% students perceived project/design based learning is important in their final year project. Almost 22% of students strongly maintain that project/design based learning is very important in their final year. It can be clearly shown in Table 2 shows that 30% of final year students recommend project/design based learning as necessary for their future engineering careers Project and design based learning approaches are used to transform these skills into active learning and to evaluate student progress in classrooms. Lehmann (Lehmann, 2008) also declares the purpose of design education is to enhance learning in order to teach students to become active participants in solving design problems around them.

Table 2: Influence of project/design based learning in future career

Project/design based learning to your career	%
Does not help	0
No effect	0
Possibly helps	15
Does help	55
Is necessary	30

Table 3: Importance of project/design based learning in final year project

Project/design based learning in final year project	%
Does not help	0
No effect	4
Possibly helps	55
Does help	19
Is necessary	22

The aim of this paper is also to obtain the staff views on project/design-based learning through face-to-face interviews. Table 4 shows that 15% of staff members agree and 85% of staff members mostly agree that design is an essential element of an engineering program. These staff members teach and undertake research in engineering design in the School of Engineering at Deakin University. Staff were also asked about their perceptions on possible ways to teach design. Table 5 illustrates staff perspectives about possible ways to teach design, such as team based learning, activity based learning, analytical thinking and self-directed learning. It is clearly illustrated in table 5 that staff views on possible ways to teach design are really encouraging for design based learning curriculum. From Table 6, it can be seen the majority of staff strongly accept their curriculum involves project/design based learning.

Table 4: Engineering design as an essential element

Engineering design as an essential element	%
Agree	15
Mostly agree	85

Table 6: Curriculum involves project/design-based learning

Curriculum involves project/design based learning	%
In Transition status	5
Possibly yes	20
Strongly yes	75

Table 5: Possible ways to teach design

Possible ways to teach design	%
Team based learning	15
Activity based learning	35
Analytical thinking	20
Self-directed learning	30

Table 7: Skills attained by students

Skills attained by students through project/design based learning	%
Teamwork & communication	30
Learning by doing	45
Problem solving	45
Self-directed learning	40
Creativity	70

Table 7 illustrates staff perspectives on the skills attained by students through project/design-based learning. The majority of staff members mentioned that creativity, learning by doing, problem solving, and self-directed learning are the most important skills attained by students through design based learning in their curriculum. The engineering teaching staff at Deakin University obtained an adequate understanding of project/design based learning, as illustrated from the results shown above. The above students and staff views proven the enhancement of student learning and staff engagement are better aligned with the newly developed PODBL model.

6 Conclusion

The project/design based learning approach is encouraging because it allows current students, staff perceptions to remodel pedagogy without distracting from the curriculum. It is inspiring for students and staff members to understand the approach and to implement it in all engineering design courses and programs. The above results shows more than 50% of students and 75% of staff views on design based learning proven the enhancement of student learning and staff teaching processes in the School of Engineering at Deakin University. This paper focus on students and staff perceptions on project/design based learning in an engineering curriculum. The above results shows that students and staff views were better aligned with the PODBL model.

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A 3-2 Modification of the 2-3 McMaster PBL Model: Increased Student Engagement through Role-Playing?

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Abstract

A qualitative pilot study with five Korean students on a ten-day PBL training workshop in Hawaii was conducted to determine if modifying the McMaster PBL method of two-three hour tutorials per week to three-two hour tutorials per week would result in increased student engagement and motivation. The 3-2 modification enabled students to acquire knowledge in the first day and to apply the knowledge in the subsequent tutorials by role-playing the physician (forward PBL) or by actually writing new PBL case and role-playing the patient, while the tutor role-played the physician (reverse PBL). In addition, a senior student was used as the tutor, while a faculty member from Hawaii served as a co-tutor/ observer. Use of the senior student may also have contributed to the increased engagement by students. Various aspects of the study were discussed briefly in terms of Barrow's description of hypothetico-deduction, Bloom's taxonomy of educational domains, and the implications Hofstede's cultural framework on teaching and learning in Asian cultures. It was concluded that Asian medical schools considering implementation of PBL may want to consider further study of the implications of role-modeling and the 3-2 model.

Keywords: PBL, role-playing, reverse PBL, student motivation

1 Background

The McMaster PBL model traditionally consists of two-3 hour tutorial sessions per week. In the first session, the "hypothesizing phase," students typically examine all the pages of a PBL case, generating and narrowing hypotheses and as more and more patient information is received successively. The second PBL session is typically termed the "reporting phase," where unclear basic science, clinical, populational and behavioral issues related to the case are reported on. Recently, Korin and co-workers (2014) used Self-Determination Theory to explain why the "hypothesizing phase" tends to be more active, energetic, and invigorating, when compared to the "reporting phase." They argue that in the first phase, students should be given the opportunity to take on the MD role and "assess their clinical competence" and "make decisions that have consequences for the patient."

The University of Hawaii, the Prince of Songkla, and Kyungpook National University Schools of Medicine implemented various degrees of the 2nd iteration of the McMaster PBL curriculum in 1989, 1990, and 1999 respectively. Kyungpook National University School of Medicine brought small groups of students for PBL training sessions to Hawaii in 2007 and has continued to send students each year. Shantou University Medical College plans to initiate PBL for 30 of its yearly intake of 300 students in 2016.

The 1990's version of the McMaster PBL curriculum calls for two 3-hour sessions per week (2-3 model). Each 3 hour session is divided into 1.5 hour halves (a + b) (Table 1, top). Generally, all pages of a new PBL case are opened and processed in the second 1.5 hour (b) of a tutorial. Learning issues are identified, and students return three days later from research to discuss their findings and close the case in the first 1.5 hour (a) of the next session. After a ten-min break, students then begin the next PBL case.

While the University of Hawaii has not had any problems with the 2-3 model, we have observed that Asian students visiting Hawaii for PBL training workshops seem to have more difficulty with the initial hypothesis generating phase. The reasons for this are probably multifold, but may be due largely to the fact that most medical schools in Asia take students directly out of high school; whereas, at McMaster, Hawaii and medical schools in the west, beginning students have undergraduate baccalaureate degrees, have shadowed clinicians for months, volunteered at community clinics, and even traveled abroad to participate in international service projects with local physicians. Hence, students in the West usually bring rich and varied past clinical experiences into tutorials. This is not necessarily so with Asian students just out of high school and may lead to difficulty hypothesizing.

A second problem appears to result in dampened first "hypothesizing phases" by Asian students. Many students have privately said that they feel uncomfortable openly discussing possible hypotheses with faculty tutors at their home institutions. Again the reason for this is unclear, but may be related to Asian cultural norms that require students to listen in the presence of teachers. Thus, Asian tutors may not want to hamper student discussions by saying too much, and students are unlikely to risk "thinking aloud." Obviously, this is not a problem in the west, where students readily challenge each other and their tutors.

We believed that these problems might be solved by making four modifications with the 2015 Winter PBL Training Session with students from Korea. First, we introduced a format in which the McMaster 2-3 method was replaced by three-2 hour tutorials (3-2 format) (Table 1). Only page one of the case was opened on the first day. We then urged the tutor to "prompt heavily" and facilitate generation of a broad list of hypotheses, as many as five to ten per chief complaint. We reasoned that allowing students to research and investigate many hypotheses after examining page 1 of the PBL case would result in students having more knowledge, which could then be applied to the case (and increase student engagement) during the first of two reporting phases.

A second modification was the introduction of the Triple Jump (TJ) method for conducting tutorials. This technique has been used effectively in Hawaii for many years. Although not an assessment, it is based on the TJ assessment designed at McMaster (Painvin *et al*, 1979), initiated years ago (Smith, 1993) and still used at Hawaii today. In the TJ method, the tutor acts as a simulated patient and provides information to the student only upon request. For example, in a case of patient with chest pain, the student must first ask, "When did the pain start?" "How long did it last?" "Can you describe the pain?" "On a scale of 1 to 10, where 10 is the most severe pain that you have ever experienced, how would you rate the pain?" Only after students have completed inquiry, is the page of the PBL case on patient history passed out to students. It was hypothesized that use of the TJ method would allow students to apply what they had learned (forward reasoning) and would result in increased engagement and motivation.

A third modification was a role-reversal between students and the tutor. In reverse PBL, students were asked to write a PBL case and to role-play the patient, while the tutor role-played the physician and attempted to make a diagnosis and solve the patient problem. That is, students were asked to write a PBL case on a disease which was in the differential being studied, e.g. streptococcal pharyngitis in sore throat. Now, the tutor was challenged to ask pertinent questions which would rule-in or rule-out various hypothesis in the differential.

The fourth modification was the use of a senior student as the tutor. We believed that there might be more vigorous discussion in the Asian setting when the faculty tutor was replaced by a senior student. In these pilot studies, the senior student was always accompanied by a faculty co-tutor as observer/supervisor.

2 Qualitative Methods

Five students (who had just completed their first year) from Kyungpook National University School of Medicine, Daegu, Korea (four year program) and one 5th year student from Fudan Medical School, Shanghai, China (eight-year program) attended a ten-half-day PBL training workshop at the University of Hawaii School of Medicine. The Shanghai student had passed USMLE Step 1 and was preparing to take the USMLE Step 2 Clinical Skills. He had worked with Hawaii faculty and other Asian students using e-Learning over the past year and served as a senior student tutor. The workshop consisted of ten two-hour sessions, with an additional hour for questions-answers. Each two hour session was designed to reflect the first and second hours, respectively, of the proposed "3-2" tutorial method. Therefore, PBL was "accelerated," because there was no intervening day for additional research that would be otherwise present in the actual 3-2 model. Each new PBL case was processed in four hours spread over three days as shown in Table 2. Groups evaluated at the end of each day and the faculty co-tutor observed, took notes, and commented when appropriate.

At the end of the workshop, students were asked to complete a questionnaire on the "helpfulness" of three of the modifications used in the workshop; namely, student role-playing as the physician (forward PBL), student as case-writer (reverse PBL), and senior student as the tutor. The questionnaire used a 5-point scale with strongly agree (5 pts), agree (4 pts), no-opinion (3 pts), disagree (2 pts), and strongly disagree (1 pt). In addition, students were asked to rank the above learning activities with ten additional learning activities or workshop features experienced by students. These included case-mapping, concept-mapping, and curriculum-mapping, among others. The student rankings were scored as follows: most helpful 1st (5 pts), 2nd most helpful (4 pts), 3rd most helpful (3 pts), 4th most helpful (2 pts), and 5th most helpful (1 pt). The surveys also had space for open-ended optional written comments. All questionnaires were completed anonymously. One student had to leave on day eight of the training session, and his responses were not included. Qualitative studies on this group will continue as they return to their home institution and continue their studies.

3 Results

3.1 Student role-plays physician (tutor simulates patient) – Forward PBL

The first case was a high-school student who complained of sore throat. Initially, students had difficulty hypothesizing possible causes of sore throat in an adolescent student. If the 2-3 method had been used, students would have made the differential diagnosis of sore throat a learning issue and gone on to page 2, then to page 3, and on to finish the case. However, only page 1 was opened in the first session of the 3-2 method. After students had exhausted ideas, the tutor began prompting heavily. "Has anyone ever heard of "fever blisters?" "Could herpes infection cause sore throat?" A discussion followed, and

Herpes simplex virus-1 was added to the hypothesis list. The tutor continued prompting heavily. "Could a sexually-transmitted disease cause sore throat?" Discussion followed on oral sex and *Neisseria gonorrhea.* Gonorrhea was then added to the hypothesis list and became a second learning issue. Heavy prompting continued until students had listed six hypotheses – again after opening only page one of the case.

For the first self-study period, each student was asked to investigate all six hypotheses, unlike in the traditional 2-3 method, where usually each student would study one learning issue and report back during the next tutorial. In addition, students were told to make brief summaries and fill out a template termed the Group Research Issue Display (GRID). This was a one page display of various infections (horizontal rows) vs. chief complaint, patient history, physical exam findings, laboratory findings, treatment, and course of illness (vertical columns). The tutor asked students to focus primarily on clinical observations that would help the physician make a diagnosis. For example, the tutor explained, "Fatigue is often found in patients with infectious mononucleosis. We call this a pertinent positive. If the patient denies fatigue, mononucleosis is less likely and this information becomes a pertinent negative and makes mononucleosis less likely." When students returned for the next tutorial, the first half of the period was spent on comparing GRIDs and reaching agreement on what the pertinent positives and negatives were for each infection.

Once the students had reached agreement, the senior student tutor announced that he would "role-play" the patient with sore throat. Students should role-play the physician and take turns asking questions about the patient's history. Only after students had exhausted all questions on the patient history, was page 2 of the case be handed out. Students then carefully read through the page, noting what they had correctly asked and what they had missed. Subsequently, students went through their hypothesis list and, after processing only the second page of the case, designated each hypothesis as being more-likely by an up (↑) arrow, and less-likely hypotheses by a down (↓) arrow.

When this was completed, students went on to page 3 of the case, which contained the data from the physical examination. The tutor asked, "What would you like to know from the physical exam page? Students asked, "What are the vital signs?" "Is there a tonsillar exudate?" "Is there posterior cervical lymphadenopathy?" Again this process was continued until all students passed, page 3 was handed out, examined, and ↑ or ↓ arrows again added to each hypothesis. By page 3, student were pretty much convinced, based on their inquiry, that the patient was suffering a case of infectious mononucleosis.

For laboratory data (page 4), students requested a complete blood count with differential. When the laboratory data revealed that monocytes were elevated and "atypical lymphocytes" were present, students knew that their diagnosis was correct. The finding of heterophile antibodies in the laboratory data further confirmed their diagnosis.

Page 5 contained the patient treatment. The tutor asked, "What will you tell the patient? Given your diagnosis, what is the significance of the bruises found on the patient's face? What is the significance of the hepatosplenomegaly?" Students quickly remembered that the patient's step-father was unemployed and an alcoholic. Therefore, the problem of child abuse in the setting of alcoholism became critical in the treatment of this patient. Splenic rupture could be fatal in patients recovering from infectious mononucleosis. What followed was a brisk discussion of what should be recommended to the patient.

Overall, we noted that students were highly enthusiastic, energetic, and engaged when “role-playing” the physician. Qualitatively, this differed from previous years in which visiting students appeared to have difficulty hypothesizing and were far less engaged, actually somewhat passive, when examining pages 2-6 of a PBL case.

3.2 Students as case-writer and simulated patient (tutor role-plays physician) - Reverse PBL

The second case was, a 17 year-old boy who presented with rash for the past two days (a case of Lyme disease). Again, only page was opened on the first day and with heavy prompting, students ended up with a list of ten infections. As in the first case, students returned the next day and enthusiastically made a correct diagnosis, while role-playing the physician (as the tutor role-played the patient).

For the self-study period, however, students were given another option. Instead of researching basic science, behavioral or populational learning issues, they could collaboratively write a new case which presented similarly, but was due to a different infection just studied. Students were told that at the next tutorial, roles would be reversed. Students would role-play the patient, while the tutor would role-play the physician. Students accepted this challenge. The next day, the tutor was presented with the case of a pregnant mother who presented with rash on the hands and feet. Using reverse-role-playing, the tutor began asking questions of the students as simulated patients. Students had to answer based on information that they had written into the new case. If there was no information, they would reply, “No information.” Eventually, the senior student tutor made correct diagnosis of secondary syphilis. The senior treated the patient with penicillin and provided advice about the possibility of congenital syphilis.

The students seemed to have great interest and enthusiasm in “reverse PBL.” At the daily evaluation session, one student commented that reverse PBL was good because “the distinctions between the different diseases became very clear.” Another student commented that the “pertinent negatives stand out.” In the final ranking of learning experiences, students ranked “student as a case-writer and reverse PBL” as the second most helpful learning activity (13 pts) during two week-training session (Table 3). It was second only to observation and participation in a mixed tutorial with Hawaii students (17 pts) as the most helpful activity overall. On the exit questionnaire on the final day of the training session, students were presented with the statement, “*Based on their research, students were given the opportunity to write a new PBL case. Students then played the role of simulated patient, while the tutor played the role of the physician. I found this aspect of the PBL training session to be very helpful*.” All four students strongly agreed with the statement, and all four students wrote comments in the optional open-ended box:

> “By writing a new PBL case, I needed to study and think more deeply and consider many things. I try to make the case to be flawless, but it was hard, but interesting also.”
>
> “It’s very interesting! Designing Reverse PBL is very interesting and requires more details! And thru all process consolidate my medical knowledge.”
>
> “By doing this, we can know how PBL cases and many clinical case are designed.”
>
> “The best part of the PBL was Reverse PBL!! Trying to write a PBL case was complicated. We need to consider lots of things, not only the symptoms of disease, but also background of patients, such as social status, social role, and so on. Also becoming SP was fun. I can see how tutors were approaching (*during the actual reversal of roles*) to get proper information they want.

> And it was good opportunity for me to think as a patient. It encourage me to become much care doctor."

3.3 Use of a senior student as tutor

In these sessions, a senior student was used as the tutor, with a faculty co-tutor as an observer/supervisor. On the last day of the ten-day training session, the exit questionnaire asked students to rank the five most helpful learning activities experienced during the training session (Table 3). The student as a case-writer (reverse PBL) was the 2nd most helpful activity and having a senior tutor as the third. Written comments included the following:

> "Having (*senior*) tutor who is very knowledgeable about the topic was VERY HELPFUL. Sometimes, as a student who just get started in medicine, (we) cannot easily connect dots. But having knowledgeable tutor was able to broaden knowledge, but also inspirational. I got motivated a lot!!!."

> "Senior tutor really stimulates us. They can talk about medical topics in the viewpoint of students."

As an example of the above, the faculty tutor noted the following feedback given to visiting students by the senior student during one of the end-of-tutorial evaluations:

> "If students practice PBL this way (*referring to the eliciting information from the tutor as simulated patient*), they will be way ahead!" (*At the time, the senior student was preparing for the USMLE Step 2 Clinical Skills Examination*).

We have also observed that senior students, used frequently in Hawaii for many years, differ from faculty tutors in that seniors have recently taken the USMLE Step 1 and Step 2 and understand the requirement for broad but focused learning in the first two years. For example, the senior student tutor was heard telling visiting students, "Lyme disease is high yield for the USMLE."

4 Discussion

In some cases, PBL can be largely passive. If, for example, medical students do not have sufficient prior experiences for knowledge activation, then working through the pages of a PBL case can deteriorate into identifying what is unknown, making learning lists, research, and follow-up peer-reporting/teaching in the subsequent tutorial. If tutors are inactive and are not tasked to prompt heavily and to "plant" seeds of inquiry, the PBL process can also deteriorate to passive learning. In this pilot study, only page one of the PBL case, revealing the chief complaint, was opened by students. After students had offered a limited hypothesis list, the tutor began prompting heavily. This resulted with an expanded hypothesis list, as few as five but as many as ten possible causes of the chief complaint. During the first research period, students were directed to research all hypotheses and to independently fill out their individual GRIDs. In doing this, students compared and contrasted each of the infections in terms of patient history, physical exam findings, laboratory findings, treatment and course of illness. Use of the GRID helped students focus on the key findings in each of the characteristics that helped physicians differentiate between contending hypotheses. In using the GRID, students were learning to focus on pertinent positives, key findings that would rule-in a hypothesis and pertinent negatives, key findings that would rule-out other hypotheses. Students knew that these findings were important, because they would be role-playing the physician in the next session and key findings would emerge in the subsequent pages of the PBL case. Thus, addition of a third tutorial allowed students to hypothesize broadly during the first tutorial and then deduce from subsequent data a patient diagnosis – a process termed hypothetico-deduction.

The most important set of abilities the physician must possess are those associated with the clinical reasoning process (Barrows & Tamblyn, 1980). Furthermore, the authors argued that clinical reasoning should be considered the scientific method of clinical medicine. Medical school must throughout the curriculum teach principles of the scientific method, including analytical and critical thinking (World Federation of Medical Education 2012 Revised Global Standards). Thus, redesign of the McMaster 2-3 system by adding a third tutorial will emphasize hypothetico-deduction, enhance clinical reasoning, and introduce the scientific method throughout the curriculum.

Addition of the third tutorial also enabled students to apply what they had recently learned. In his taxonomy of educational objectives, there are three domains (Bloom et al 1956). In the knowledge domain, acquisition and comprehension of new information – which involves learning, recall, discussion and summary of new knowledge, are considered lower levels of learner expertise. On the other hand, applying newly gained knowledge, for example role-playing the physician, would be considered a higher level of knowledge expertise. Analysis, for example identifying pertinent clinical positives and negatives through comparison and contrasting of GRID patterns, would be considered an even higher level. Finally, synthesis and creation of new ideas, for example the writing of a new PBL case, is one the highest levels of knowledge expertise. In this study, students appeared to be challenged and deeply engaged by the higher levels in the knowledge domain.

In recent years, we have departed from the peer-teaching that usually characterizes the passive reporting phase in the 2-3 model. The most recent McMaster Tutor Guide advises that "at all costs, a series of mini-lectures by students is to be avoided" (Walsch, 2005). Instead, we have introduced alternatives such as the "group LI" in which all students research the most important Learning Issue and, here, the GRID, which is filled out by all students. The first half of the second tutorial then is characterized by discussing, demonstrating, summarizing, and explaining, instead of reporting. Further, we have introduced case-mapping (mechanistic case diagramming) and concept-mapping to replace peer-teaching and reporting in the follow-up phase. However, even these mapping activities would fall at the lower end of the knowledge domain in Bloom's taxonomy. Only one visiting student ranked any of the mapping activities in the top five (5^{th} for case-mapping), while role-playing in forward- and reverse-PBL was highly ranked by all students (Table 3). This suggests that it may be time in the development of PBL to de-emphasize knowledge acquisition and emphasize higher levels of knowledge application and synthesis.

In addition to the knowledge domain, Bloom's classification also describes skills-based as well as affective types of educational goals. Use of forward-PBL (where students role-play the physician and must inquire using appropriate language and choice of terms) and reverse-PBL (where students collaboratively write a new PBL case and role-play the simulated patient) creates learning opportunities in both latter domains. An example of where a learning occurred in the skills-based domain is evidenced by the statement from one student, "We need(*ed*) to consider lots of things, not only the symptoms of disease, but also background of patients, such as social status, social role…" Examples of affective learning outcomes were the statement from students who wrote, "I got motivated a lot" (referring to working with the senior student tutor) or, "It encouraged me to become a much care physician" (*referring to thinking like a patient in reverse PBL*).

In this pilot study, visiting students appeared to be highly engaged during the return sessions of the 3-2 method, doing forward and reverse role-playing. In previous years, students from this Korean medical school were generally less energetic and less engaged in both opening and return sessions using the 2-3 method. Students had difficulty hypothesizing in the opening sessions and seemed to be uncomfortable in return sessions when asked (by Hawaii tutors) to discuss, debate, decide, deliberate on issues they found confusing. In the 3-2 method, however, the return sessions were replaced by role-playing. Geet Hofstede is widely known for his pioneering work on the five dimensions of culture: power-distance, individualism-collectivism, masculinity-femininity, uncertainty-avoidance, and long-term orientation. Problem-based learning evolved out of the west and has flourished in cultures with scores at the generally at the opposite end of scores for each cultural dimension, when compared with scores for Asian cultures. For example, the scores in the power-distance dimension for Canada (39) and USA (40) are at the opposite end compared with the scores for S. Korea (60) and China (80). In this dimension, learning is student-centered for low scoring countries and teacher-centered in high scoring countries. That is, students regularly initiate discussions in the former, while teachers initiate discussions in the latter (Wursten & Jacobs). Again in the individualism-collectivism dimension, the score for S. Korea (18) is at the opposite end of the scores for Canada (80) and USA (91). In the former, harmony in the group is generally expected and it is important for any member not to lose face, while confrontation and challenge is expected in the latter, and loss of face is quickly brushed off. Finally, in the uncertainty-avoidance dimension, USA (46) and Canada (48) are again at the opposite end of the spectrum from S. Korea (85). In this dimension, low-scoring cultures generally find intellectual disagreement stimulating, while high scoring cultures find intellectual disagreement a sign of personal disloyalty (Wursten & Jacobs).

The PBL model practiced in Hawaii was adopted from McMaster, largely without modification. Thus, with previous visiting students from Korea, we had been trying to introduce an educational pedagogy that evolved out of the west, while students from this country are more comfortable with a teacher-centered, authoritative, non-discussive approach to teaching and learning. Now we must ask whether the removal of discussion sessions of the 2-3 model was really the grounds for the enhanced student engagement in the 3-2 model, rather than the role-playing and hypothetico-deduction as we had originally assumed and planned. Follow-up inquiry with this focus group will be designed to answer this possibility.

Our thoughts on the use of the senior student tutor in this study are mixed. Originally, use of the senior student was proposed to solve two problems as we move forward into implementation of PBL in Asian medical schools. First, large medical schools in China, some with 500 and 600 students per class, will have difficulty finding sufficient numbers of faculty as tutors. Second as discussed above, most Asian countries have high cultural power-distance-indexes, which are expected to exist as barriers to successful PBL. Asian students are dependent on teachers, treat teachers with respect, and all communication is initiated by the Asian teacher. Therefore, we proposed that newly entering medical students be placed in a vertically structured Learning Societies (Tam and Kwan, 2011). Rather than have an entire class of 600 students of equal age and background as classmates, the newly entering student would be one of 60 freshmen, 60 sophomores, 60 juniors and 60 seniors. Using this model, senior students within a society, having once been tutored by their upper class persons, would serve as tutors and clinical skills preceptors. This could potentially solve both the manpower and cultural barriers to PBL implementation in Asia. Regarding the later, all students in this study rated having a senior student in the top five of helpful learning activities (2nd, 5th, 5th, 4th). In follow-up studies with this focus group, we will attempt to determine which and to what degrees students believed were responsible for increased engagement: role-playing, removal of discussion, or having a senior student as tutor.

We also realize that there may have been educational value for the senior student as well. In this pilot study, we failed to investigate the impact of tutoring, simulating the patient and subsequently simulating the physician, on the senior student. Did he feel that there was any value to role-playing the physician in reverse PBL? Did having to be a role-model and a guide to the younger, visiting sophomores for two weeks have any impact on him? These and other questions will be investigated in follow-up studies.

We felt compelled to report our early findings and share the verbatim comments of students. Their enthusiasm and excitement, so unlike previous groups, was unmistakable and appeared to approach the American Association of Medical Colleges' stated goal that medical schools must "restore a sense of joy and enthusiasm in our medical students for the excitement, wonder, and future of the biomedical sciences and human medicine" (Emerging Perspectives on the General Professional Education of the Physician, 1984).

6 Conclusion

This pilot study suggests that schools may wish to investigate curricular structures which create opportunities for students to analyze and apply new information. In medical education, such opportunities would be afforded by implementation of the 3-2 modification of the McMaster 2-3 model, especially in Asian medical schools. As the acquisition of knowledge (Bloom's taxonomy) becomes less important in current student-centered, self-directed learning models, curriculum planners may want to focus more on application of knowledge and the development of skills and attitudes. In addition, Asian curriculum developers may want to consider that PBL evolved from the west and only portions of PBL, such as hypothetico-deduction, may be practical and useful in the east, which has deeply differing cultural traditions.

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Table 1. Comparison of the 2-3 model vs. the 3-2 model. The 2-3 model (top) has two, three hour tutorial sessions each week. A new case opened in (b) and closed in (a). The 3-2 model (bottom) has three, 2 hour tutorials each week. A new PBL case is opened on Monday (b) and closed on Friday (a).

First Tutorial	Second Tutorial	Third Tutorial
1st hour: close previous case - - - - - - - 2nd hour: -open pg. 1 of PBL case -generate and list hypotheses - - - - - - - First research period: -fill-in GRID	1st hour: group members discuss GRIDs and consolidate learning - - - - - - - 2nd hour: pages 2-6 are completed. Students role-play the physician and seek information from the tutors (who role play the patient. New learning issues are generated. - - - - - Second research period: students research new issues or write new PBL case (termed “reverse PBL”)	1st hour: group members prioritize and collectively discuss most difficult issues. Students may choose to summarize and close cases by case-, concept- or curriculum-mapping or working on USMLE Step 1 and Step 2 MCQ’s. Students may also choose to role play the patient using “reverse PBL” using cases they have written. Now the tutor role-plays the physician. - - - - - - - - *2nd hour: open new case*

Table 2. Outline of the 3-2 PBL method used in the accelerated 10-day training session.

Table 3: Rankings of top five of thirteen learning activities

by individual students

Learning Activity	Top 5 Rankings by Students	Score
Use of the GRID	3rd, 2nd	7 pts
Tutor as simulated patient	3rd	3 pts
Student as case-writer (reverse PBL)	1st, 2nd, 2nd	13 pts
Case-mapping	5th	1
Concept-mapping	none	0
Curriculum-mapping	none	0
Solving USMLE Step 1 MCQ's	5th	1 pt
Requesting faculty mini-lectures	none	0
Evaluation at the end of each day	none	0
Observing/participating in actual Hawaii tutorial	1st, 1st, 1st, 4th,	17 pts
Attending "flipped classroom" with Hawaii students	none	0
Having senior student as tutor	2nd, 5th, 5th, 4th	8 pts
Having active tutor	3rd, 4th, 3rd	8 pts
Other (please fill-in)	none	0

Explanation: The GRID (Group Research Investigation Display) is a table containing disease, patient history, physical exam-findings, laboratory results, and treatment in columns across the table vs. five to ten different diseases in the horizontal rows. Case-mapping (mechanistic case-diagramming) is used by groups to integrate ideas within a given case; whereas, concept-mapping is used to integrate across PBL cases. For example, the concept of immunity can be distinguished by humoral immunity (case of streptococcal pharyngitis) and cell-mediated immunity (case of syphilis), distinct immunological concepts, each with different effector cells and elaborated molecules. Curriculum-mapping is useful in schools with "full" PBL curricula. In such schools, there are no courses and therefore no course syllabi. Learning is essentially self-directed, and students are responsible for "mapping" their own curricula.

Engagement of students with Robotics-Competitions-like projects in a PBL Bsc Engineering course

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Abstract

This paper analyzes the experience of the innovation project "Adaptation of the Integrated Project-2 subject as a platform to promote students to International Robotics Competitions". Integrated Project-2 (IP-2) is a compulsory subject of the second semester of the 3rd. year of the Mechatronics Engineering Degree at UVic-UCC that integrates and mixes-up various areas of engineering such as: mechanical design, electronic design, programming devices, planning and implementation of mechatronic projects and simulation of business reality. The main aim of this research project is to verify if it is possible to achieve a better engagement of the students without losing the expected outcomes with a balanced combination of the spirit and shape of the well known international robotics competitions with the background and structure of business projects. The goal is to consolidate outcomes that are considered best practices for a professional, such as the ability to integrate diverse technologies and the soft skills that leads to a successful project completion: teamwork, leadership, ability to organize heterodox working teams, reliable public dissertation, social interaction, clear documentation... The paper makes a detailed analysis of the experience during three consecutive editions in which this subject has been taught developing this methodology, and it explains the different variations and peculiarities that have been introduced every year. As a critical key findings from the educational experience we mention that it has been proven very necessary that the faculty team has a diverse and complementary profile in order to give response to the different needs that arise in the projects; it must be also highlighted the difficulties facing this methodology with more numerous groups of students, such as the purchase of materials; and finally analyze the experience from the point of view of students and professors.

Keywords: Robotics Competitions, Mechatronic Engineering, PBL, Assessment, Tuition

1 Background and Motivation

The Project-based learning (PBL) methodology has been around for many years, initially formalized for primary and secondary level students, however since then it has being growing the application of this and similar active-learning methodologies such as Problem Based-Learning in a wide range of disciplines and in all the levels of education. One of the principal reasons of the interest from the Engineering perspective comes from the studies that were conducted in many countries to determine the technical and personal abilities required of engineers by Industry (Henshaw, 1991; Lang 1999). There were pointed out some key concerns: engineering graduates needed to have strongest communication and teamwork skills within an International culture, they needed to have a broader perspective of the issues that concern their profession such as social, gender, environmental and economic issues, and finally, they were graduating with good knowledge of fundamental engineering science and computer literacy, but they didn't know how to apply that in practice. Moreover these trends have even been increased with the globalization and the digitalization process of the last two decades, and all these concerns have only been addressed partially. In our case that vision encouraged us to build a first step into this direction when the new curriculum in Mechatronic Engineering was designed five year ago. We introduced there two compulsory subjects related to interdisciplinary Projects creation: Integrated Project 1 (IP 1, 2nd year) and Integrated Project 2 (IP 2, 3rd year), both of 6 ECTS, complementing the traditional Bachelor Thesis work at the end of studies (4th year), of 12 ECTS. All of them were subjects devoted to the implementation of complex projects. In Integrated Project 1 and 2 the focus is on a collaborative learning scheme based on a project development team (Project-Based Learning, PBL) with a philosophy called Learning-by-doing, where each team of students carry on their own project from the design to the final implementation. In the IP 1 students create a more oriented work, as they are in the 2nd year they have just made few specific subjects, which is the reason why the project has a more theoretical approach. In IP 2 the project integrates and mixes-up the various disciplines taught till there and simultaneously at the Engineering degree such as: mechanical design, electronic design, programming devices, the planning and implementation of mechatronic projects and a simulation of business reality. The expected outcomes were to increase all the skills in our students that are considered best practices for the professional practice of the engineering profession, such as the ability to integrate diverse technologies and the soft skills that leads to a successful project completion: teamwork, leadership, how to organize heterodox working teams, reliable public dissertation, social interaction, clear and helpful documentation...

In this paper we will analyze the detail of an innovation project named “Adaptation of the Integrated Project-2 subject as a platform to promote student to International Robotics Competitions” carried out at the subject Integrated Project-2, the aim of the project was to achieve a balanced combination of the spirit and organization of most of the well known international robotics competitions with the background and structure of business projects to consolidate outcomes that are considered best practices for the professional practice of the engineering profession, such as the ability to integrate diverse technologies and the soft skills that leads to a successful project completion: teamwork, leadership, how to organize heterodox working teams, reliable public dissertation, social interaction, documentation...

From the very beginning the professors involved knew that the Project-based approach in the definition of the syllabus was one of the requisites from the coordination of studies, and this is why they addressed the problem of what type of projects could be more suitable. There were two major types of projects: Industrial projects or more academic ones (to make them of utility they could fulfil the needs of the laboratories or any other subjects). From different experiences analyzed, it was found the motivational factor would be one of the key factors to reach successful project completion, because if the project was ambitious enough it was essential to find the involvement and commitment of the students. In this moment we began to consider the possibility of providing the students a challenge similar to the Robotic Competitions Challenge, but with rules of an engineering project.

Within the field of robotics and mechatronics there are some well known Robotic Competitions of different modalities addressed to enthusiasts, experts or students, most of them with the aim of having fun and sharing experiences. Perhaps the First Lego League (First, 2013) is one of the best known; in this case it is focused mainly on primary and secondary education. During the last four editions UVic-UCC hosted one of the first national qualifiers, and at the same time some of our students where couches of teams from the nearby institutes that were participating in the call, moreover a group of students created a team that participated in the First Tech Challenge FTC, a competition addressed to students aged 18 to 23 years at European level. Recently (09/27/2014) the World Robot Olympiad 2014 Competition was also organized at the UVic-UCC. There are also similar initiatives more local like the contest Robolot (Robolot, 2013) addressed to high school and vocational training students, with various modalities of robots; another case is the "Mercat de Tecnologia UVic" (UVic Technology fair) also organized in the UVic-UCC (Catalan market of Technology , 2013), although it has a wider focus a great part of the proposal presented by Secondary schools are demonstration robots build by students. In the European Universitary context there are some International Robotics Competitions such as the Robocup leagues (Robocup, 2013), focusing on robots that play football but also other competitions grouped in the European RobotChallenge (Robot, 2013) or the Eurobot (Eurobot, 2013), where you can find rescue robots or fighting robots, dancers or labyrinth solvers, or fast line-followers. At the national level there are two well known competitions like Alcabot (Alcabot, 2013) and AESSBOT (Aessbot, 2013). Although, as far as we know, none of these competitions have a direct connection with a compulsory subject of a formal Bachelor or Engineering degree, however some of the Universities supporting these competitions often offered some preparation courses as training activities. An example that inspired us to follow that track was the subject Autonomous Robot Design Competition MIT (USA) (Autonomous MIT, 2013).

To summarize we would say that the objectives of the project could be stated into 3 ideas:

a. Take advantage of the dynamics of competitions / demonstrations of robots as a motivational element using PBL (Project-Based Learning). Find possible ways to measure this engagement.

b. Eventually, the projects developed could be presented in an international competition Eurobot type / RobotChallange. This reinforces the need for learning English and practising it in the workplace, and also serves as a contrast to the international students from the same field

c. For the Faculty members, disseminate the experience in specialized forums in order to compare it with other teaching experiences and improve the definition and execution.

2 Theory and methods

As a starting point the literature review about the application of PBL indicates that this type of methodology is especially suited to subjects from advanced courses in the field of engineering (Mills, 2003; Capellera, 2013), because then the students have a basic background in the key contents of the area and they are able to face projects that could be considered at least close to professional ones. On the other hand, from the experience of the faculties involved, there was the presumption that the better kind of Robotic Competions that could be used as reference to define the projects were Mission-based ones, not tied to any specific platform, as they are more open and enable to work different aspects of any project, depending in the interests and the profile of the students.

At the beginning of every course the teams are organized as "Independent Engineering Offices" to achieve this goal. That means they receive a mission that must be accomplished by a Robot they have to design and build, they also receive a budget they can use to buy the needed material, and they finally receive some indications about the kind of facilities and devices they can find and use in the Labs.

2.1 Team building and roles

The teams had been grouped by different ways during the three editions. During the first edition default groups were made by teachers and everyone was forced to take on different roles at different stages of the project, the periods were a week in one role. In the second edition students defined the groups; however they were forced to change the roles in periods of two weeks.

The roles defined in the “Independent Engineering Office” by default were: Project manager, Mechanical Designer, Electric and Electronic Designer, Device and Electronic Programmer. Depending on the project and the expertise of the students, the roles could be shared or divided. The goal has been always to cover all the expertises needed in a successful design and production of a real Mechatronic Project.

The third edition was different because there were students enrolled with different profiles: the students from Industrial Organization Engineering were nominated Project managers of each “Independent Engineering Office”, their first decision was to choose the members of each of the teams, it was organized as a small brokerage event and each manager talked to each one of the candidates about the project, the skills and the interests of the candidates, after a limited amount of time there had to define the teams in the class.

Table 1: Number of students per team IP - 2

Course	A	B	C	D
2011-2012	3	4	-	-
2012-2013	3	4	4	-
2013-2014	4(+1)	3 (+1)	5(+1)	3(*)
*The members were also project managers (+1) during that course				

2.2 System simulation

The simulation of a professional project is organized as follows: the faculties act as clients of the “Independent Engineering Offices” and at the same time act as advisors in their respective specialities. As we commented previously in the subject IP-1 the students had been working on the theoretical aspects of project management at the same time that they had been leading with the development of a basic design prototype of one project. Whereas in IP-2 they work from the very beginning in the design and implementation phase of their project: from the initial sketch, passing though the complete design and development of the different parts and concluding with the implementation of a physical prototype of the project.

In the past three editions of the subject the students had made the design and implementation of a robot from scratch according to a mission. The first year every team started with a mission, with full specifications, a budget and a preliminary Gant Diagram of the work. During the second year they were given the mission and the preliminary Gant, leaving the specifications and budget to be set at the end of the first week by themselves. This change was used to simulate better the concept of how a customer orders to the Engineering Office an specific project, usually some kind of clients explain their needs or what they want to solve, but they do not have enough technical expertise to define detailed specifications, in this case Lecturers act with a double role as clients and as guides for the students on what it is necessary to know to define the initial technical specifications. What they learn with this approach are some critical questions that might be asked at the beginning of any project, but at the end of the day the student propose the technical specifications of the project. The third year followed the dynamics of the 2nd year, and the students were responsible for setting specifications.

2.3 Project Development and Role assignment

During project implementation, each group is responsible for their own project, but at the same time they must establish cooperation with other groups: first due to the mission as it is designed in a way that the robots interact with each other and the Students must coordinate their designs and communication protocols; secondly because students are aware that at the middle of the course they can be switched from one project to another. During the first edition we used this possibility –because the project was a single complex one for all the class, but divided into two parts, and one of the teams was really much more effective than the other- the representatives of the companies that where assessing the final presentation that year were really impressed, and they found that the readjustment of the teams and the cooperation between teams are very realistic issues in professional practice, and were one of the focus of big arguments and strongest complaints in real life projects. However from our experience the switch of projects would affect negatively to the final achievement of project objectives and favour the lost of the engagement in teams involved; the third edition was made without reassigning work; the discussion section address this issue further.

In order to emphasize the issues of project documentation and project management they had to maintain weekly a website that summarizes the done work and its organization and distribution. Students must update their documentation at least weekly as well as they have to share the information and their work on the Digital Campus.

In each phase the teachers validate the work done to permit a forward step to the students. The students had also been entrusted to do a forecasting for the needed material, making a reasoned and justified selection of components and materials as well as the purchase itself, normally passing the order to a virtual "Purchasing Department", in some cases they were demanded to contact suppliers and purchase directly.

Once the design phase concludes with all the tests carried out by simulation, the project passes to the stage of manufacture of components and their assembly, this work must be done in parallel with the development and testing of the electronic part. After the assembly and the test of the parts separately the project ends with the complete assembly and final testing, after that follows the checking and validation of compliance with the specifications.

To conclude the project there is a public presentation and a demonstration of its operation. In the first and second edition this session was attended by experts form companies, which addressed questions and comments on the projects. The students themselves assessed as very positive and rewarding experience the public presentation and the availability to receive assessments and comments from the external professional side. In the last year could not be made this way, basically due to a lack of time to fit calendars with external professionals.

2.4 Improvements

In the second and third year, we added that the members of the group should make a brief oral presentation related to the progress of the project at the beginning of the week, explaining the work done the previous week and the jobs forecast for next week. Last year the explanations were shared by all group members, talking each one of their own targets and purposes.

3 Results

The results can be assessed in two planes, in the one side a more tangible one, from the projects developed and on the other side the intangible aspects, the learning experience in the classroom:

- First let us briefly concentrate on the projects, their documentation and widgets that are in the university itself. In the table this information is summarized and there are links to the web pages of each project.

- On the other hand the more intangible experience of several tests and solutions adopted in each edition and assessment in teaching and educational level. In this section we want to make a critical exposition of the various solutions adopted and the results that have been achieved.

Table 2: Types of projects

Course	Description of the Project
2011-2012	A robot line follower with articulated arm with gripper. A group is for the design of the autonomous mobile robot and the other is devoted to the design and implementation of the articulated arm with gripper that is attached to the autonomous mobile robot.
2012-2013	Set of 3 cooperative robots: 1 Robot with conveyor lift; 2 Tracker autonomous robot that solves a maze; 3 Flying robot with vision, guided by remote control.
2013-2014	Set of 3 rescue robots: 2 Air Robots guided by remote control and an Autonomous Rescue Ground-Robot . Plus an entrepreneurship proposal to create a company for education and selling of the robotic kits designed by the peers.

In the first edition (2011-2012) it started the experience with few number of students. There were two working groups of 3 and 4 people, in this case we chose to do a project with only two parts, a mobile robot that was able to keep a line that includes an articulated arm with a gripper that was able to detect the colours of the objects (ping-pong coloured balls), finally the balls had to be deposited when the circuit ended in one of the two boxes depending on colour. The summary of the work can be found still at the following websites, where a weekly progress of the work done by the students was shown in conjunction with the main working documents, each team has to maintain their own website to disseminate their progress:

https://sites.google.com/site/projecteintegrat3/home

In the second edition (2012-2013) the mission was about Rescue Robotic Sets. Students were left in charge of a set of three robots that perform a collective and particular mission. The ground robot reused the ground platform of the previous year, and had to transport a small autonomous robot and all the terrestrial pack was guided by a third aerial robot. The summary of the work can be found at the following links:

https://sites.google.com/site/projecteintegratii/

In the last edition (2013-2014) the mission was again about Rescue Robotic Sets: two aerial robots - Unmanned Aerial Vehicles (UAV)- and one autonomous terrestrial Robot. Initially the air-robot must be able to detect a Beacon (a localized element that emits a known and recognizable signal) and then must serve as guide to the land rescue Robot, which should be able to move independently in an environment with obstacles. Moreover this terrestrial robot could be asked to jump and dodge obstacles of 10cm hight with his own sensors. The last team of the class was in charge of a new part devoted to commercialize the projects developed by peers, this part was the project proposal done by the engineering students of Industrial Organization. A collection of project information can be found at :

https://sites.google.com/site/pintegrat20132014/

Here are some samples of robots implemented in the past course 2013-2014 :

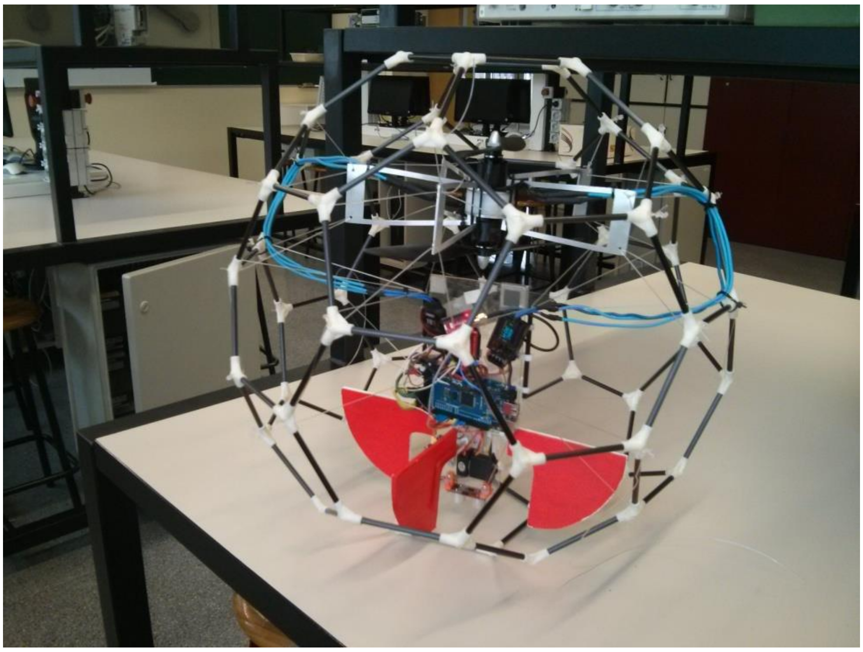

Figure 1. Robot air rescue BolaVola (course 2013-2014)

One of the teams built this sphere-flying-robot, it is powered by two rotors with a common axis and a rudder to steer the movement system. The design is inspired in Gimball, a crash happy flying robot developed at Swiss Federal Institute of Technology in Lausanne. The final tests have verified that it is able to rise if captive (tied with ropes to the ground), but it was not properly regulated properly to be stable in flight.

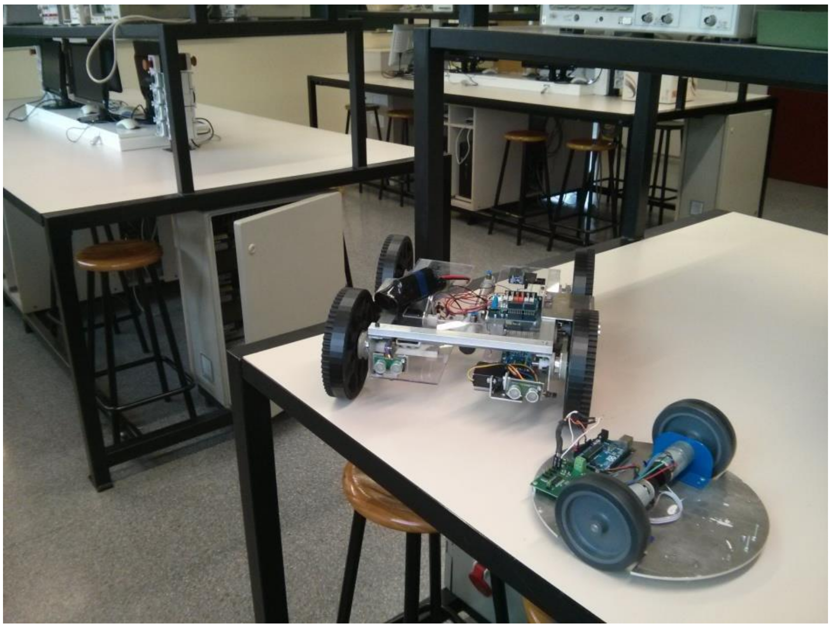

Figure 2. Land Rescue Robot (course 2013-2014) and robot crawler (2012-2013)

The land rescue robot apart from being an autonomous system that detects and avoids obstacles, has a mechanism that allows jumps from a compressed air piston , the resulting system has not been able to end ' raise the weight (approximately 4 kg) further lift the rear wheels .

Figure 3. Robot air rescue AirDroneUvic (year 2013-2014)

These are the skeletons of the quadcopter, this year we chose a couple of strategies in parallel, on the one hand to make the mechanical design and the other a dual control system, based on a Arducopter module and a second based on a BeagleBone platform. Again mechanical design has to do correctly but the control has been able to complete it.

4 Discussion

The discussion could be summarized in the following questions:

1. Which is the best approach to build the teams and the roles? In each edition it was used a different solution. During the first two editions the roles within the teams were initially based in dynamically assigned turns, so that all students play the role of team coordinators as it is a turn over (the first edition took turns in a week, and the second edition we had two weeks turns). In the third edition roles have remained static during the project, mainly because there were students in the classroom from different profiles: Students of Engineering degree specialized in Industrial Organization, which were responsible for Project management; students from the degree in Mechatronics Engineering; Bachelor Degree in Industrial Electronics and Automation; and a student of Computer Science Erasmus. All of them have ended assuming different roles (but fixed) within the projects, depending on their expertise.

However although we were initially for the rotation of roles and that every students work aspects of leadership, planning and team management apart from their technical skills, we agree that not always is possible, especially when in the class there is a mixture of profiles. The question of the leadership inside the teams is quite a tricky issue that could open a new full debate around it.

2. Definition of the project and its implementation? In this case the first year was specified more rigidly what to do and their specifications. When you leave absolute freedom to design alternatives, you have more risk that what is proposed is not easily achievable. At an early stage it is very valuable the expert guidance among design alternatives, but sometimes this is not possible (even more if the professors are no experts in a particular technique needed for the correct approach to the problem to be solved). Depending on the kind of projects developed, either robotic ones or not, the profiles and expertises from the professors would be difficult to have, this could be a big concern in the planning of the course.

3. Another conflictive aspect has been the cost and the ways of purchasing materials for the projects and how to keep safe all the material and the half-constructed devices. The material costs are high and the main difficulty is that much material should be considered expendable because it could be accidentally damaged so easily, and moreover is a kind of material that sometimes appears very sweet and easy to “disappear”. This year we had a real plague of disappearances of already purchased materials that could had been reused in future editions.

Table 3: Total budget to buy material for all the projects

Course	Cost of the Project
2011-2012	1697,26€
2012-2013	1949,50€
2013-2014	1846,61€

4.- The individual assessment is always difficult when the work is done in groups, we adopted a mixed formula, a percentage of the evaluation is for the group and the other part is individual: for it we have made individual assessment based on rubrics fulfilled during presentations and weekly impressions of teachers. In contrast to the group mark, that has been evaluated mainly from reports and documents submitted at each stage. In this case it seems optimal evaluating individual editions in which students have alternated roles in the team, in the last edition as roles have been more fixed due to the difference in profile of the studies the members of the groups, this could not take advantage. In this edition, the organization of groups has been worse than in previous years, as students of Industrial Organization devoted more time to their project, basically a development of a business plan for a Robot-sells, than in the management of the groups.

5.- Regarding the external evaluation of the projects in the first two editions were invited entrepreneurs and professionals to the final presentations and demonstrations of the projects, their comments and evaluations were very interesting and positive for both the students and the teachers, in this last edition was not easy because of the final presentations that were delayed in September and we declined to ask a new change to the external professionals.

5 Conclusion

In conclusion we will review the objectives of the project and a critical assessment will be made, but the main conclusion is that the experience is very rewarding and positive and must follow the work in order to make it available a higher number of students with a cost that is sustainable.

Related to the first objective must also conclude that the approach to robot competition increases students' motivation and therefore their engagement is usually higher than the one in other classes. This was measured by question-tests addressed to students. However it must be noted the difficulty to implement professional practises (like teams or tasks changes), as it is seen by students as punishments if they are not justified and mentioned in advance.

Regarding the second objective of the international competitions and language we have not yet been able to make firm steps, only one trial in one of the groups of the second edition, because an Erasmus student joined the classroom, then the complete internal working group was done in English, including the presentations and the reports. For the teachers this is an issue that is not easy and therefore there is a need if ways to achieve these skills for teaching and giving support in English. On the other hand the difficulties for the robotic competitions are the calendars and the budged, because rarely fit properly the and therefore may not be achievable. Another question would be robotics competitions scope of regional level; this could be an interesting and stimulating element at a more reasonable cost.

The third objective related to the dissemination has been partially accomplished, with a contribution at 2013 UNIVEST (Reig et al, 2013), and also from the presence of the Market Technology UVic-UCC. But it seems there is still a large amount of knowledge to acquire from external experiences.

To conclude it must be noted that one of the most difficult challenges is to find a way that becomes sustainable economically when the number of students increases, more than assigning more people to less teams. As we have already equipped laboratories and ICT programs and resources available, the early strength we need to do is to buy material reusable for the subsequent editions (controllers, motors, circuits, batteries, ...), but as mentioned much of the material purchased is unusable for its fragility and because material is often very sweet and easy to remove. In another vein there are plans to purchase equipment that will enable the manufacture of functional parts, this last edition we had access to a small milling machine, than can work with plastic materials very useful to make parts of the robots, and also we have had access to 3D printers that could do fully functional parts, all this machinery permits more flexibility for the designers and the materials used, and in a few time it would be more cheap than paying for their fabrication in an specialized place.

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The role of Project-Based Learning in Engineering Curriculum: the case of the Industrial Engineering and Management program at the University of Minho

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Abstract

One of the key questions arising from literature in Higher Education is the mismatch between curriculum and professional practice. This work presents an analysis of an engineering program, based on a model of curriculum development that includes three dimensions: professional profile, curriculum elements and framework of competences. These dimensions were considered in the methodological approach that involves a case study of the Industrial Engineering and Management (IEM) program at the University of Minho, Portugal. Data were collected through a combination of methods, including a survey, narratives, interviews and focus group. The aim was to get to know the perceptions of students and teachers of IEM program and professionals working in this engineering field. The findings highlight the relevance of project-based learning within the engineering curriculum in so far as it provides students with opportunities to develop both technical and transversal competences related to their professional practice. This implies developing learning situations in which it is possible to solve engineering problems, linking theory and practice based upon an interdisciplinary approach. Furthermore, the implementation of project-based learning have implications for curriculum development, namely in regard to the definition of the assessment (e.g. milestones, feedback, etc.), coordination and communication between the faculty, content selection according to the problem to be solved, amongst other issues with impact in teaching practice.

Keywords: Engineering Education; Curriculum Development; Project-Based Learning

1 Introduction

Curriculum design in higher education deals with important challenges, some of which result from complex demands of the labour market and society. Issues such as globalization, fast information spreading, advances in technology and sustainability have to be taken into account. Higher Education institutions are often criticized for the lack of preparation of graduates to solve real problems (Knight & Yorke, 2004). In this sense, one of the main challenges in higher education is to prepare students for the demands of companies and societies. The Engineering programs need to meet this challenge, in order to reduce the gap between university curricula and professional practice, which is recognised in several studies (Jackson, 2012; Markes, 2006; Nair, Patil, & Mertova, 2009; Stiwne & Jungert, 2010; Tymon, 2013).

Engineering programs have been innovating the teaching and learning approaches, as recommended by UNESCO report for Engineering Education "University courses can be made more interesting through the transformation of curricula and pedagogy (…) less formulaic approaches that turn students off" (UNESCO, 2010, p. 32). For instance, active learning methodologies (Prince & Felder, 2006) have been implemented by many engineering programs all over the world, in order to provide students with different contexts and situations where they can develop competences and engage more deeply in the learning process. For example, project-based learning is an active learning approach that “provides students with the opportunity to bring together knowledge-based skills from a number of subject areas and apply them to real-life problems” (Dickens & Arlett, 2009, p. 268). Project-Based Learning (PBL) is another alternative model that can be used to create an environment propitious for the development of both, technical and transversal competences. Implementations of this type of approaches all over the world have some common characteristics, namely: teams of students solve an open problem linked to the professional practice for a predefined period of time, delivering a result / product (Graaff & Kolmos, 2003; Kolmos & Holgaard, 2010; P. C. Powell & W. Weenk, 2003). These link with the professional practice, the hands-on, and the teamwork characteristics allow students to achieve extra motivation that will create an adequate ground for a deep learning (Fernandes, Mesquita, Flores, & Lima, 2014). The CDIO is also an approach that contributes for curriculum innovation in engineering. CDIO is based on four principles inspired in the engineering practice (Conceive - Design - Implement – Operate) and began at MIT (Massachusetts Institute of Technology) taking into account the negative feedback given by the companies regarding to graduates’ profile (Crawley, Malmqvist, Östlund, & Brodeur, 2007). However, changing the practices in engineering education contexts implies a complex process regarding, for instance, to faculty motivation, students’ dropout or lack of institutional support (Besterfield-Sacre, Cox, Borrego, Beddoes, & Zhu, 2014; Matusovich, Marie C. Paretti, McNair, & Hixson, 2014; Meyer & Marx, 2014).

Even though there are several studies on the evaluation of PBL models (Fernandes, Flores, & Lima, 2012; Hall, Palmer, & Bennett, 2012; Spronken-Smith, Walker, Batchelor, O’Steen, & Angelo, 2012; Struyven, Dochy, & Janssens, 2005), this work intends to give a different perspective, based on an integrated curriculum development model. Additionally it presents a PBL evaluation result that emerged from the data collected in a wider research project aimed at investigating the relation between the professional profile and the curriculum dimensions. Thus, this study characterizes the role of PBL in the curriculum and the relation to the professional profile. The study was conducted within the context of an engineering program - Industrial Engineering and Management program at University of Minho, Portugal. This analysis was based on a Model of Curriculum Development, which integrates three dimensions: curriculum processes, professional practice and competences.

2 Model of Curriculum Development

Specific technical knowledge is not enough for engineering practice. Other requirements are needed, such as working in teams, making decisions, solving problems, communicating, creating innovative solutions. Different terms are used to refer to these competences: “generic”, “transferable”, “core”, “professional”, “employability”, “soft”. In this study the term used is “transversal competences” which refers to those competences which can be transferable between different functions, but must be integrated into technical competences for a successful practice of a profession. These competences are being identified by accreditation boards, namely by ABET (Accreditation Board for Engineering and Technology), EUR-ACE (European Accreditation Board for Engineering Education) and Engineers Australia, so they must be also considered in engineering curriculum because “engineering curricula play an important, if not crucial, role in the education process of professional engineers” (Boud et al., 2009, p. 491). Curriculum development enables the conditions, situations, experiences and opportunities for students to develop competences related to their professional practice. According to this idea, Hoffman (1999, p. 283) states: “the design of learning programs may be based on the inputs needed or the outputs demanded”. The professional practice requires the combination of both technical and transversal competences and for that reason they must be included in the curriculum. However, the curriculum and the pedagogical practice are not always aligned with this purpose. Analysing the connection between curriculum and professional practice, taking into account a framework of competences, is essential to improve engineering programs and pedagogical practices. Thus, a Model of Curriculum Development was developed within a wider research project and three dimensions were considered - curriculum processes, professional practice and competences (

Figure 1). The curriculum processes were inspired in the ten criteria to assess the quality of teaching in Higher Education identified by Zabalza (2009).

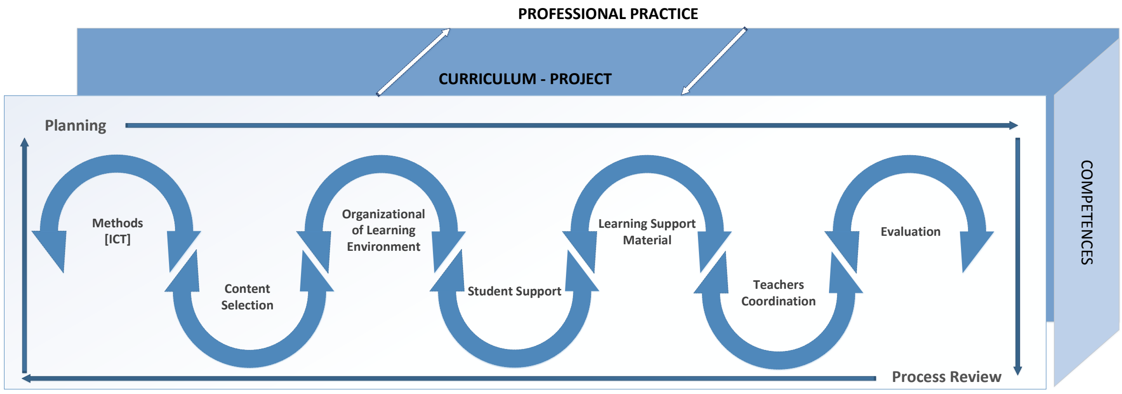

Figure 1: Model of Curriculum Development

This model shows the interaction between all the key components and highlights the importance to relate curriculum with professional practice. Thus, planning the curriculum as a project involves thinking about the activities that will be developed, the strategies to present the contents to students, the learning outcomes that should be defined, amongst others questions. Issues such as methods; contents and strategies to communicate the content to the students; the organization of learning environment to interact to students; student support (e.g. tutorials); learning support material (e.g. guides); teachers' coordination; and the evaluation are also considered in this model. These elements cannot be defined separated from each other. All of them should be aligned (Biggs, 1996) in order to make links between curriculum and professional practice, providing opportunities for students to develop competences. According to Zabalza (2009), the principles of professional practice should provide the orientations for curriculum design. This implies a rigorous and consistent analysis about the perceptions and contexts (social, environmental, cultural) related to professional practice, in order to incorporate them in teaching and learning situations, which aligns the curriculum processes: learning outcomes, methods and strategies, contents, resources and evaluation. Within this context, students have the opportunity to be in contact to their professional context that enable them to enhance even more the making-sense of their learning process (Fernandes et al., 2014).

This model shows the importance to understanding curriculum as a project, involving a set of processes that must be planned considering not only the alignment between them (Biggs & Tang, 2011; Cowen, 2006), but also the contexts of professional practice. The competences that are expected from professional practice must be considered in the curriculum development in order to reduce the gap between these dimensions. In other words, if students do not develop the competences related to the professional practice, the curriculum is not providing the contexts and situations relevant to engineering practice. Furthermore, this model provides an overview of the curriculum, carried out by an analysis where is possible to identify the curriculum processes that contribute to students' competences and those that need to be improved. It is within this framework that this paper was developed, taking into account the perspectives of students, teachers and professionals about the curriculum of Industrial Engineering and Management program at University of Minho.

3 Methods

This paper is part of a wider research project that is being developed at the University of Minho, Portugal, since 2010. It aims at analysing the curriculum elements and competences related to professional practice, in order to contribute to the improvement of the quality of the training program in engineering programs. The Industrial Engineering and Management Integrated Master program (IEM-IM) at the University of Minho was analysed, as a case study, taking into account the key dimensions of the Model of Curriculum Development presented earlier – professional practice, curriculum processes and competences. The perspectives, experiences and expectations of students, faculty and professionals (including alumni) about these dimensions were taken into account. The research design, illustrated in Figure 2, presents a set of methods for data collection used in the different stages, namely document analysis (to identify the competences and other dimensions related with the professional profile), questionnaire (to get an overview from the participants mainly about the professional profile defined in the previous stage), interviews, narratives and focus groups (to understand the relation between curriculum and professional profile). From data analysis, provided by triangulation (Denzin & Lincoln, 1994), it was possible to get an overview of the curriculum of IEM-IM, considering its the strengths and weaknesses identified. Project-based learning (PBL) experiences within engineering curriculum emerged as an added value for professional practice. PBL has been implemented in IEM-IM since 2004/05. In the first year of the course there was a PBL process implemented in the first semester. Two additional PBL processes were implemented in both semester of the fourth year. This model was inspired in the Project-Led Education (PLE) work of P. Powell and W. Weenk (2003). Several studies have already been developed within this context (Fernandes et al., 2012; Lima, Mesquita, & Flores, 2014; Mesquita, Lima, & Flores, 2013; van Hattum-Janssen & Mesquita, 2011).

This paper seeks to address the following research questions:

- What is the role of PBL in curriculum development within the IEM-MI training program?
- How does it contribute to the development of competences relevant to future professional practice?

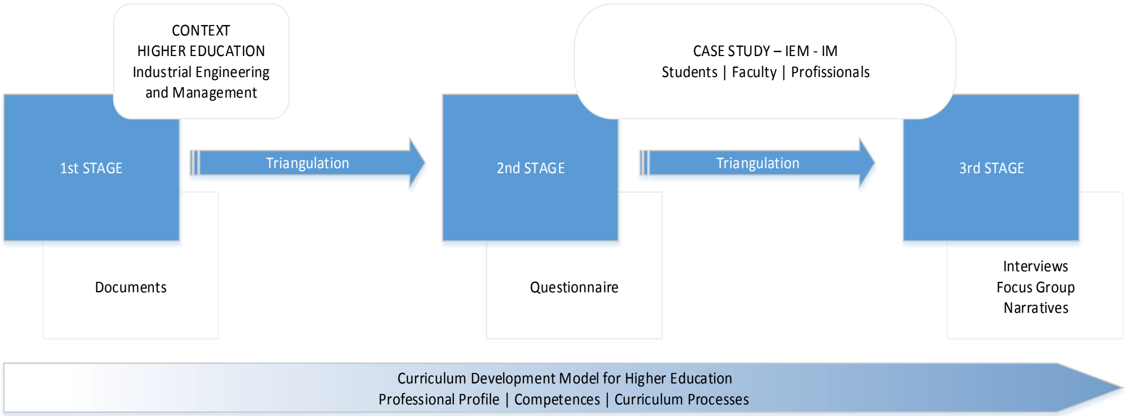

Figure 2: Research Design –data collection, participants and the model developed within this project

4 Findings

The analysis of IEM-IM curriculum was supported by the dimensions defined in the Model of Curriculum Development (

Figure 1) considering the perspectives of students, teachers and professionals. The relevance of PBL experiences within IEM-IM curriculum emerged from the data for their contributions in the preparation of students for professional practice, particularly due to the opportunity to link theory and practice, the interdisciplinary approach and the development of both technical and transversal competences.

4.1 Linking theory and practice

PBL provides learning situations in which theory and practice are linked in such a way that create a learning environment for students to solve a problem in teams. According to students, this approach contributes to their motivation and engagement in the learning process. The following quotes illustrate this:

> «With the projects, for instance, we didn't say: "let's go study", we say "let's go work!". I think this says a lot about what happens. We work, indeed, because we need to link what teacher said in class with what we are doing in the project. So, we are not just studying the concepts and repeating them over and over again, or just doing exercises! We are working! » (Focus Group 4th year Students P1)

> «I think that this is the best way [through PBL] to link theory and practice. And it is not the theory that we've already had, but the theory that we are having in that moment. This makes more relevant what we are learning. » (Focus Group 3rd year Students P4)

Teachers also recognize the importance of linking theory and practice to enhance students' motivation in the learning process. PBL was used as an example to illustrate this purpose.

> «I think that 4th year students need to see the application of what they are listen during the lectures, because they were three years waiting for that moment, I mean, to see the relevance of what they are learning. So, if they are in the class and do not realize what is going to contribute for their future as an engineers, they are not motivated to listen, to participate, whatsoever! But then I see them working in the project and everything changes. In fact, the project enables students to apply knowledge in a real situation, and this is what they are looking for and what they need. » (Focus Group Teachers P2)

In the case of 4th year, the projects are developed with industrial companies. These are a powerful experience for students because they have the opportunity to be in contact with their professional context, as some students mentioned:

> «I think the projects that we have developed in the companies were the best thing that happened to me at the university. It is a really advantage because you see how things work and you also understand that they could be different from what you saw during the lectures. For instance, in the real worldit is difficult to get information. At the university the teacher give us the exercise with all data that we need to solve, but in a company data are spread around the departments and incomplete. » (Focus Group 4th year Students P1)

> «When these projects are related to companies, where we had a chance to come in, observe, learn and even participate with our perspectives and opinions, this is really good, because learning in practice is much more relevant. » (Narrative Final Student 31)

4.2 Fostering an interdisciplinary approach

An interdisciplinary approach is one of the main characteristics of project-based learning, which is related to the nature of a real problem. This is not undermined by knowledge boundaries and enables linking theory and practice described in the previous section. Interdisciplinary projects challenge teaching practice. Teachers involved in this study identified some of them, such as the difficulties of communication and cooperation between teachers, the complexity of planning and management of the project (e.g. organizing milestones, defining the problem, etc.), heavy workload when comparing with traditional approaches, amongst others. This can be noted in following quote:

> «The project also brings additional difficulties in order to foster the link between the courses and the integration that is needed. In fact, with the project we are in a different level, it is more complex and demanding for teachers, because everything needs to be coordinated and everybody needs to be engaged and committed. » (Focus Group Teachers P3)

However, teachers involved in this study also recognized the advantages of the interdisciplinary projects, in which students are able to solve engineering problems.

> «The courses are organized in "lockers" and we know that this is not what the students find out when they go outside. But we can link some courses with each other and the IEM-IM shows that this can happen with the projects. » (Focus Group Teachers P1)

4.3 Developing competences

University teachers' perspectives about PBL point out some dimensions that are discussed in the literature, namely the importance of teachers' role in order to create learning situations for students to develop competences related to their professional practice. One of the concerns of the faculty relates to technical competences, as mentioned by the following quote:

> «With the project I think that we cannot cover a lot of technical issues. That is possible in a lecture, where the teacher talks for two hours. In the project we didn't talk for two hours! For instance, to explain a technique, like Kanbans, I can even explain to students using examples and giving some exercises until they get the idea, but if they have contact with reality and feel real environment, the learning process is totally different (…) The student already had the experience and it would be easier, when he/she goes to a similar situation, and has to apply the technique. The learning process is much more effective in this way than in a lecture where I am taking about kanbans. So, the quality of the technical knowledge in a project is wider; you cannot cover everything, it is true, but the knowledge that student achieve is higher. » (Focus Group Teachers P4)

This perspective is also reinforced by the professionals (alumni students), which highlighted PBL as an added value for their professional practices, particularly those projects that were developed within industry context. When graduates go to their professional contexts, they face and deal with similar situations as those experiences provided with the project.

> «For example, I have never had that feeling "oh, what I learned in the university is so different from what I am living now!" Not at all! In this company, I show that what I learnt is useful. There were situations where an issue is under discussion and I had never been afraid to give my opinion and explain my perspective, supporting with what I learnt at the university. I was sure about what I was saying… but the projects that I was involved in allowed me to get this confidence, because if it was the first time that I was in a company. » (Interview Professional – Alumni P7)

For students PBL create opportunities for them to develop competences related to professional practice, not only those that requires technical knowledge, but also transversal ones, such as teamwork, time management, communication skills, amongst others.

> «A project was presented to us right at the beginning of the 1st year and we have to learn how to deal with it. When we go to a company it will be almost the same, we have to work with people whom we do not even know… but it will be the similar experience that we've had with the project during which we've learned how to deal with the difficulties. » (Focus Group 2nd year Students P1)

> « (…) but then it is exactly what is going to be asked to us in a company. You have to work in teams, even bigger than the teams that we had in the project, and maybe we have to work with other engineers from different areas. I think that we are well prepared, because we are having similar experiences here. For instance, I had a lot of problems within my project team, especially at the beginning and I had to learn how to deal with it. I have learned to pay attention to people and somehow I have learned how to deal with situations that I am not used to, because everything has to be all right at the end. » (Focus Group Students 3rd year P2)

5 Final Remarks

Drawing on the findings from this study, it is possible to recognize the importance of PBL within IEM-IM curriculum in order to improve student learning and prepare them for professional practice. The main contributions that emerged from the findings are the link between theory and practice, the possibility to foster an interdisciplinary context and the development of students' competences.

Thus, the PBL experiences play a significant role within the IEM-IM program, for instance, professional situations become more familiar and students are able to understand the relevance of the content addressed within a course, for instance. PBL is also considered by graduates as an added-value for professional practice (Mesquita et al., 2013). Other studies reveal similar results, such as Kolmos and Holgaard (2010). Evidence highlights that PBL provides opportunities for students to be in contact with real problems within interdisciplinary contexts where it is possible to solve engineering problems (Heywood, 2005) or, in other words, to *practice the professional practice* (Lima et al., 2014). This provides an important contribution for students' motivation and engagement in learning process (Fernandes et al., 2014). Furthermore, students are aware that engineering problems require a combination of technical and transversal competences, and for that reason working in teams, for instance, is an industry requirement for engineering practice (Lima, Mesquita, & Rocha, 2013). PBL provides learning opportunities where students need to combine technical and transversal competences, in order to solve the engineering problem they are facing.

The contribution of PBL for professional practice has implications for curriculum development, particularly for teaching practice. The Model of Curriculum Development presented in this paper support the analysis of IEM-IM curriculum and it is possible to relate the challenges that PBL provides for teaching practice with the curriculum key elements, particularly in the context of PBL. PBL has implications for teachers' coordination because of interdisciplinary contexts and also the organization of teaching processes, such as assessment. If the students are provided with learning situations based on pedagogies of engagement (Smith, Sheppard, Johnson, & Johnson, 2005) the methods of assessment need to be different from the traditional approach (Fernandes et al., 2012). Feedback practices, for instance, are quite relevant in a curriculum oriented to competences development (Flores, Veiga-Simão, Barros, & Pereira, 2014). PBL have also implications for other curriculum issues, such as learning environments, student support, in the use of Information and Communication Technology, amongst others that may be discussed in a future work.

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PBL Application in a Continuing Engineering Education Context A Case Study

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Abstract

The point of departure in this paper is to explore the Aalborg problem based learning model (Aalborg PBL Model) as an approach for continuing engineering education. It is explored how a PBL approach for continuing engineering education (FWBL); is conceptualised by the actors involved in the process of setting-up courses and furthermore how the model performs in practice. The intention is to explore what actually takes place in the process of constructing a continuing education courses inspired by a PBL approach.

The scene set for investigating the principles of PBL in a continuing engineering education context is the European Social Funded project, the Via Nord project, which was based upon a collaborative setup between Small and Medium-sized Enterprises and Aalborg University.

The research approach is action research, with its focus on action as a participatory process, concerned with developing practical knowing. The empirical data collected is primarily dialogues and observations supported by various documents produced in relation to the Via Nord project.

The paper will contribute new knowledge on - how the actors involved in continuing education processes conceptualisation courses inspired by a PBL approach.

Keywords: PBL, continuing engineering education (CEE), case study

1 Introduction

The development of employees' skills and competences has become a key driver of economic growth in the developed world. This assumption is also to be found within the engineering field, where it is widely recognised that it is mainly through enhancing engineering's skill and competences that future competitive advantage will emerge. Consequently companies need to be able to identify precise areas where they have, or can build, distinctive competences that will enable them to develop new products and compete effectively.

However, skill and competence development aiming at especially post-graduate engineers are still an area of potentially progress. Even though several supplier organisations of continuing education has attempted to honour the need of post-graduate continuing education – by developing various models ranging from web-based approaches; individual designed programs and tailor-made courses e.g. models, which are flexible and to different extend individually designed. During the years 2003 till 2007 Aalborg University's CPD Unit (the Continuing Professional Development Unit) contributed to the field of continuing engineering education through practise to develop an approach, which contains the ability of companies for distinctive competences development and at the same time meets the post-graduate's work-related motivation (Lorentsen, 2010). The various practices and pilot courses accumulated into the Facilitated Work Based Learning model (Fink et al., 2006). The CPD Unit's intentions with the model was to introduce a new approach for continuing engineering education (CEE), inspired by work-based learning (WBL) (Bound et al., 2001) and problem-based learning (PBL) (Kolmos et al., 2004)) along with the principle of facilitation (Rogers, 1967) and with a student centred approach (Kolmos et al., 2008).

The FWBL model was primarily developed within the engineering field and the companies involved as pilot studies were all engineering companies. The main motivation on which the FWBL model was developed is '*the philosophy of FWBL is to transform many years of experiences with Problem Based Learning into an industrial context'* (Fink et al., 2004, p. 2). Back from the early pilot studies, FWBL has been described as a course for *'individuals/groups of employees in a given company who in co-operation with the university establish a training programme where the employees at their work continuously go through a well-defined and tailor-made learning process. The training programme is facilitated by teachers from the university and if possible, based on relevant development projects in the company'* (Nørgaard et al., 2004, p. 2). The argument, that the PBL model can be transferred to an industrial setting as an approach for establishing a work-related learning process within a company, is that the point of departure in both the university context and the company context is problem solving (Fink, 2001, p. 4), as illustrated below.
Through the co-operation with companies on continuing education the CPD Unit became aware that several companies are using a problem oriented and project organised way of developing their products. The similarity to problem-based learning in university educational theory and practice is striking, which brought forward the inspiration to try to transfer the PBL model into an industrial context.

Learning by Problem solving	***Engineering Problem solving***
- The problem is a tool - Learning is the goal	- Professional skills are the tools - The goal is to solve the problem

Figure 1: Problem solving

Blending these two ways of thinking is obvious. Companies work on solving professional problems every day and often this problem solving work is organised in groups or teams, very similar to the principle of the PBL model. However, the goals are different. The university students use the problem as the means for academic learning where the employees use their 'academic' skills to solve the problem. The goal at the university is learning, where the goal in a company context is problem solving. The challenge is to use a modified PBL concept to combine productive engineering and academic learning, to combine industrial tasks for engineers with their tasks in studying. Learning objectives will be defined based on the needs for new competences within the company, and a university academic staff will facilitate the learning and knowledge transfer from university.

The scene set for investigating the principles of PBL in a continuing engineering education context is the European Social Funded project, the Via Nord (ID3405), which was based upon a collaborative setup between Small and Medium-sized Enterprises (SME) and Aalborg University (AAU). The purpose of Via Nord project was to bring research based competence development centre stage – and into the SME's in the Northern Region of Denmark. To make post-graduate engineering competence development available as individually designed courses with a take-off in the needs of the individual company - and carried through within the company. The goal was within a three years period to develop and run 80 PBL inspired continuing education courses. This however, turned out to be a very challenging gaol to reach since the Via Nord project lacked involvement from the SME's due to numinously reasons. But fortunately one case turned out to be very positive and informative in relation to exploring PBL in a company context. The Kroghs A/S case which will provide the core empirical data of this paper.

The research approach is action research, which is defined by a participatory process concerned with developing practical knowledge in an attempt of improving e.g. life of human beings (Lewin, 1946; Reason et al., 2003) and the case studies methodology (Flyvbjerg, 2006, 2011). The data collected for the analyses are dialogues, minutes of meetings, observations, and documents from the practise of the Via Nord project.

The inspiration for the FWBL model – PBL and WBL

The model implemented in the Via Nord project as a mean to develop competences in the Northern Region of Denmark - was the FWBL model, which was developed based on inspiration of problem-based leaning (PBL) and work based leaning (WBL). In literature with focuses on the relation between job and work, one main track is WBL and the PBL approach is described in various academic contexts.

One of the PBL approaches is the Aalborg PBL model, which is the main inspiration for the FWBL model. In 1974 Aalborg University was inaugurated and right from the beginning it was founded on, at that time, the new educational concept, PBL. Several attempts have been made to define the concept but one of the pioneers was Howard Barrows, who in the late 1960's was involved in the early stages of the development of PBL at McMaster University in Canada. Barrow defined the concept in terms of specific attributes as being student-centred, taking place in small groups with the teacher acting as a facilitator, and being organised around problems (de Graaff et Kolmos, 2003, p. 657). In Denmark the problem-based and project-organised model was developed based on ideas from among others Illeris, who formulated the principles of PBL as problem oriented, project work, inter disciplinarily, participant directed learning and the exemplary principle and team work (Kolmos et al, 2004, p. 10). The Aalborg PBL model is a problem-based and project-organised model, which has gradually developed at a profession-based level (Kolmos et al. 2004, p. 9). The continuous improvements are a part of the teaching and learning culture at Aalborg University, which also was the driving force in implementing PBL as an approach for CEE.

The PBL principles, which are acknowledge by Aalborg University are:

- Problem orientation: Problems/wonderings appropriate to the study program serve as the basis for the learning process.
- Project organization: The project stands as both the means through which the students address the problem and the primary means by which students achieve the articulated educational objectives. The project is a multi-faceted and often extended sequence of tasks culminating in a final work product.
- Integration of theory and practice: The curriculum, instructional faculty members and project supervisors facilitate the process for students of connecting the specifics of project work to broader theoretical knowledge. Students are able to see how theories and empirical/ practical knowledge interrelate.
- Participant direction: Students define the problem and make key decisions relevant to the successful completion of their project work.
- Team-based approach: A majority of the students' problem/project work is conducted in groups of three or more students.
- Collaboration and feedback: Students use peer and supervisor critique to improve their work; and the skills of collaboration, feedback and reflection are an important outcome of the PBL model.

(Barge, 2010)

Looking into the teacher–student relationship at any level inside or outside the university, 'the banking model', as defined by Paulo Freire, is still to be found where '*education thus becomes an act of depositing, in which the students are the depositories and the teacher is the depositor* (red) … *in the banking concept of education, knowledge is a gift bestowed by those who consider themselves knowledgeable upon those whom they consider to know nothing'* (Freire, 2009 p. 72). The teacher-student relationship with the teacher as narrator of a subject and patient, listening students to memorize the narrated content, must be rejected. '*They must abandon the educational goal of the deposit-making and replace it with the posing of the problems of human beings in their relations with the world'* (Freire, 2009 p. 79).

When abandoning the banking model and implementing the posing of problems – in the PBL model, the teachers undertake a different role. PBL is defined by practising a student centred approach (participant direction) with emphasis on students' motivation and learning experiences. *'Therefore, the concept facilitation is more and more often used as the overall concept for teacher's role and function in the PBL-system'* (Kolmos et al. 2004 p. 10). J. Gregors defines facilitation literally as, '*easing*'. Its art is in drawing out the wisdom already embedded and lying dormant in the psyche of the learner. Facilitators are people with the skills to create conditions within which other human beings can, so far as is possible, select and direct their own learning and development. A facilitator is a '*process guide'* who works with a group to assist it to achieve a self-defining purpose. '*The facilitators philosophy informs their approach and its manifested as a concern with the psychological growth of the person'* (Kolmos, 2008, p. 10). In PBL, the teachers are facilitating the learning process, which also was adapted to the FWBL where the teaching also is based on facilitation. To be a facilitator of learning Rogers (1967) point out that the most important basic attitudes are sincerity and purity and when the facilitator is an authentic human being who appears as he or she is, and enters into relations with the learner without any exteriors, the chance of being successful is greater. Being a facilitator in CEE is for most academic staff a new role but fortunately the Aalborg University academic staffs has experiences from facilitating students within ordinary studies.

Work based learning has its origin in higher education aiming at developing employees' competences in a collaborative setup between companies, employees and higher education institutions. The concept is not unequivocal and explicitly defined, it is often used in different contexts with different meanings and there is a wide variation in the mix of elements included, but David Boud provides an operational attempt to describe the concept. '*WBL programmes meet the needs of the learners, contribute to the longer–term development of the organisation and are formally accredited as university course'* (Boud et al. 2001 p. 4). The involved partners in WBL collaborations are: the company, the employee, and the university academic staff and a long-term collaboration between the partners is often intended. The employees are the focal point, since they are responsible for negotiating agreements with both the superior manager and the university (Boud et al. 2001). The WBL course is based on the experiences of the individual employees and the goal can be a degree or a nationally recognised qualification (Burns, 2003). Unlike most conventional courses, there is no fixed syllabus; core content or essential disciplinary materials in the WBL programme '*work is the curriculum'* (Boud et al. 2001, p. 4, 7). The university academic staff is connected to the course and to different extents contributes to the learning process.

2 The FWBL model

The process of FWBL does not follow a rigid scheme such as a standard five-day course. This learning process will normally run for more than half a year and often longer depending on the extent and depth of the learning objectives, the intensity and the time frame of the project, in which the FWBL is incorporated. The FWBL process can be described in 5 continuous phases as presented in the paper '*The Methodology of Facilitated*

Work Based Learning' by Fink et al., 2006:

- Contact phase
- Defining the learning objectives
- The learning contract
- Implementation of FWBL
- Evaluation

Contact phase

The contact between company and university is often new for both parties, or at least the situation might involve new people. To ensure a fruitful collaboration, it is very important to make sure everyone is involved and in agreement. Therefore, the time used on harmonising wishes, expectations and requests is often very well spent. The company' manager will introduce the overall theme of the learning objectives; the professional area, the extent and the depth. These learning objectives will relate to the company' internal project in which the FWBL course will be incorporated. But very important is also that the strategic leaders are familiar with the FWBL model and the difference between this approach and more traditional methods of continuing education. The university will in this phase focus on communicating the FWBL approach. The dialog in this phase will be in the nature of a mutual interaction between equal partners (Kvale, 2004).

Defining the learning objectives

The process of defining the learning objectives is essential to the success of the FWBL course. The contact phase is the introduction phase - now it is important to be explicit. The academic staff member will, in dialogue with the strategic manager, complete a very precise description of the defined learning objectives. This description will partly be based on what is needed and in alignment with the company strategy and partly on the preferences of the employees. Based on the defined learning objectives, the academic staff members will carry out interviews with each individual participant to determine his or her competence level in relation to the learning objectives. The dialogue in this phase will have some power asymmetry. The university academic staff member defines the situation, introduces the theoretical subject to be discussed and guides the process by asking predefined questions (Kvale, 2004). However, the university academic staff member must be aware that the aim is not to meet objectives for academic reasons but to determine the participant' level of skills and competences in relation to the company defined learning objectives.

The learning contract

The learning contract is prepared in agreement with the outcome of the previous phase. The learning contract is negotiated and signed by all three partners to create ownership and commitment from all, on an equal basis. The learning contract will as a minimum consist of:

- A description of the theme or the project to which the learning course is connected
- A definition of learning objectives
- An agreement on the methods
- An agreement on the time frame
- A definition of the success criteria for the learning process
- A description of the process and the evaluation

Implementation of FWBL

When the learning contract is signed, the FWBL course is ready to begin. The contents, proportions, professional area and time frame of the FWBL course will depend on what the three partners agreed within the contract. In an attempt to integrate the learning in the organisation, the training will take place in the company. The academic staff member acting as a facilitator will give face-to-face facilitation to the participants and will continuously make sure the learning is in progress and in accordance with the learning contract. It is very important that the academic staff member as a facilitator is not acting as a consultant with the intention of helping the employees to solve their problem. Rather, the facilitator will focus on theories and methodologies to guide the participant's to gain skills and competences to solve their problem and find new solutions to their everyday work.

Evaluation

Evaluation will have two targets. Firstly, to ensure quality of the FWBL course – the process, and secondly to make sure that the learning objectives are accomplished. The FWBL process will be subject to an evaluation throughout the whole course. The purpose of this evaluation is primarily to ensure the quality of the course and if possible and/or necessary to modify the course and the contract. The evaluation of the learning objectives will be in agreement with the description in the leaning contract. If the employee is going to earn credits (ECTS) by the learning process, a formal assessment must take place. Otherwise, the evaluation must give evidence to indicate that the learning objectives have been reached. The participant can as part of the evaluation e.g. give an oral presentation for his/her colleagues of this learning outcome to establish some knowledge sharing within the company.

Even though the FWBL model is described in a continuously five-step process it is in practise an iterative approach e.g. the identified learning objectives can change over the time of the FWBL course, which will entail changes in the course. This above description of the FWBL model was very much the process, which permeated the Via Nord project since the intention was to design 80 FWBL courses in collaboration with SME's in the neighbouring surroundings of Aalborg University. This however turned out to be a challenge and time consuming process due to various reasons, which will not be elaborated in this paper. But based on information of the case, the Kroghs A/S case was selected as an 'extreme-case-form' with the purpose '*to obtain information on unusual cases, which can be especially problematic or especially good, in a more closely, defined sense'* (Flyvbjerg 2006, p. 230). The Kroghs A/S case was selected due to criteria of the success with developing a course inspired by the Aalborg PBL model and in that sense it was an (extreme-case-form) extremely positive case.

The Kroghs A/S case

The overall analyses of implementing the FWBL model in the Via Nord project show that the SME's struggle with the concept, however the Kroghs A/S case was different.

Kroghs A/S is a family owned company specialized in producing high quality products for the concrete and asphalt industry. Kroghs A/S was founded in 1935 in Klim only a stone's throw from the beautiful cost line of the North Sea. During the years, Kroghs A/S has continuously developed their product portfolio and today they are a full-line supplier of raw materials in all qualities. The need for constant development of their products was also the motive for the Kroghs A/S case. For some years, they had tried to get knowledge on polymer – to be able to produce a concrete/polymer based dry mortar with a different characteristic than their already existing products.

When introducing the Via Nord project to the Kroghs A/S it was introduced as a model for continuing education with parallels to the Aalborg PBL model. This was straightforward since the employees (Lars) participating in the case was an engineering graduate for Aalborg University, which of course made him familiar with the PBL model. The academic staff member (Donghong) involved in the case had never before been involved in CEE activities but he was very interested and open to the idea of using the Aalborg PBL model in a company context and it seemed as if he right away understood, that what he was going to do was similar to when he facilitated students in their problem based and project organised studies at AAU. His research field was in polymer solar cells and chemical plaster used for resistant of antibiotic, but no research knowledge on concrete.

Already at the first meeting at Kroghs A/S, after a short introduction, Lars and Donghong started to discuses the problem of developing this new product of a mixture of concrete and polymer. Lars showed Donghong some samples of polymer powder and catalogues with product description. Lars had different types of samples, but he indicated, that he did not fully understand the different of the samples because he had difficulties reading the chemical product description. Donghong explained the chemical descriptions of the different types of polymer, some were polymer types, which were used for wall painting in-door and others were much stronger. He explained by drawing polymer molecule on a piece of paper (they look like small worms or snakes) but obviously they were very different types. It caught Lars' attention he was leaning across the conference table pointing in the catalogue and asking more questions about the outlined chemical description. Lars took out an academic article on polymer concrete and they discussed the article in brief, trying to identify the polymer chemical structure. Apparently Lars was inspired by the article and had in mind to test some of the samples of polymer in the Kroghs A/S laboratory but he needed more knowledge on the chemistry of polymer. With Lars' background as civil engineer and 8 years at Kroghs A/S his knowledge on concrete was huge but his knowledge on chemistry dated back to his college education. They opened one of the small bags with polymer and smelled it (the powder had texture as detergent). Then Lars started drawing on the same paper that Donghong had just sketched the polymer molecules. Now, Lars was drawing concrete molecules (they mostly look like small starts or thrown-up pebbles at a windscreen). They discussed the chemical process, which was activated when poring water to the mix of polymer and concrete and also how the drying process works, which makes it all come together. They leaned across the table and alternately asked questions, explained and illustrated on the same piece of paper. They continued for a while conceptualising the problem - then Donghong leaned back and said '*that's something I know about, I can help you with that*!' and this was how the Kroghs A/S conceptualisation of the polymer concrete problem started.

3 Analysis of the Kroghs A/S case

To be able to clarify what was going on in the practices of the Krohgs A/S case the '*disclosive space'* concept was introduced as the theoretical grips of the analysis. A disclosive space is defined by four characteristics; equipment, purpose, identity and style (Spinosa et al., 1997). Spinosa et al. describes equipment as '*a totality of interrelated pieces of equipment, each used to carry out a specific task'* (Spinosa et al., 1997, p. 17) in the analysis of the Kroghs A/S case the '*equipment'* is to be understood as the FWBL model. And the second characteristic 'purpose' is described as '*these tasks are undertaken so as to achieve a certain purpose'* (Spinosa et al., 1997, p. 17). Following the account of a disclosive space, the third characteristic is '*identity*', which Spinosa et al. describes as '*this activity enables those performing it to have identities*' (1997, p. 17). But people do things in different ways, which bring along the last characteristics '*style*' - while according to Spinosa et al. '*there is more to the organisation of practices, however, than interrelated equipment, purpose and identities. All our pragmatic activity is organised by a style* [red.] *and in the end it is style that brings it all together'* (Spinosa et a., 1997, p. 19).

The actors of the Kroghs A/S case were familiar with the Aalborg PBL model. The participant had an engineering degree from Aalborg University and the academic staff member had 10 years of experiences from the PBL environment. Therefore, the FWBL model immediately turned up as meaningful to them in undertaking the activities of developing a polymer-concrete product and furthermore it fitted with the practice they both had for teaching and learning, even to an extend where they were incapable of seeing it as extraordinary. The problem statement (the polymer/concrete product) was very clearly articulated even before the first meeting and Lars was very aligned with the purpose and apparently did not have any difficulties, what so ever, of completely engaging in the process. Donghong also seemed to have found a purpose, besides teaching FWBL – which was to publish a journal paper on the polymer / concrete topic. Also the Kroghs A/S course brought along opportunities to acquire identity for the actors – Lars would be acknowledged as the employee who develop the very specialized product and perhaps thereby increase the Kroghs A/S market shares and Donghong would be recognised as a researcher in the field of polymer modified concrete. This forging of identity might have had an impact on their engagements in the activities but not the vital impact. Both actors' styles supported the coordination of the activities The Kroghs A/S was very enthusiastic about the project and was the driving force. Donghong was calm and polite and had an encouraging style. Their style matched, which made it all come together.

What made the Kroghs A/S case special was that the actors was familiar with the Aalborg PBL model but most important was that the problem statement (the purpose) was clearly identified, it was a '*need to have'* for the Kroghs A/S and further the actors build on to their identity and in the end their style matched, which made the collaboration work.

Conceptualising the problem statement became the process of solving the problem in the Kroghs A/S case aligned with the students studying within e.g. Aalborg University, when they are solving problems as the means of their learning process. Figure 1; illustrating the problem solving process in a university context and a company context, is successfully combined in the Kroghs A/S case where the polymer / concrete problem is solved simultaneous with Lars developing knowledge and competences within polymer chemistry, which he might be able to use in his future work in maintaining and developing the Krohgs A/S product portfolio.

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xBL – the glue of flipped classrooms

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Abstract

Flipped classroom delivery can result in an improvement in the efficiency of delivery, an improvement in learning outcomes, or a combination of both. Attribute development beyond the Cognitive includes the Affective and the Psychomotor. Re-tasking contact time in a flipped-delivery approach to include Active Learning and Inquiry-Based Learning results in an improvement in learning outcomes, enabling the Cognitive to be reinforced while facilitating the development of both the Affective and the Psychomotor. The use of Inquiry-Based Learning activities in a flipped-delivery course to improve student learning is discussed, and a study to investigate this is described.

Keywords: Flipped Classroom, On-line Delivery, Active Learning, Inquiry-Based Learning

1 Introduction

The flipped classroom is a form of teaching where traditional lecture and homework times are swapped, with out-of-class (homework) time being used to watch pre-recorded lectures, and lecture time being used to engage in some form of active learning. Once a lecture has been flipped and placed on-line, instructors often find themselves operating in unchartered territory, not exactly sure how to use the newly available contact time with students. This paper offers an analysis of this author's use of active learning techniques to enhance the experience of the flipped classroom by students in an undergraduate engineering course.

Active learning techniques include Problem-Based, Project-Based, Inquiry-Based and Challenge-Based Learning (collectively referred to as xBL). These techniques operate in a domain where the Problem, Project, Experiment or Challenge provides the structure for the course, and lecture delivery serves to both support and advance the learning process. xBL activities are more flexible than traditional lectures, and consequently they are well suited to the flipped-delivery classroom.

The widely-adopted structure of the 50-75 minute lecture held two to three times per week has evolved over time in response to both instructor and student stamina. In the xBL context, it is often preferred to have longer contiguous periods of time so as to advance a specific teaching and learning activity. As more courses within a specific degree program undergo the lecture flipping process, new opportunities arise in terms of curriculum design, timetabling, and resource allocation.

By recording lectures into short (5-15 minute) segments that cover specific topics or sub-topics and labeling each recorded segment, a cluster of indexed and searchable segments evolves. For instance, lecture segments for a course in Thermodynamics could be labelled as follows: 1. Equation of State; 2. Heat and Work; and 3. Heat Engines. Assuming that a typical course includes approximately 125-150 such segments, a 42-course degree program could be represented by 5000-6000 segments. All of the lecture content that a typical undergraduate degree program requires could be represented by a "constellation of segments."

By transforming a degree program into an indexed and searchable constellation of segments, it is possible to re-imagine that program. Boundaries created by physical limitations of time (timetabling or scheduling) and space (physical classroom or lecture theatre availability) are partially removed, enabling program designers to organize programs in ways not previously possible. Boundaries between courses then become less rigid, enabling a more natural flow of related content from one course to another. The time-based nature of this flow can be present-to-present, present-to-past, or even present-to-future.

The paper will explore this new structure using the flipped-delivery design for two courses in a Mechanical Engineering program, one that uses xBL activities and the other that does not. The paper explores whether xBL activities, when coupled with flipped delivery, can result in an increase in student learning. The paper concludes by examining how xBL activities can be used to connect, or glue, the constellation of on-line segments together.

2 Background

In the Fall of 2013, an experiment was conducted whereby a third-year (junior level) Mechanical Engineering course was offered in a blended format using YouTube for the on-line content delivery (Hugo, 2014). Although the content was developed and delivered specifically for the University of Calgary (UCalgary) course with 89 student registrants, it was also possible for students not registered in the course to watch the content. The course instructor had taught the same course five times previously (2001-2005), and this served as a reference point to which the blended delivery approach could be compared.

In the blended delivery format, face-to-face live interaction was reduced by 66% and was reserved for a once-a-week active tutorial involving concept questions that related to weekly assignments. However, outside-of-class access to the professor's delivery of the lecture material was limitless and left to the discretion of the student. Both electronic personal response systems and Mazur's peer instruction technique (Mazur, 1997) were applied during the once-a-week active tutorials. Course delivery also included laboratories, which remained unchanged from the traditional approach as in the courses taught from 2001 to 2005.

Student performance with traditional lecture-based delivery (taught from 2001-2005) versus flipped delivery, all taught by the same instructor, was examined. Figure 1 reveals no significant difference in student performance on the final exam where a comparison is made between the 531 students who took the traditional lecture-driven course from 2001 to 2005 and the 89 students who took the course in the blended format in 2013.

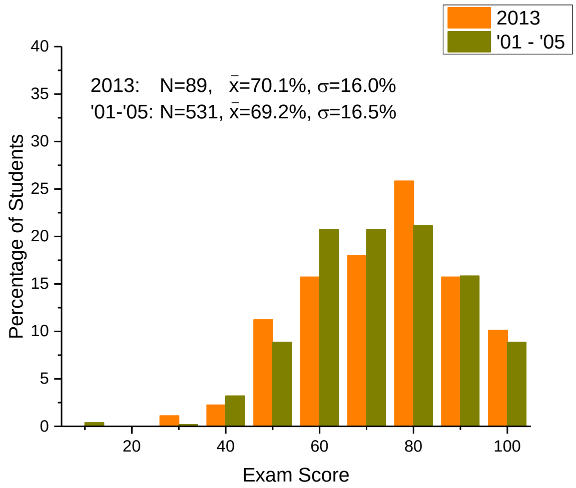

Figure 1: Final Exam Performance - 2013 versus 2001-2005

Mid-semester feedback gathered by a Student Liaison Committee on the flipped delivery model was mostly positive, but it also included some constructive criticisms. Example criticisms included students expressing the following: 1. a desire for additional problems to be solved during the lecture; 2. a desire for more opportunities to ask the course instructor questions; and 3. concern over the fact that they were paying tuition to watch what they surmised were free YouTube videos, even though the on-line offerings were developed by the course instructor specifically for the Fall 2013 course offering. Using the personal response systems, students were asked to perform a priority ranking of all of the constructive criticisms that were received during one of the active tutorials. The concern over tuition was the one criticism that seemed to particularly resonate with the students. This was not overly surprising given that student tuition has become a contested issue within Canada since the onset of the Great Recession in 2007 (CBC, 2013). Overall, however, the student feedback could best be summarized by the following comment: *Students would like more time to ask questions to the professor and more time for interaction.*

Student feedback, as quantified by the UCalgary Universal Student Ratings of Instruction (USRI) instrument, rated overall instruction for the blended delivery course at 5.76 / 7 as compared to 6.81 / 7 obtained from the traditional lecture approach that characterized the 2001-2005 courses. Despite the decrease from 6.81 to 5.76, overall instruction at 5.76 / 7 was still in the upper 60th percentile of all third-year courses taught at the Schulich School of Engineering during the Fall of 2013. It was concluded that, as the technology for blended delivery continued to improve, so would the overall rating of instruction.

A recent paper (Terwiesch & Ulrich, 2014) argued that the availability of new on-line delivery technologies (which the paper's authors refer to as SuperText) will enable Regular classes to be transformed into a New Frontier, be it more efficient delivery models (a horizontal translation in Figure 2) or improved learning (a vertical translation in Figure 2). With the 66% reduction in face-to-face contact, Figure 2 concisely demonstrates that the Fall 2013 YouTube course delivery experiment (Hugo, 2014) was essentially a horizontal translation; that is, an improvement in efficiency without a change in student learning. Given this assessment, the current paper explores the second dimension in Figure 2, that is, the examination of methods by which student learning can be improved.

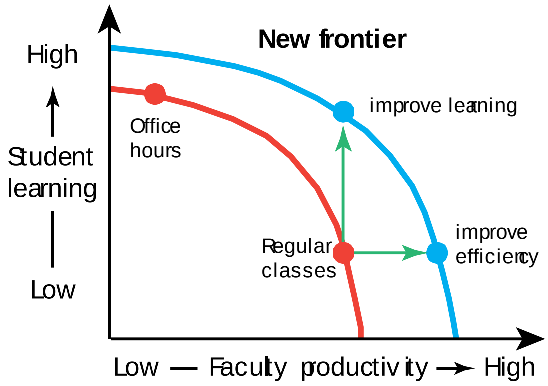

Figure 2: The new frontier of course delivery (Terwiesch & Ulrich, 2014)

2.1 Research Question

The student feedback obtained from the Fall 2013 experiment clearly indicated a strong student desire for increased interaction. Given this feedback, this paper explores whether xBL can be applied to a flipped-delivery course to improve student learning (a vertical translation in Figure 2) while simultaneously increasing the amount of student-instructor interaction. In exploring this question, a course to be delivered in Summer 2015 will serve as the basis for which the investigation will be performed. This paper describes the design of the investigation and concludes with broader observations on further program design.

3 Constructive Alignment

In exploring teaching and learning activities that can be used to improve student learning using the flipped-delivery model (the vertical dimension in Figure 2), it is useful to begin with the concept of Constructive Alignment as proposed by Biggs & Tang (2011). The application of Constructive Alignment to engineering education is graphically illustrated in Figure 3, based on an article by Felder & Brent (2003).

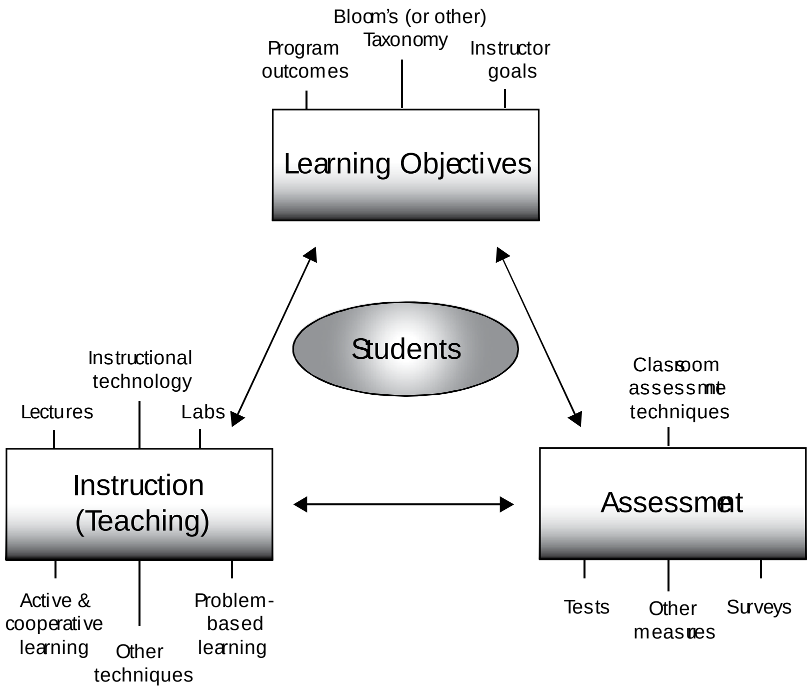

Figure 3: Elements of Course Design (Felder & Brent, 2003)

The Learning Objectives in Figure 3 pertain to what we want the students to understand at the conclusion of a teaching and learning activity. The learning objectives could be the instructor's goals for a specific activity or course, the learning outcomes of an entire degree program, or the learning outcomes derived from a learning taxonomy, such as Bloom's Taxonomy. In considering Bloom's Taxonomy, higher education has traditionally focused on only the Cognitive domain, often neglecting both the Affective and the Psychomotor domains. The reasons for this are varied; however, one important reason resides in student assessment, a second vital component in Constructive Alignment. A review conducted by the Quality Assurance Agency for Higher Education (QAA, 2003), as described in Boud and Falchikov (2006), commented that *the main deficiencies identified in university courses were not related to teaching and learning, but to assessment practices*. They continue by writing that *reviewers had found a very narrow range of assessment methods in use and over-reliance on traditional examinations.* Traditional examination-based assessment is best suited for the Cognitive domain; hence, this helps explain why the Affective and Psychomotor domains are often neglected.

This focus on the Cognitive domain may also help to explain the reason that repeated observations have been made noting the absence of particular skills in engineering graduates. For over two decades, industry leaders have commented on the lack of professional skills observed in engineering graduates (Boeing, 1996). The results of a recent survey (Kirkpatrick & Danielson, 2012) of over 1500 industry engineering managers, 635 early career Mechanical Engineers, and 80 Mechanical Engineering department heads reveals that, despite recent attempts to reform engineering education, engineering graduates still lack certain skills. Particularly notable are significant differences between Industry Supervisors and Educators in areas such as technical fundamentals; problem solving and critical thinking; design skills; interpersonal / teamwork skills; and an ability to perform experiments, as shown in Figure 4. The identification of some of these deficiencies has been a partial driver for engineering accreditation organizations throughout the world (Hanrahan, 2011; IEA, 2014) to implement the requirements for graduate attribute tracking and outcomes-based assessment. Other deficiencies such as technical fundamentals, problem solving and critical thinking are cited less, but nonetheless still concerning.

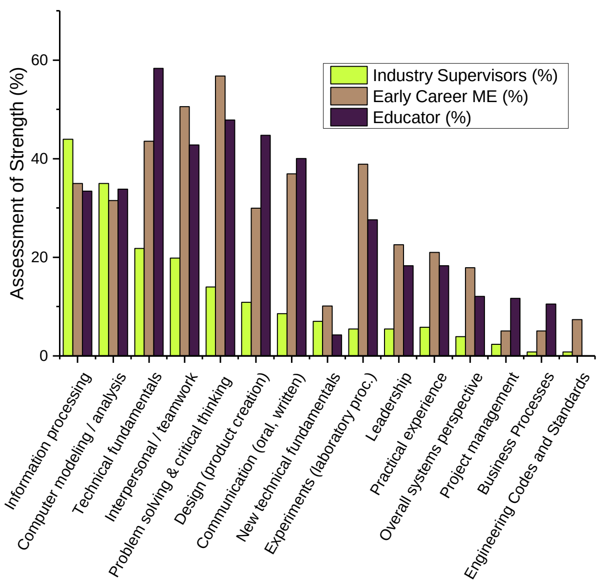

Figure 4: Assessment of Strengths in Mechanical Engineering Graduates (Kirkpatrick & Danielson, 2012)

With the ability to move lecture content to on-line in the flipped delivery model, an opportunity arises to use contact time in ways not previously possible. Desired outcomes of this change process include the ability to increase meaningful contact time with students, and to provide teaching and learning activities that develop not only the Cognitive domain but also the Affective and Psychomotor domains. Within CDIO (Crawley et al., 2014), these are referred to as dual-impact learning experiences, and they can include classroom-based active learning or xBL-based methods.

3.1 Spectrum of Teaching and Learning Activities

Figure 5 illustrates the spectrum of teaching and learning activities in relation to the learning outcome domain from Bloom's Taxonomy. Teaching and learning activities are shown to range from the more traditional faculty-centered lecture / laboratory / tutorial activities to the more student-centered xBL approaches.

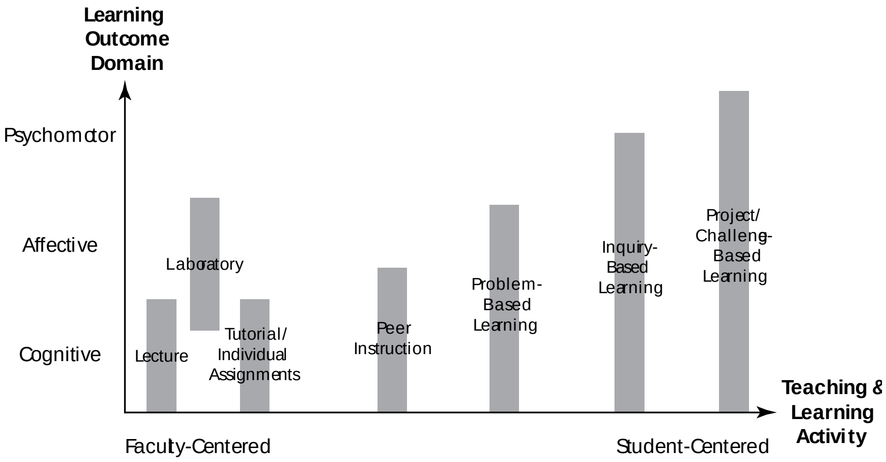

Figure 5: Spectrum of Teaching and Learning Activities

As mentioned earlier in this paper, a second-year (sophomore) Fundamentals of Fluid Mechanics course will be offered in the flipped-delivery format during the Summer of 2015. This course is normally offered during the 13-week long Winter semester (January – April) and consists of three 50-minute lectures per week, 75 minutes of tutorial per week, and 150 minutes of laboratory every second week. In this mode of delivery, tutorials have traditionally consisted of problem solving activities/assignments while the laboratory has involved performing three pre-arranged experiments that include the collection, analysis, and reporting of data in the form of a written laboratory report.

Two of the laboratory experiments involve the use of equipment by the vendor Armfield, and include the following: Impact of a Jet and Energy Losses in Pipes. Equipment for each of these experiments costs around $10,000 which includes $6,000 for a flow bench and $4,000 for the experiment itself. Due to the high cost of the equipment used for these experiments, group size is often as high as eight students and the written laboratory report is a group report. In transforming this course using the flipped-delivery format, an opportunity arises whereby the Teaching and Learning Activities can become less faculty-centered and more student-centered (Figure 5) with an explicit goal being to address some of the deficiencies identified in Figure 4.

At a little over six weeks, the Summer semester at UCalgary is approximately half the duration of the regular Fall or Winter semesters. A comparison of weekly contact hours between the Winter and Summer semesters is shown in Table 1. Offering the course in the Summer semester provides longer continuous blocks of contact time versus what would be available in the Winter semester. The Summer format provides an advantage in that multiple activities can be planned for a single lecture or tutorial session. Example activities could include Active Learning using Peer Instruction, especially if placed right after a homework assignment has been submitted (Hugo, 2014). It could also include a problem-solving session where the instructor works step-by-step through a problem solution and the students work along with the instructor, pausing at key decision points in the solution procedure for open classroom discussion.

Table 1: Weekly Contact Time – Winter versus Summer Semesters.

Semester	Contact Time (minutes) Lecture (all students)	Tutorial (all students)	Laboratory (4 groups)	# of Weeks
Winter	3 @ 50	1 @ 75	0.5 @ 150	13
Summer	3 @ 110	1 @ 150	1 @ 150	6

As indicated in Figure 5, a wider range of learning outcomes can be impacted by moving to xBL activities such as Inquiry-Based Learning or Project-Based Learning. By replacing the existing pre-arranged (and more passive) laboratory experience with Inquiry-Based Learning activities (involving both construction of the experimental apparatus and the formulation of a test plan), deficiencies identified in Figure 4, including interpersonal / teamwork, oral and written communication, and experimental procedures, can start to be addressed. The true flexibility of the flipped-delivery approach is that both lecture and tutorial time can be used to introduce, guide and conduct xBL activities. An example of this process as applied to a single laboratory experiment is provided in the next subsection.

3.2 Inquiry-Based Learning – *Bottle Rocket Example*

A common topic in most introductory fluid mechanics courses involves Control Volume Analysis using the Momentum Equation. One particularly challenging Control Volume Analysis problem is that of a Control Volume undergoing linear acceleration. Given the challenge that it presents to students, an experiment involving an accelerating control volume is desired. Fortunately there are a number of relatively simple experiments that can be conducted in order to demonstrate this concept including CO2-popelled cars, air-powered balloon cars, or compressed-air water bottle rockets. Although these projects are often conducted by students in grade school, it is possible to increase the sophistication of a project through the introduction of relatively low-cost instrumentation. This could include the addition of sensors, embedded processors, data acquisition systems, and high-speed video.

3.2.1 Design of the Bottle Rocket Experiment

Figure 6 shows a series of images collected during the vertical acceleration of a water bottle rocket. A search of the internet using the words "water bottle rocket" reveals a wide number of potential projects. Of particular interest is the website www.instructables.com, which has listings that include complete sets of instructions on how to build a variety of projects, including water bottle rockets. One project that is appealing from an Inquiry-Based Learning perspective involves the use of low-cost radio telemetry for data collection during rocket acceleration (MakersBox, 2011).

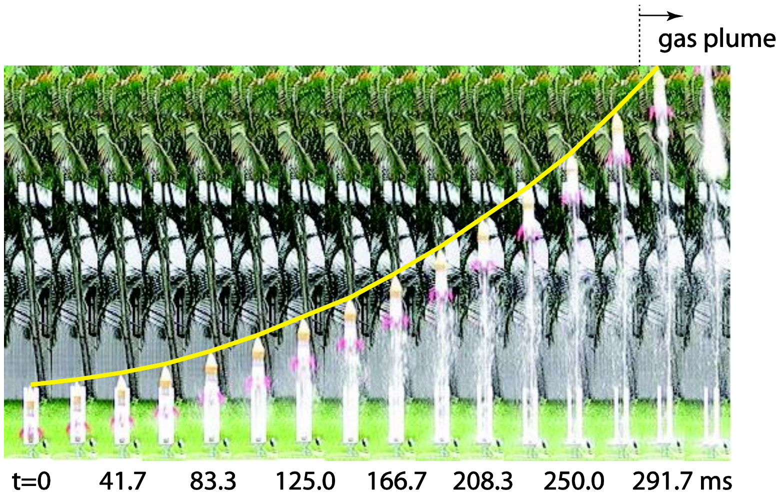

Figure 6: High-Speed Video Sequence of the Launch of a Water Bottle Rocket

The author of the current paper has used Instructables projects for Inquiry-Based Learning in a set of courses that he has taught as part of a Canadian-Chinese partnership over the past five years (Hugo et al., 2015), and he has found that these projects, if carefully selected, can be an excellent source for improving both student engagement and the development of some of the deficiencies highlighted in Figure 4 (see Figure 7 in Hugo & Gu, 2010). At the conclusion of one of these experiments in 2014, a student commented, "I can hardly wait until I get back to my dorm room so that I can analyze this data." It is believed that when students build the experimental apparatus themselves, they attain a vested interest in seeing both the experiment work and in understanding its behavior. As educators, this is the type of motivation that we desire to instill in our students.

3.2.2 Impact on Student Learning

Assuming that the low-cost telemetry system (MakersBox, 2011) will be used on a Water Bottle Rocket for an Inquiry-Based Learning activity in the Summer 2015 Fundamentals of Fluid Mechanics course, students will be forced to rely on knowledge that they would have been exposed to in earlier courses as part of the UCalgary Engineering program. These courses would include Dynamics, Fundamentals of Electrical Circuits and Machines, Computing for Engineers, Computing Tools for Engineering Design, and Numerical Methods in Engineering.

It is interesting to note that, in the traditional delivery of the Fundamentals of Fluid Mechanics course, the Armfield Impact of a Jet experiment would cover the topic of Control Volume Analysis using the Momentum Equation. Due to the 150-minute duration of the laboratory, students typically arrive in the laboratory with the experiment set up and ready to go. Although efficient from a time usage perspective, the consequence of this is that students rarely understand how the experimental apparatus is configured or even what it does. Data collection and analysis, if performed *without* reliance on previous reports by other students (often referred to as "roadmaps" by students), *may* result in reinforced learning of the specific topic to which the laboratory pertains. It does not, however, result in reinforcing the learning from other courses.

The Inquiry-Based Learning approach, on the other hand, enables students to acquire an understanding of the topic to which the project / experiment pertains, but it also reinforces the learning from other courses within the program. In the case of the Water Bottle Rocket experiment, it is possible for learning to be reinforced from up to five earlier courses. According to Ambrose et al. (2010), this is important to the learning process in a number of ways. The first is that the teaching and learning activity is able to link new material to knowledge from previous courses (Activating Prior Knowledge). The second is that the students are actively engaged in the learning process, as indicated by the student quote in the previous subsection (Connect the Material to Students' Interests and Provide Authentic, Real-World Tasks). Finally, by highlighting connections to other courses, knowledge structures are reinforced (Make Connections Among Concepts Explicit) and become interconnected. As more courses within a program undergo the flipping process, their content will become available to students in the form of searchable and indexed segments. This will enhance a student's ability to refer back to content from other courses, resulting in an improvement to the learning process and a softening of the boundaries between courses.

The use of xBL teaching and learning activities also appeals to a wider variety of learning styles. According to the Felder-Silverman learning style model (Felder et al., 2005), the range of learning styles includes the following:

1. **Sensing-intuitive** – concrete, hands-on, practical learning versus more conceptual and theoretical learning style.
2. **Visual-verbal** – visual learners prefer visual representations (flowcharts, diagrams, etc) while verbal learners prefer written and spoken explanations.
3. **Active-reflective** – active learners prefer to learn by trying and doing things (often together) while reflective learners prefer to think things through (often alone).
4. **Sequential-global** – sequential learners like to go step-by-step through a process, whereas global learners like to see the "big picture" all at once.

The Water Bottle Rocket Inquiry-Based Learning experience would appeal to the Sensing-Visual-Active-Global learning styles. Student learning can be improved by appealing to a more diverse group of student learning styles.

3.3 Course Design: Lecture Flipping and TLA Integration

In planning a flipped-delivery course, the first step is to prepare the lecture material for on-line delivery. During the Fall 2013 experiment (Hugo, 2014), it took approximately six hours for the paper's author to convert each traditional lecture hour into an on-line delivery format. This process included re-organizing notes that had been prepared for a 50-minute lecture into smaller segments; recording each of these segments; editing the raw video feed; embedding multimedia content where appropriate; rendering the edited video into a file compatible with video distribution; and, lastly, uploading the video segment to the video distribution system. It is important to note that the last two steps required approximately 33% of the total six hours to complete and could be performed autonomously.

After converting the lecture material, the next step was to determine how to allocate the different teaching and learning activities throughout the duration of the course. In general, an instructor has a wide degree of freedom in making these choices. If a course only has scheduled lectures, then this would involve determining what types of in-class activities the instructor will do with the students. If using Peer Instruction and Active Learning (Mazur, 1997), it will be necessary to develop Concept Questions for the topics covered in the course. If the course consists of assigned problem sets, it would be most appropriate for the Concept Questions to evaluate the important concepts in each of the assigned problem sets.

If the course has a scheduled laboratory, then it is possible to include one or more xBL activities. As described with the Water Bottle Rocket example earlier in this paper, these need to be chosen in a manner that blends well with the course content, ideally covering topics that are associated with key learning outcomes for the course. Finding appropriate activities associated with key learning outcomes and then adapting them to the laboratory environment takes time, but the wide availability of project sharing that exists on the internet makes this process much simpler than it was in the past. Once projects have been chosen (and ideally tested), the instructor then prepares the learning environment for the students by ordering appropriate materials and supplies, low-cost instrumentation and measurement equipment, and securing the appropriate Engineering Workspaces (CDIO Standard 6, Crawley et al., 2014) required for the activity. Project results can be communicated by the students using both oral and written methods, using appropriate rubrics to assess student work. Given that the projects involve teamwork, it has also proved useful to use a rubric for teamwork evaluation (consisting of both peer and self-evaluation).

One final point concerns the amount of time that students would need to spend on the flipped delivery course. The instructor needs to recognize that students will be using out-of-class time to watch the video content. Consequently if the in-person contact time is being used for other activities, the instructor will need to adjust the length of activities assigned the students so as to not overload them. This is sometimes difficult to quantify, but it should still be carefully considered by the instructor.

4 Methods

This section discusses the nature of the student sample, the instruments and measures used, and the procedures by which the instruments and measures will be delivered to the student sample. In order to assess the proposed research question of whether xBL can be applied to a flipped-delivery course for both increased student learning and increased student-instructor interaction, two of the three traditional laboratories in the Fundamentals of Fluid Mechanics course will be offered in parallel to an xBL activity of similar topic. It will take two weeks to complete each of these traditional-to-xBL comparative studies. Each laboratory section will be broken into two blocks, with one block conducting the traditional laboratory in week one followed by the xBL activity in week two, and the other block conducting the xBL activity first in week one followed by the traditional laboratory in week two. This experiment will be conducted during the Summer of 2015.

4.1 Sample

A total of 65 students have registered for the Fundamentals of Fluid Mechanics course to be offered during Summer 2015. A quota of 20 students was placed on each of the four lab sections, and students have unevenly self-registered with 20 students in B01 (Monday), 14 students in B02 (Tuesday), 20 students in B03 (Wednesday) and 11 students in B04 (Thursday). Lab sections will be divided into groups of approximately 5 students per group.

4.2 Instruments and Measures

In order to assess how traditional laboratories compare to xBL in a flipped-delivery course, students will be assessed using a Fluid Mechanics Concept Inventory at the end of week one and then again at the end of week two for each of the two-week traditional-to-xBL comparative studies. Students will also be asked to complete a survey at the conclusion of each two-week cycle, evaluating how they perceived both the traditional laboratory as well as the xBL activity. An evaluation of the level of student-instructor interaction for both traditional and xBL activity will also be performed.

4.3 Procedures

The traditional laboratory will be offered in a manner similar to previous course offerings involving a 3-hour laboratory period where students perform an experiment, followed by a group report submitted the following week. The xBL activity will be more open ended than the traditional one, and students will have access to the laboratory during both lecture and laboratory periods to work on their projects. The xBL activity will conclude with group presentations made by the student teams.

5 Evolution Towards Degree Programs

As more courses are transformed through the lecture-flipping process, more of the lecture content will become available in the form of searchable indexed content. The flipping of the Mechanical Engineering course in Fall 2013 (Hugo, 2014) resulted in the development of 145 lecture segments that ranged in duration from 3 to 15 minutes. If every course in a 42-course degree program underwent the lecture-flipping process, approximately 6000 lecture segments would be made available to students. It is anticipated that there would be some overlap in content between courses, and thus the final number of lecture segments for a degree program would be lower than 6000. Regardless of the final number of segments, the topics of these segments then become the knowledge map for the degree program.

Figure 7 shows two different semesters in a typical Engineering program. Each of the buildings represents a single course, with each brick representing a week in the semester and the different colored bricks denoting specific aspects of each course as specified at the bottom of the figure. The five buildings to the left of the figure indicate one semester, while the six buildings to the right indicate another semester. What is noted in the representation portrayed in Figure 7 is how isolated each of the courses is from one another. This isolation exists for a number of reasons with the most important being that each instructor is responsible for his/her own course. The ability to link content between courses is difficult due to the careful planning and coordination that would be required amongst instructors.

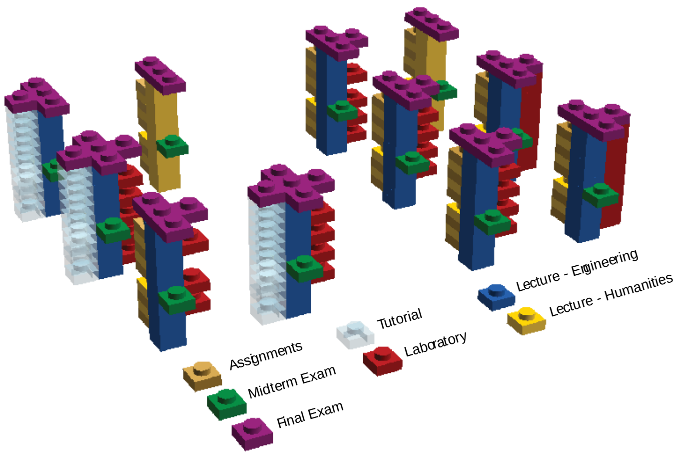

Figure 7: Two Semester Representation using a Traditional-Delivery Model

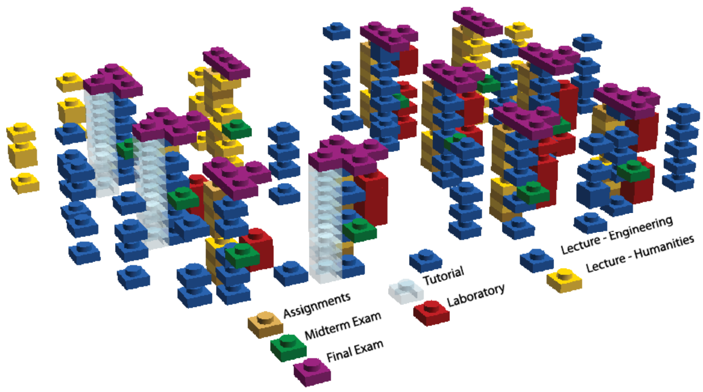

Figure 8: Two Semester Representation using a Flipped-Delivery Model

A flipped delivery model is illustrated in Figure 8 where the two semesters seem to be less rigid. Central "buildings" still represent courses; however, discrete lecture modules are now randomly distributed. The figure shows continuous blocks of laboratories which represent Inquiry-Based Learning projects. Given that the lecture material is now more widely distributed, it becomes possible for courses to "borrow" content from one another. Given the availability of this content, it is now much simpler to coordinate content from one course to another course. In this model, the majority of the instructor's time is spent on defining the Inquiry-Based Learning activities, the assignments, the midterms and the exams with less time on lecturing.

6 Conclusions

This paper has explored methods by which the flipped-delivery model can be used for either an improvement to the efficiency of the learning process or an improvement to the learning process. It was argued that the improvement of learning can extend beyond the Cognitive Domain to include both the Psychomotor and Affective Domains of Bloom's Taxonomy. Student-centered teaching and learning activities that include Active Learning, Inquiry-Based Learning, and Project-Based Learning are all able to reinforce the Cognitive Domain while activating the Psychomotor and the Affective Domains. The adoption of a flipped-delivery model enables the contact time between student and instructor to be used for alternative teaching and learning activities. By applying more student-centered teaching and learning activities, it is possible for improvements to the learning process to be made, specifically to address deficiencies in areas such as technical fundamentals, problem solving and critical thinking, design, interpersonal relations / teamwork, and experimental skills. This process requires the instructor to move from one who delivers content to one who creates the learning environment in which content is explored.

As more courses undergo the flipping process, more indexed and searchable content will be available to students. Although it is not believed that the structure of the individual course will disappear completely, it is believed that the boundaries between individual courses will be softened. Inquiry-Based Learning activities that span across several courses, as described in the paper, will become more common. With this, the xBL teaching and learning activity will become the glue that binds the curriculum together. It is hypothesized that the flipped classroom approach will improve learning as students will be able to more effectively build knowledge structures by building from prior knowledge. Moreover, they will be able to understand the connections between concepts. Most importantly, when given real-world problems, students will be more engaged in the learning process.

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Use of ICT tools to manage project work in PBL environment

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Abstract

Engineering Education at Aalborg University, Denmark, is project organised and problem based (PBL). From the first semester, students learn to solve problems through projects. Problems are identified and formulated from real and open situations. Once the problem is formulated, students plan and develop methodologies in order to solve the problem and argue for possible solutions. The learning process is also project organised, which means that it is a unique task, goal oriented, with deliverables, and resource-limited., In all first year engineering bachelor programmes, students have the course "Problem Based Learning in Science, Technology and Society" (PBL course) which provides knowledge and tools to support student problem formulation and solving, as well as project work. Some of the tools are ICT tools, such as Trello, Scrum Board and Zotero, which aims are to organise and manage the project work through time and activity planning, allocation of resources and documentation. The ICT tools are suggested to students in order to support their learning processes but there is no systematic assessment of which kind of ICT tools students use and why. This paper aims to investigate what kind of ICT tools students use to manage the project work in a problem oriented learning environment. The study takes a qualitative approach whereas content analysis is the method used. The documents analysed are students' processes analysis reports. The results show that the tools suggested through PBL course are used by students (e.g. Trello, Zotero and LaTex) however these are not enough to manage the project work. The results show 24 different ICT tools used by students. The most used tools are Facebook, Skype, Trello, Dropbox, Google docs, Zotero and LaTex. These tools aim to manage communication within groups, time and activity planning and documentation process.

Keywords: Problem Based Learning, Project Management, ICT tools

1 Introduction

Everyday new Information and Communication Technologies (ICT) are developed, integrated and have an impact in education systems. ICT tools provide possibilities and opportunities for innovation in learning in higher education such as new ways of communicating, storing and sharing knowledge, and collaborating across the globe. These technologies also provide new platforms and spaces for learning and learning activities. They are used to support diverse activities in education namely to help establishing long distance educational programmes and courses, see for example tools such as MOOC (massive open online courses), or Moodle (open-source web application for producing modular internet-based courses). Other tools support higher education systems learning processes by providing tools to manage, scheduling lectures, group meetings, etc. (Bygholm & Buus, 2009). ICT tools can be an add-on to the learning strategy already used by students and teachers, or create a whole new learning strategy. They can form interfaces between physical learning spaces, such as classrooms, libraries, group rooms, and virtual learning spaces (figure 1) (Dirckinck-Holmfeld, 2009).

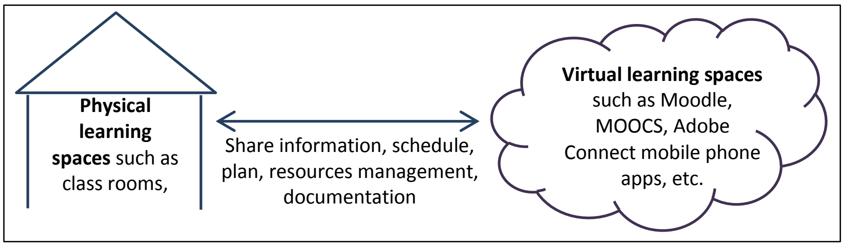

Figure 1: ICT tools used as part of learning processes creating an interface/ interaction between physical and virtual learning spaces

Students who integrate higher education are part of digital era where computers and mobile devices are part of daily live and new free software and applications (so called apps) are easily appropriate to facilitate communication, access to information, socialisation, etc. This generation use diverse ICT tools to organise and support their learning, including the project work. See for example the number of free and available tools which can be found in a simple search on the internet.

Engineering Education at Aalborg University is problem oriented and project organised (PBL). PBL is an active, student centred approach where the learning process is driven by identification, formulation and solving a real problem. Problems are identified and formulated from real and open where both problem solving processes and solutions are unknown to students. In a problem oriented learning process, students engage in investigative processes in order to solve the problem formulated and develop the knowledge they do not have (Olsen & Pedersen, 2008) (Barge, 2010). PBL is also project organised, which means students address the problem through project work. In the project work students organise, plan and document the solving process, manage resources, formulate goals and deliver a product. In this learning environment the emphasis is both in the process (e.g. managing project work) and in the product (e.g. deliver a solution, or answer, to problem formulated and a written report) (Olsen & Pedersen, 2008; Spliid & Qvist, 2013). According to Olsen and Pedersen (2008, p.63) project work '*requires and develops qualification and tools whose usefulness extends beyond the academic qualification expressed in a project report*'. Example of these qualifications are ability to communicate and collaborate with others, reflect in working processes, provide and receive criticism, develop work plan, allocate resources, apply appropriate knowledge and tools (Barge, 2010) (Kolmos, Holgaard, & Dahl, 2013) (Spliid & Qvist, 2013).

In all first year engineering bachelor programmes, students have the course "Problem Based Learning in Science, Technology and Society" (PBL course) which provides knowledge and tools (including ICT tools) to support student problem formulation and solving as well as project work.

2 PBL course and enhancement of project management skills

The Aalborg PBL model can be characterised as: as problem oriented, project organised, integration of theory and practice, participant-directed, team-based, contextual and collaborative (Barge, 2010). For the 1st year engineering students this means to enter in a learning environment where:

- Each semester is organised of three courses of 5 ECTS each and a project of 15 ECTS;

- The curriculum learning goals are met through 50% of course work and 50% of project work;
- Groups of 6-7 students are formed and to each group is allocated a group-room and supervisor;
- A problem of societal relevance is identified, formulated and solved;
- A project is organised, planned and carried out;
- Group collaboration is formalised through a group contract. Typically a group contract includes basic rules of conduct and behaviour regarding group work, namely working hours, meetings, contact with supervisors, etc.;
- The project is assessed through a report and oral group examination.

In an active, student centred environment it is needed to provide students' knowledge, skills and competencies for their project work and collaboration when planning and conducting a scientific problem solving approach. To fulfil this purpose the course "Problem Based Learning in Science, Technology and Society" (5 ECTS) is offered the 1st year students. According to (Mosgaard & Spliid, 2011), the PBL course focuses on:

- Introducing methods and tools to manage project work;
- Providing feedback through consultation and commentary to the project's working processes and management;
- Securing an experimenting and reflective space for groups.

The PBL course includes lectures, seminars and workshops which introduces methods and tools to manage the project work, including ICT tools. Figure 2 illustrates a typical organisation of PBL course in the first semester of engineering programmes. For example, it presents resources provided to students through lectures, activities students engage (e.g. gathering experiences, participate in seminars, etc.) and documents produced (e.g. P0 and PBL process analysis reports, and portfolio). Written process analysis is where students evaluate their process in project work, and use this analysis for future projects. The portfolio is a tool where students collect their written reflections and the assignments they carried out after the PBL lectures (Mosgaard & Spliid, 2011). Notice that this simplified scheme of PBL course given to first year students and may not reflect its complexity and its specificities for the different engineering programmes.

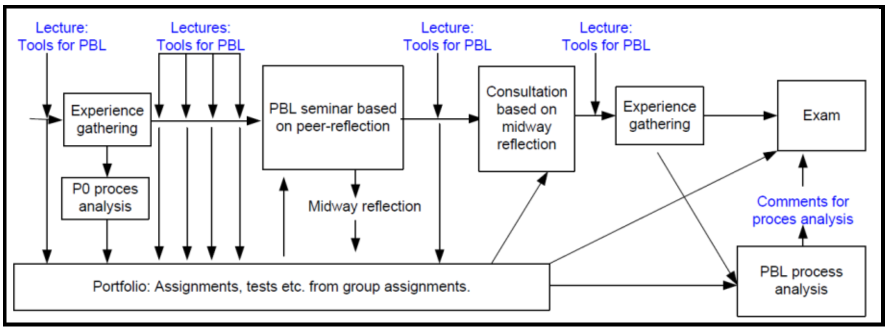

Figure 2: Organization of PBL for first semester (retrieved from Mosgaard & Spliid, 2011)

The ICT tools given PBL courses are mainly related with time management and documentation. Examples of ICT tools used to organised learning are Trello (activity and time planning based on to do list, done, progression) or Zotero (manage references).

In the first year groups also have the opportunity to submit short reports describing the project work processes and management in the middle of the semester. This report, called process analysis report, provides the basis for feedback through consultancy and commentary. The process analysis report is a description and analysis of group working processes throughout the semester. It focuses on four main areas: project management, cooperation within group members, and cooperation with supervisor and learning processes (individual and collective). The PBL course also provides knowledge and guidelines for reflection on project working processes. The guidelines, which are based on Kolb's (Kolb, 1984) and Dixon's (Dixon, 1999) cycles of learning include:

- Concrete experience/ generate where experiences are described including methods and tools used such as project plans, schedules, group contracts, extracts of log books, etc.
- Reflective observation/ integrate where students should reflect upon how the working processes went taking into consideration the good experiences and not so good experiences reported in previous point.
- Abstract conceptualisation/ interpret where groups should critically analyse their work and reveal why things went the way they did. Here, students should reveal the underlying and general factors that have influenced processes.
- Active experimentation/ act where groups should point good advices for the next project through for example "stop to do", "start doing", and "continue doing" lists.

Process analysis aims to engage students in a reflective process whereas students can improve and enhance their problem based and project work for the coming semesters. Furthermore the process analysis report is part of the project examination and secures an experimenting and reflective space within project work (figure 2).

Some of the tools are ICT tools, such as Trello, Scrum Board and Zotero, are provided by the PBL course and aim to organise and manage the project work through time and activity planning, allocation of resources and documentation. The ICT tools are suggested to students in order to support their learning processes but there is no systematic assessment of which kind of ICT tools students use and why. Gathering such knowledge allow academic staff, in particular the lecturers for PBL course, to better understand the students' needs for digital means and provide better support to students. It also allow a better understand which types and functionalities of ICT tools could enclose to better adjust the needs of PBL environments and group work. This paper reports an explorative study and aims to investigate what kinds of ICT tools students use to manage the project work in the problem oriented learning environment by addressing the following research questions:

1. What are the main ICT tools used to manage project work?
2. What are the purposes of the ICT tools used?

3 Research methodology

The methodology applied to this study is a documentary analysis of process analysis reports of B.Sc. Medialogy at Aalborg campus. In 1^{st} semester 2014, the B.Sc. Medialogy has a total of 23 groups; 6-7 students compose each group. The following presents the context of PBL course and process analysis reports of the B.Sc. Medialogy in 1^{st} semester 2014.

3.1 PBL course and process analysis reports

In the B.Sc. Medialogy programme, the PBL course, delivered in the fall 2014, includes a total of 13 sessions and covers a range of topics of PBL and STS. For example, students have lectures and workshops introducing PBL and STS, project design and contextual mapping, creativity work, STS methodologies and research methods, collaborative learning, project management, scientific writing, theory of science, project presentation, process analysis guidelines, etc.

The PBL course presents four project management ICT tools: Gantt Project, Trello, Scrum Board and Zotero. Gantt Project, Trello and Scrum Board are internet-based software tools for time management and activity planning. While Gantt Project provides a long-term overview of project, Trello and Scrum Board are based on short-term time and activity planning. The two later tools are similar to a "to-do list", where students attribute each activity to a person and check the progression of its completion. Zotero is internet-based software to manage references used in the investigative process of solving the problem and in the report.

In 1^{st} semester 2014, each one of the B.Sc. Medialogy groups had the possibility to submit two process analysis reports: one mid-term (or midway) process analysis report and a final process analysis report. The mid-term process analysis, delivered in November, allow the groups to have feedback through consultation and commentary to the project's working processes and management from the PBL course lecturers. The final process analysis reports are submitted in December, jointly with project report, for examination.

In this study, a total of 40 process analysis reports were delivered by groups, where 17 reports were mid-term process analysis reports and 23 were final process analyses reports. As mentioned above, students describe, explain and argue about the project work processes namely collaboration, division of tasks, meetings, and the tools used. These reports are analysed through content analysis. Content analysis can be defines as a "*strict and systematic set of procedures for the rigorous analysis, examination and verification of the contents of texts*" (Cohen, Manion, & Morrison, 2007, p. 475) (i.e. written communicative materials). According to Cohen *et. al.* (2007, p. 275) content analysis focuses on language and linguistic features, meaning in context, and is verifiable in its use of codes and categories. It also present itself as an alternative numerical analysis of qualitative data whereas relative frequency and importance of certain topics in given written material.

The content analysis is done in two phases. Phase one regards the analysis of the 40 process analysis reports and registration of information in analysis grids. Each process analysis report has a correspondent analysis grid where the ICT tools and purpose of use is listed. The second phase is a meta-analysis of the analysis grids filled, resulting in a list of all ICT tools used and the number of groups who used them. The following explains in more details each phase of content analysis.

3.2 Phase one of content analysis

In phase one of content analysis, two instruments are developed: a flow chart and content analysis grid. The flow chart, illustrated in figure 3, provides a systematic procedure on how the content analysis of each report is carried out.

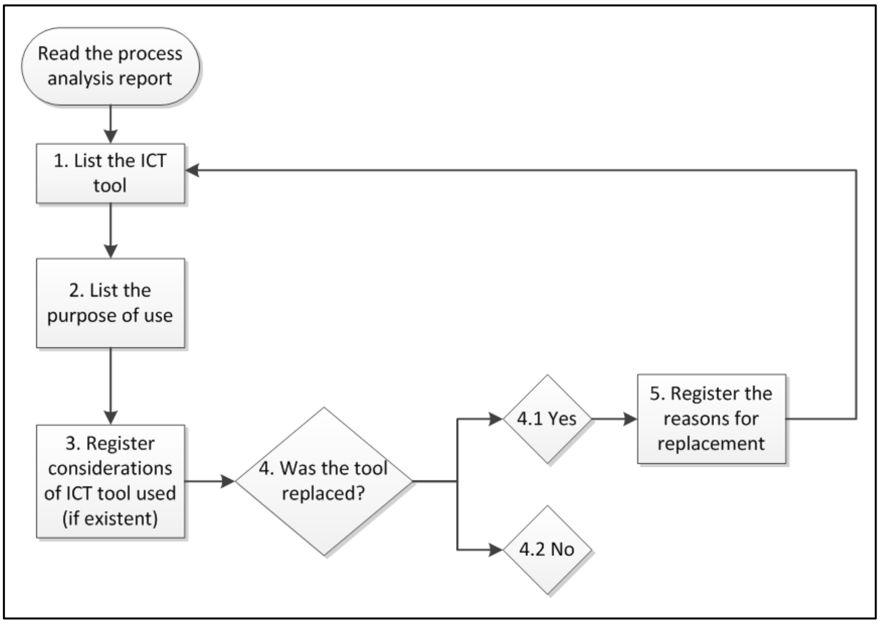

Figure 3: Procedure for content analysis of mid term and final process analysis reports

The content analysis procedure starts with reading the process analysis reports, followed by registration of: 1) of ICT tools stated in the report, 2) the purposes of use of the ICT tool to manage, 3) considerations of ICT tool (e.g. why it is used), 4) if the ICT tool was replaced during the project and 5) why. This information should be registered in the content analysis grid (figure 4).

Content analysis:

Document identification/ group number: ______________________

ID code for anonymous purpose: ____________________________

1. ICT tool	2. Purpose of use	3. Students' considerations	4. Replaced	5. Reasons for replace	6. New tool
			Yes ☐ No ☐	---	---
			Yes ☐ No ☐	---	---
			Yes ☐ No ☐	---	---
			Yes ☐ No ☐	---	---
			Yes ☐ No ☐	---	---
			Yes ☐ No ☐	---	---
			Yes ☐ No ☐	---	---
			Yes ☐ No ☐	---	---

Figure 4: Content analysis grid for data collection

Phase one of content analysis is applied to 40 process analysis (17 mid-term process analysis reports and 23 final process analysis reports) and filling in of 40 content analysis grids. The content analysis grids are, by their turn, analysed in phase two where number and type of ICT tools are listed and related with their purpose of use and number of groups using them.

3.3 Phase two of content analysis

The phase two of the content analysis aims to compile and give an overview of the ICT tools used by students and to which purpose. After the content in all reports has been analysed, all the ICT tools stated in 40 analysis grids (which are generated from the reports) are listed in a matrix of 'ICT tool and purpose X Group No'. The first column of the matrix concerns the ICT tools used reported by the students, ordered by purpose of used. The first row concerns the 23 groups, identified by number. The matrix is filled with a numeric code of 1 and 0, whereas 1 means 'use of ICT tool' and 0 means 'no use of ICT' tool by the group. This procedure of analysis results in two matrixes, one regarding midterm process analysis reports and one regarding final process analysis reports with information which and how many ICT tools each group reported in their project work. The results presented in the following are based on both phases of content analysis.

4 Results and discussion

This paper aims to investigate what kinds of ICT tools students use to manage the project work in a problem oriented learning environment. The study takes a qualitative approach whereas content analysis is the method used. The documents analysed are the processes analysis reports from 1st year students from B.Sc. Medialogy. In total 40 process analysis reports, from 23 different groups, are content analysed. From these 40 reports, 17 are midterm process analysis reports and 23 are final process analysis reports.

From the 17 mid-term process analysis reports submitted, 13 explicitly report the use of ICT tools to manage project work. The analysis shows that group 16 used 9 ICT tools while groups 4, 5, 9 and 20 did not explicitly state use of ICT tools (figure 5A).

From the 23 final process analysis reports submitted, 21 explicitly report the use of ICT tools to manage their project work. Group 16 continues to be the group reporting more use of ICT tools with 10 in total. The process analysis reports from group 4 and 5 do not report which ICT tools students used to manage their project work, however this does not mean that they did not use any (figure 5B).

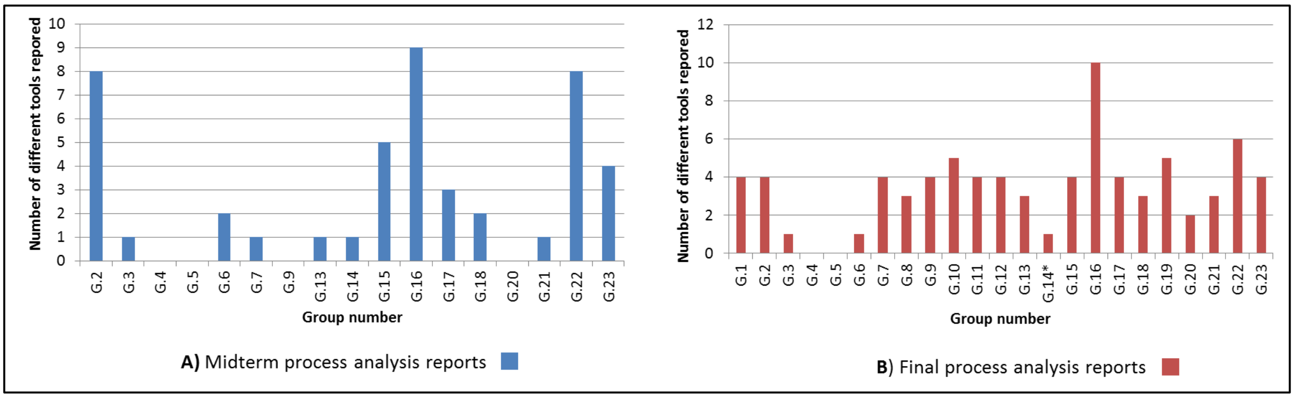

Figure 5: Number of process analysis reported analysed in relation to total number of groups, report submitted and reference to ICT tools

The results show a total of 23 different ICT tools which is used by groups to manage project work. These tools are: Facebook, Skype, live-chat, joint calendar, Moodle forum, AAU e-mail, Trello, KanBan, WeekPlan, Grantt Project, Excel, Google calendar, Dropbox, Google drive, SVN, Google docs, LaTex, Word, Popplet, PiratePad, Zotero, RefWorks, Aalborg University Bibliotheca (AUB) database.

Figure 6 illustrates the main aspects of the project work to which students use the ICT tools pointed in the above. The main aspects of project work are: group communication and collaboration, time and activity planning and documentation and reporting.

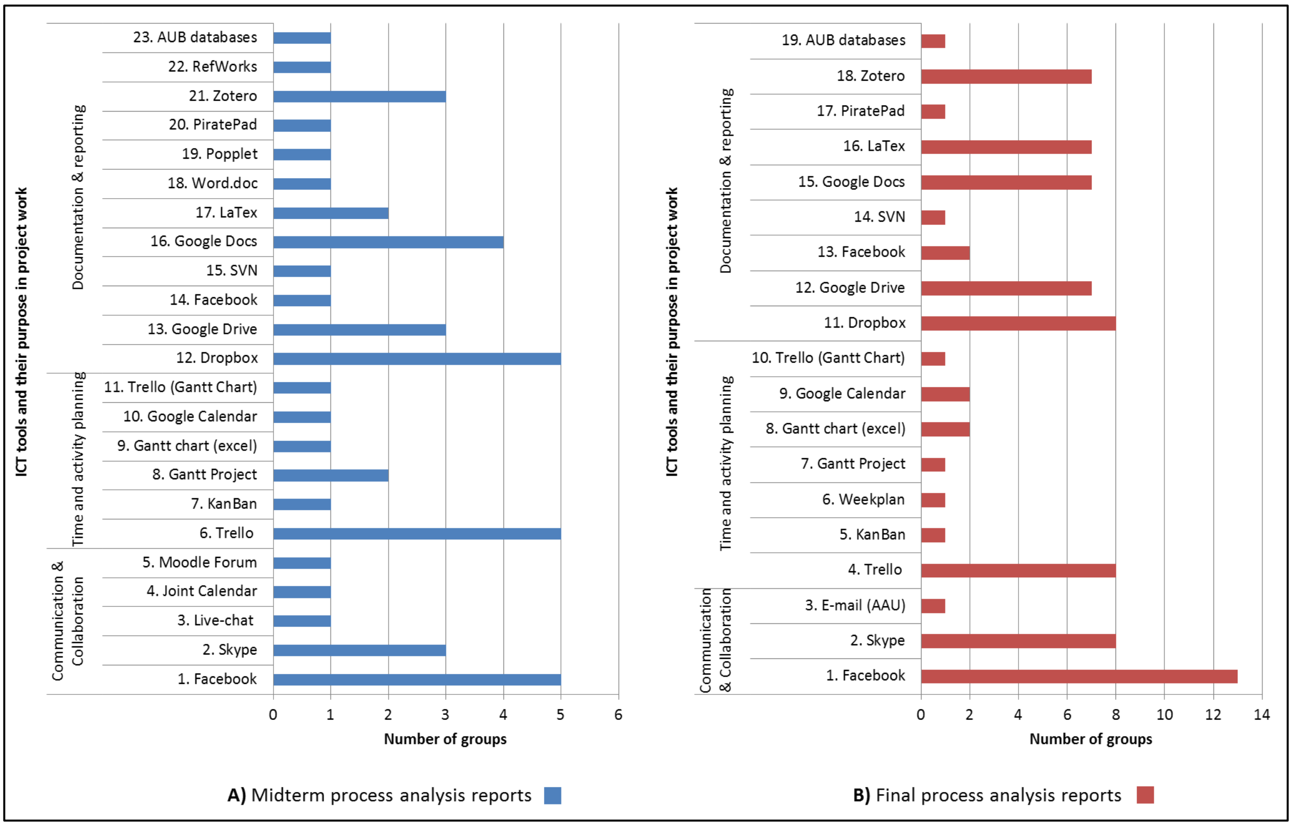

Figure 6: Type and purpose of the ICT tools reported to be used both in midterm process analysis and final process reports

For example, Facebook, Skype, live-chat, joint calendar, Moodle forum, AAU e-mail are tools used to manage group communication and collaboration in long distances, i.e. in case of absence in group meetings and group room. All of these tools are internet-based tools.

Trello, KanBan, WeekPlan, Grantt Project, Excel, Google calendar are tools used for time and activity planning. Kanban is a method for managing knowledge work with an emphasis on just-in-time delivery while not overloading the team members (see for example kanbanflow.com). With exception from Excel, all of these tools are internet-based tools as well.

Dropbox, Google drive, Facebook, SVN, Google docs, LaTex, Word, Popplet, PiratePad, Zotero, RefWorks, Aalborg University Bibliotheca (AUB) database are tools used to manage the documentation and reporting of the project. Some of these tools, such as Dropbox, Google drive, SVN, are internet-based systems to store several types of files (e.g. written, audio, video), while other documents are used for collaborative writing (e.g LaTex, Word, Popplet, PiratePad), manage references (e.g. Zotero, RefWorks) and search documents (e.g. Aalborg University Library (AUB) database). Piratepad is a web-based collaborative writing tool, which enables authors to simultaneously edit a text document, and to see participants' edits in real-time, by attributing to each author a colour (see for example piratepad.net). Popplet is web-based mind map tool with aim to organise ideas (see for example popplet.com). RefWorks is reference management tool (see for example www.refworks.com), and SVN. SVN stands for Apache Subversion, which allows its users to keep a track of all current and historical versions of files, such as web pages and documentation (see for example https://subversion.apache.org).

The results also show that students use more ICT tools to manage documentation and reporting processes (with 12 tools), followed by time and activity planning (with 7 tools) and group communication and collaboration (with 6 tools) (Figure 6).

In the midterm process analysis reports a total of 23 ICT tools are reported. Facebook is the most used tool being referred by 6 groups. Trello and Dropbox tools follow Facebook where 5 out of 13 groups report to use these tools (figure 6A). In the final process analysis reports 14 out 21 groups referred using Facebook to manage group collaboration. Skype, Trello and Dropbox follow Facebook where 8 out of 21 groups make reference in using them (figure 6B). Facebook and Trello are tools, which are repeated in lists of ICT tools presented in figure 6. Group 2 and group 16 use these tools with two distinct purposes. Group 2 reports using Facebook for documentation and share documents but not for communication. Group 16 reports using Trello to generate Gantt chart in order to have an overview of the project.

5 Conclusions

This paper presents a study conducted at the Faculty of Engineering and Science, Aalborg University, Denmark, which aim is to investigate the state of art of the ICT tools used by students to manage their project work in a PBL environment. The research is conducted in 1st semester of B.Sc. of Medialogy and content analysis is the main method used for data collection. The PBL course covers the topic of project management and organisation however it only provides four main ICT tools to students. These tools are Zotero, Gantt Project, Trello and Scrum Board for documentation, time planning, respectively. The examination of the process analysis reports shows that different ICT tools are used to manage the communication, time planning and documentation in project work. The main tool used for communication is Facebook, followed by Skype. The main purpose of these tools is to facilitate communication within groups when members are absent from the group room. The time planning tools are divided into two groups: tools for long-term time planning and tools for short term time planning. The tools used by groups are Gantt Project and Trello, both introduced through PV course (i.e. academic staff). Both tools used did not have the same impact in project work. Even though groups start to use Gantt Project as long-term time planning, most groups stopped using throughout the semester by forgetting to update the tool. The documentation is an aspect of project work for which groups' appropriate more and different tools. Students use tools to storage working papers, documents searched, etc., such as Dropbox and Google Drive. For writing papers, students appropriate a tool, which allow them to write collaboratively, such as Google docs. However the final report is submitted in LaTex format, which is suggested by academic staff. The same is for Zotero, which is a tool used to manage the different references of report.

In sum, the students used 19 different tools for communication, time planning and documentation. The tools suggested by the academic staff, through the PBL course or supervision, are mainly related with time planning (Gantt project and Trello) and documentation (Zotero and LaTex). It seems that the project work demands other tools from students, which the PBL course does not cover and it is handed over to the students to choose and use the tools. These are, for example, Facebook, Skype, Dropbox, Google Drive and Google Docs. Even though this study allows outlining the main ICT tools used in project work, it lacks a full understanding of students' reasons behind the use of the tools reported by them. This is aimed to be investigated in follow up studies involving interviews with 1st year students from the B.Sc. Medialogy. Furthermore the study here reported also provides the ground to extend and involve first year's students at faculty level.

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Exploring immersive virtual environments to facilitate internationalised student learning - a case study

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Abstract

There is a growing trend towards increasing internationalisation of engineering education. The sharing of different global perspectives is perceived to enhance engineering education and more fully equip graduates for professional practice. A global outlook is also viewed as an important part of a practicing engineers skill set, and is emphasised by many institutions as something that needs to be evidenced in order to achieve chartered status.

There are a number of challenges when trying to incorporate international cooperation in teaching activities. These include participants being in different time zones and differing pedagogical approaches. This poses the question, how can more internationalised engineering education be practically, and effectively, achieved?

The Humanitarian Engineering and Computing Group, at Coventry University, developed a range of immersive virtual learning environments (iVLEs) in Second Life. These iVLEs allow people to participate in lessons/workshops from any location where they have access to a PC with an internet connection (and the appropriate software installed). This potentially removes one of the barriers (namely not being in the same physical space) to international collaboration. How effectively the immersive virtual space aids communication and collaboration is investigated in this study.

One of these exercises was piloted on a number of occasions, including with students from a number of universities taking part simultaneously. Initial findings suggested a high level of satisfaction and comfort with communication in the environment. Despite not having previously known each other and having little experience of Second Life students were able to successfully participate in the exercise. The data gathered suggests this could be a useful tool for international collaboration between students.

This project involved a consortium of UK universities including University of Leeds, University of Liverpool, Middlesex University, Northumbria University and University of Nottingham led by Coventry University with funding from the Royal Academy of Engineering.

Keywords: immersive virtual worlds, Humanitarian Engineering and Computing, Online International Learning, internationalisation

1 Introduction

Humanitarian Engineering and Computing is the application of engineering and computing techniques to produce sustainable, culturally appropriate solutions that overcome obstacles to opportunity and development. It is not necessarily about major prestige projects that push the boundaries of technology, but rather the application, and transfer, of technology to benefit the many and address social inequality. Humanitarian Engineering and Computing is applicable at a local, national and international level and is not restricted to disaster response.

As indicated above, a humanitarian engineering intervention could be a small-scale local project rather than an international endeavour, still internationalisation, and equipping practitioners to be globally aware, is highly relevant to this field for a number of reasons. Most obviously practitioners could find themselves working in international contexts and as part of international workforces. Another significant reason is to do with facilitating technology transfer and learning lessons. There are examples of good practice from across the globe that can be developed or adapted to other situations at low cost but with a considerable positive impact (such as use of vernacular construction techniques). In these situations being able to effectively operate in an international context is useful. Internationalisation is therefore an important component of Humanitarian Engineering and Computing education. What methodologies can be employed to achieve excellence in internationalisation?

2 Beginning the journey – significant influences

At Coventry University, the Humanitarian Engineering and Computing Group's approach to internationalisation is the result of the convergence of a number of drivers.

Firstly, internationalisation of the curriculum has been identified as a priority at Coventry University as a means to enhance the student learning experience. The approach at Coventry University ties in with the Higher Education Academy's assertion that education should equip "21st century graduates to live in and contribute responsibly to a globally interconnected society" (HEA 2014). A major strand of Coventry University's approach to internationalisation is Online International Learning (OIL). OIL involves Internet-based interaction between students at Coventry University and students at non-UK universities on learning tasks or activities (Rajpal & Villar-Onrubia 2015).

A further, critical component of internationalisation is the development of intercultural competencies. These can be thought of as "the ability to communicate effectively and appropriately in intercultural situations based on one's intercultural knowledge skills and attitudes" (Deardorff 2006). So how do you develop these skills in your students?

Coventry University has been at the forefront of implementing an 'Activity Led Learning' (ALL) approach into teaching. The development of ALL at Coventry University drew on a range of examples of best practice including University of Aalborg's work on Problem-Based Learning (PBL). ALL brings together aspects of PBL, project-led learning and industry-focussed learning (Wilson-Medhurst et al 2008). ALL integrates student-led discovery, complex problem solving activities and work-based learning where an Activity could take a range of forms e.g. a problem, project, case study or research question (ibid.). ALL is at the heart of teaching on many undergraduate courses. ALL, as the name would suggest, emphasises student learning through active participation in a range of interactive activities, with the lecturer as facilitator, rather than through more traditional lecture-centric methods (Wilson-Medhurst 2008). An example would be applying industry standards to real situations as part of a forensic investigation rather than learning about the standards through lectures (Bird et al 2014). Therefore the Coventry University approach to developing intercultural competence would be to incorporate it into ALL. Doing this effectively, in a way that is internationalised, however presents challenges.

These challenges can include difficulties in communication and differing pedagogical approaches (although understanding and addressing issues such as these could be seen as central to developing intercultural competence). From a logistical point of view other challenges could be overcoming differences in time-zones, planning and developing exercises and obtaining resources (for materials or travel). Increasing the number of variety of different groups you work with also increases the complexity of these challenges. As the chair of the UNESCO UNITWIN Network in Humanitarian Engineering, the University has a number of partner institutions around the world and the creation of a sustainable, and workable, global means for the exchange of ideas and discussion is another motivating factor for this study.

3 Developing the idea - towards a potential solution

3.1 The possibilities of the 'virtual'

As stated previously, there are a number of challenges when designing and implementing exercises. Indeed, it has been observed that in sectors where traditional face-to-face exercising is employed that they are often time-consuming to develop and also expensive and resource intensive to implement (Ford and Schmidt 2000, Schaafstal et al 2001). A possible means to overcome these particular issues could be to depart from the 'traditional' and venture into the 'virtual'.

There has been research into the concept of global virtual teams, and their involvement in the implementation of engineering projects (Soetanto et al 2012). Developing intercultural competence is particularly relevant to engineering education, humanitarian or otherwise, given the likelihood that there will be some international aspect to the work they are likely to be involved in following graduation. In the study, conducted by Soetanto et al, two groups of students (one in the UK and one in Canada) collaborated on a project. This study showed some successes (in satisfaction levels) but also some barriers to success (trust among team members) (ibid.) Another study into virtual teams also showed that another contributor to success was the sharing of different perspectives/expertise, and savings in terms of time and money were possible (although some similar barriers to success were observed) (Lee-Kelley and Sankey 2008).

3.2 Immersive Virtual Learning Environments

The two studies mentioned above indicated that it is possible to use 'virtual' interaction and collaboration to promote internationalisation through international collaboration on projects. An additional challenge in traditional exercising is how to accurately recreate reality, particularly with constraints on resources. Is there also a way that virtual methods can be used to overcome these constraints too?

There have been a number of promising projects undertaken at Coventry University using immersive virtual environments for teaching. In particular, these include projects using the Second Life platform, in the fields of Disaster Management and Health and Life Sciences. Immersive virtual environments provide an engaging means of escaping the confines of the lecture theatre.

A possible benefit of using iVLEs as opposed to video conferencing or another solution is that the immersion can make participants feel as though they are interacting with each other how they would in the 'real world'. Edirisingha et al found that students who had participated in activities in an iVLE described the experience as if they were describing something they had done for real (Edirisingha et al 2009). This study also reported that 'socialisation' had been smooth due to the comparative realism of interaction and the environment provided an exploratory learning experience when compared to more traditional paper-based exercising (ibid.). The Edirisingha study also used the Second Life platform. In early studies it was suggested using iVLEs could also lead to achievement of improved learning outcomes. One example where participants collaborated in a virtual design activity found the results were surprisingly ingenious (Schnabel and Kvan 1999).

The Humanitarian Engineering and Computing Group elected to explore the functionality of immersive virtual learning environments (iVLEs), again using the Second Life platform, and test its suitability in this field (including, eventually, the international aspects).

The first hypothesis that this project intended to put to the test was that using an iVLE for teaching, in the context of Humanitarian Engineering, would lead to improved student experience and achievement of learning outcomes than delivering the same exercise using more traditional means (in this case through immersion in a virtual environment rather than a round table discussion using paper information sheets). In addition to this, it was felt that using an iVLE would be suitable for internationalised learning, as students would be able to interact as if they were together in a 'real' space. This is based on the assumption that the iVLE (including how the exercise has been adapted) enhances, rather than detracts, from the learning experience.

The first application was to pilot the delivery of some existing materials on project management using a virtual classroom in Second Life (the design of which was based on plans for dedicated ALL classrooms in the Engineering and Computing Building at Coventry University, which at the time had not been built). Following this pilot, funding was secured to develop a more ambitious teaching environment.

4 The exercise

4.1 Outline of the exercise

Funding to develop this exercise was provided by the Royal Academy of Engineering. This project involved a consortium of UK universities including University of Leeds, University of Liverpool, Middlesex University, Northumbria University and University of Nottingham led by Coventry University.

The chosen exercise was based on an existing table-top exercise used by the Humanitarian Engineering and Computing Group. The exercise centred on the planned construction of a large hydroelectric dam in Sudan. The exercise was developed to enhance knowledge and skills in stakeholder management in a developing world context through communication, teamwork, and interaction. The scenario in the exercise involves debating whether or not the construction of the dam should proceed.

This particular exercise was chosen because of a number of reasons. Although it has been successfully used in the classroom on a number of occasions the original exercise is clearly quite far removed from being on site in the desert. Perhaps by adapting this into an iVLE a more realistic, exploratory learning experience could be created. The exercise also focusses on developing skills that are necessary for the well-rounded 'global engineer'. Debate and interaction are also central to the activity providing an opportunity for internationalised learning experience (through interaction with overseas peers). There is also not necessarily a 'correct answer' so there is room for differing international perspectives to be brought into consideration and explored in detail.

The basic premise is that different stakeholders (i.e. those that have some interest in, or will be affected by, a project) will have different perceptions of a project and will experience differing impacts. The exercise aims to illustrate that it is important to consider the views of all stakeholders, rather than just those of a particular group. This is applicable to a wide range of projects be they humanitarian in nature or otherwise.

In order to create a virtual version of this exercise it was important to identify the key parts of the existing exercise. It was then considered how they could be recreated (or enhanced) making use of the functionality of the iVLE. The following paragraphs describe the student journey through the iVLE version of the exercise.

It should be stressed that the whole exercise takes place in the iVLE; in the following paragraphs where 'rooms' or 'areas' are referred to, these are 'rooms' or 'areas' within the iVLE.

At the start of the exercise participants enter a simplified orientation area to familiarise themselves with operating, navigating, and interacting with and within the Second Life platform. This orientation area guides participants on how to perform only the actions they will need to participate in the exercise (for example: walking, talking and sitting down/standing up). There are many other things that it is possible to do within Second Life (such as flying or building) that are not necessary in this exercise. It has been observed that when people first enter Second Life they can be distracted by the wealth of options available to them; they may start flying around the environment or altering the appearance of their avatar for example.

The orientation area was designed to signpost participants to essential functions only in order to minimise distraction. The aim of this was to increase participant satisfaction and engagement by reducing the amount of time they need (around 15-20 minutes) to familiarise themselves with the user interface, which in turn allows them to get into the exercise itself more quickly. Facilitator involvement is minimal at this stage as all the information required is available within the environment itself.

Participants were also provided with a preconfigured avatar to participate in the exercise, and encouraged to choose from a limited range of existing appearances (rather than customise their own). This reduced time required to set up the avatar and kept the focus to essential skills for participation in the exercise only.

Once participants are familiar with the in-world environment, they are divided into two groups and are teleported to two locations: those who can view the completed hydroelectric dam and those who can view the nearby desert that will be flooded due to the construction of the dam. This is done in another area of the simulation, which participants are directed to following successful navigation of the orientation area. The area where the two groups are formed takes the form of a large room where the floor is divided into colour-coded sections. Each colour-coded section is linked to one of the exercise scenarios (although it is not made explicit which is which). Individual participants indicate which group they will be in by standing in one of the colour-coded sections. During this part of the exercise the participants will also continue to familiarise themselves with navigating, and interacting within, the exercise environment. The facilitator can intervene if participants are experiencing technical issues or if groups are unbalanced (i.e. if a group is much larger or smaller than the other). The facilitator is responsible for teleporting each group to their particular scenario.

A detailed suite of information about the strengths and weaknesses of the construction of the dam, from the perspectives of a range of stakeholders, was prepared and is included in the exercise. This information includes construction and technical specifications, details of financing, local community concerns, and details of local antiquities etc. The information that each group has access to depends on which environment they are teleported to, but neither group will have access to all the information. Each group is asked to make decisions based on the limited portion of the information that is available to them. Ultimately, each group has to debate and decide whether they would support the construction project or otherwise, and the reasons why. The group's decision, and the reasoning behind it, is recorded during the debate using a facility available within the scenario. The facilitator is present in the virtual environment to support the exercise, stimulate discussion where necessary, and address any technical issues.

Figure 1: Participants debate, the merits of the dam construction project, in the desert environment

Once each group has reached a decision, participants are asked to make a presentation (in another in-world environment, this time a corporate boardroom) on how and why they reached their findings and decisions. All participants reconvene in the boardroom, and this is the first time that all participants will be exposed to the views of all the featured stakeholders. As with previous stages of the exercise, the facilitator joins the participants in the boardroom and manages the presentations.

After the information exchange, participants have a chance to review their decisions. This takes place in another room, similar to the one where the participants were split into groups, in that it is divided into colour-coded areas (for “yes”, “no” and “can’t decide”). Participants can interact on a less formal basis than in the boardroom to attempt to influence each other’s decisions. As with the group formation room, participants indicate their decision by standing in the relevant colour-coded area. There isn’t necessarily a ‘correct’ answer at the end of the exercise. This area can also be used to debrief participants at the end of the exercise although this can also be done back in the real world if more time is required. The exercise stimulates debate amongst the participants that could easily be explored in more depth in subsequent classroom (virtual or otherwise) sessions.

4.2 Piloting the exercise

The exercise was demonstrated and piloted on a number of occasions. Initial pilots involved all participants being present in the one computer lab. This is similar to the original paper-based exercise in the sense that all the participants occupy the same physical space. The only thing that was varied was that rather than using the paper-based version the students took part in the exercise in the iVLE. This allowed any facilitation issues to be addressed. Participants were a mix of home-based and international students.

Following these initial pilots a full pilot research was conducted with students at five universities in the UK participating simultaneously. A facilitator/observer was involved in the pilot at each university. This was much closer to the reality of how the exercise would be organised in an internationalised session (where participants would be in more than one university and across borders). Involving participants at five sites, rather than two, increased the complexity of delivery and coordination but was done to fully explore the potential, and limitations, for multi-site delivery.

5 Preliminary Findings

5.1 Research Methodology

The findings in this paper are based on data collected following two pilots of the exercise. The first involved students at a single university; the second was a multi-university pilot (as described previously).

The single university pilot involved twelve students. Of these six were male and six were female. All of these students were international students studying here in the UK. Only one of the students involved had prior experience of using Second Life (the iVLE used for the exercise). All of the students involved completed the questionnaire following the exercise.

The multi-university pilot also involved twelve students however due to technical difficulties not all students were able to experience the full functionality of the exercise, though they were all able to participate to some extent. A sample of six students completed the post exercise questionnaire. Of these students five were male and one was female. Two of the students sampled were international students. All six of the students had not used Second Life before.

In total this study is based on a sample of eighteen students. Eleven of the students were male and seven were female (although during the exercise some students chose to inhabit avatars of the opposite gender, there are both male and female avatars available). Fourteen were international students and only one had prior experience of Second Life. This sample is representative of a student group that would be participating in Online International Learning as there is a mix of UK and overseas students so as such provides a good basis for study.

As described in the previous paragraphs, participants were asked to complete a short questionnaire reflecting on their experience. Perhaps contradictorily, given that the entire exercise was conducted in the iVLE, participants were asked to fill in a paper questionnaire. The questionnaire used was largely based on one that was used in earlier studies into working in iVLEs conducted between some of the partner institutions. Participants completed the questionnaire immediately following conclusion of the exercise.

5.2 Achievement of Learning Outcomes

The participants that took part in the pilot exercises were asked how they felt their skills had been improved (or otherwise). The exercise focusses on stakeholder analysis and decision making; as such there isn't necessarily a 'correct' answer, or answers, for participants to reach in order to indicate successful completion of the exercise. This poses a challenge when measuring the efficacy of the exercise. In order to try and gauge achievement of learning outcomes participants were asked their level of agreement to two statements relating to this. These were as follows:

- "I was able to better critically appraise a project using this exercise"
- "I was able to better understand stakeholder management using this exercise"

Responses to these statements are detailed in the figure below:

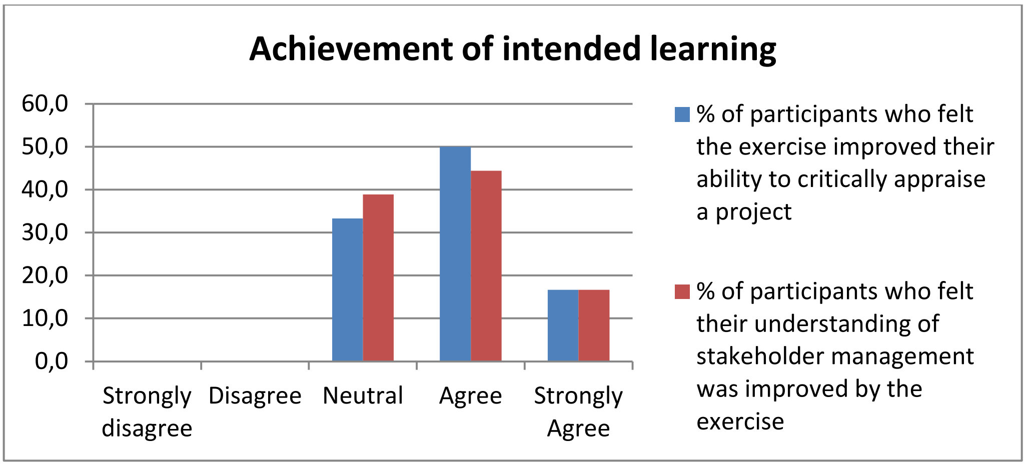

Figure 2: Student perceptions of achievement of intended learning

There were a relatively high number of 'neutral' responses however so further investigation of this could be useful. This may have been influenced by technical difficulties during the pilot exercises.

It is worth stating that when it comes to building intercultural competence through exercising there are often explicit and implicit learning goals. The explicit learning, in this case in relation to stakeholder analysis, are not necessarily the key learning goals. Development of intercultural competence is more dependent on the interactions between participants, and how well they are able to navigate the task together. With this in mind the number of neutral responses above is not necessarily that significant however technical issues could also significantly impact on the smoothness of interaction and navigation through the task.

To try and address this implicit learning more clearly, participants were also asked if they felt the exercise had been 'successful'. Their responses are shown in the figure below.

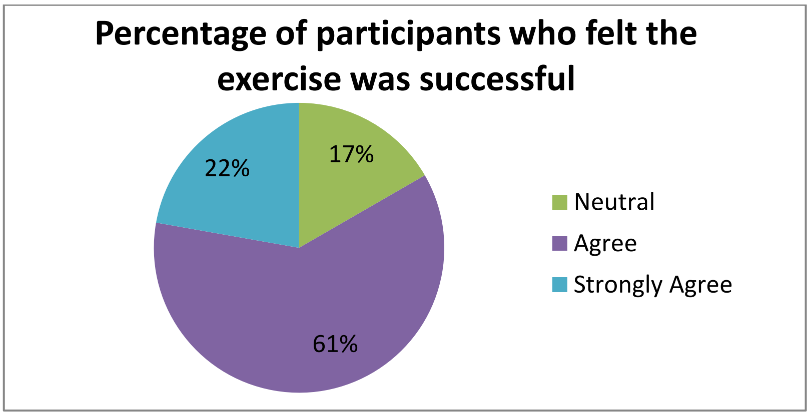

Figure 3: Student perceptions of how 'successful' the exercise is.

Again, no participants reported a negative response, and there were also a smaller proportion of 'neutral' responses recorded. This would seem to give a clearer indication of how successfully intercultural competence learning can be facilitated (particularly with more respondents reporting that they 'strongly agree' than giving a neutral response).

5.3 Communication and discussion

The philosophy behind the exercise was to create a realistic environment, in terms of the general appearance of the virtual space and how people are able to interact with each other and the environment (with obvious exceptions such as teleporting between environments).

Discussion was planned as an integral part of the exercise and as such ease of communication between participants was an important feature of the exercise. Indeed, in order for intercultural learning to occur it is essential that participants interact with one another.

There are two main means of communication in Second Life, voice chat and text chat (although the body language of avatars is potentially a powerful contributory factor for the overall realism of the exercise). Participants were encouraged to use voice chat rather than text-based chat. Again, the reasoning behind this was to ensure that how participants navigated and interacted in the exercise was as close to how they would in a real situation as possible; and would hopefully feel natural and intuitive.

The participants were asked how well 'normal' communication ('normal' communication' meaning face-to-face interaction as would be experienced in a lecture or traditional workshop based delivery. This meaning is commonly used in this type of study (Edirisingha et al 2008, Short et al 1976)) was achieved, and how it contributed to their groups progress. The results are included in the figure below.

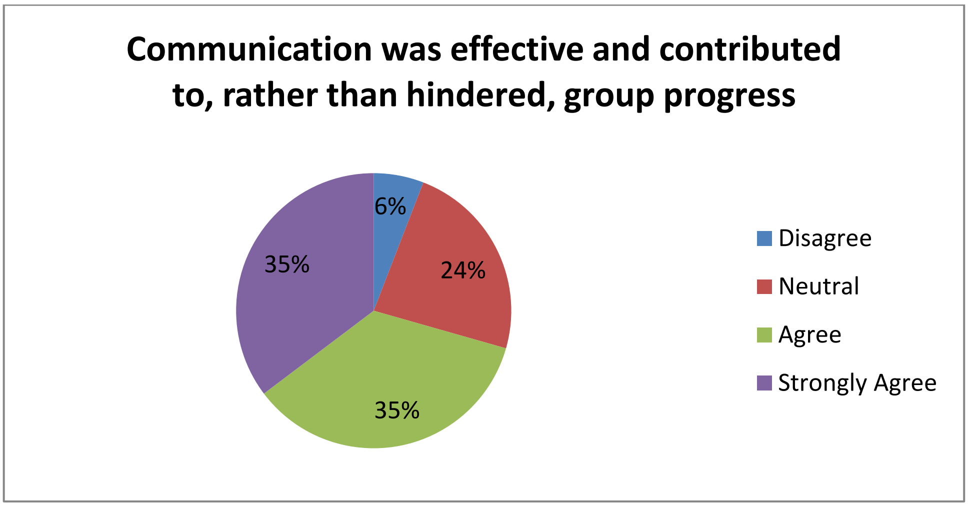

Figure 4: Effectiveness of communication

70% of participants were in agreement that communication had worked well and enabled the group to effectively arrive at their conclusions.

During both pilots, some participants encountered technical issues that meant voice chat was inoperative. When asked which means of communication they preferred the results were less conclusive (see figure below). An interesting finding however was that some of the international students, perhaps where English is not their first language, felt more confident communicating via the text chat option. Participants were asked which means of communication they preferred and the results were inconclusive. Further investigation into the ideal communication methodology, so that all participants feel enabled to participate fully, is necessary.

5.4 Teaching in Virtual Worlds versus 'Traditional' teaching delivery

The participants were asked a number of questions about how suitable Second Life was for the exercise undertaken, and how it would compare to other teaching media. The results are detailed in the figure below.

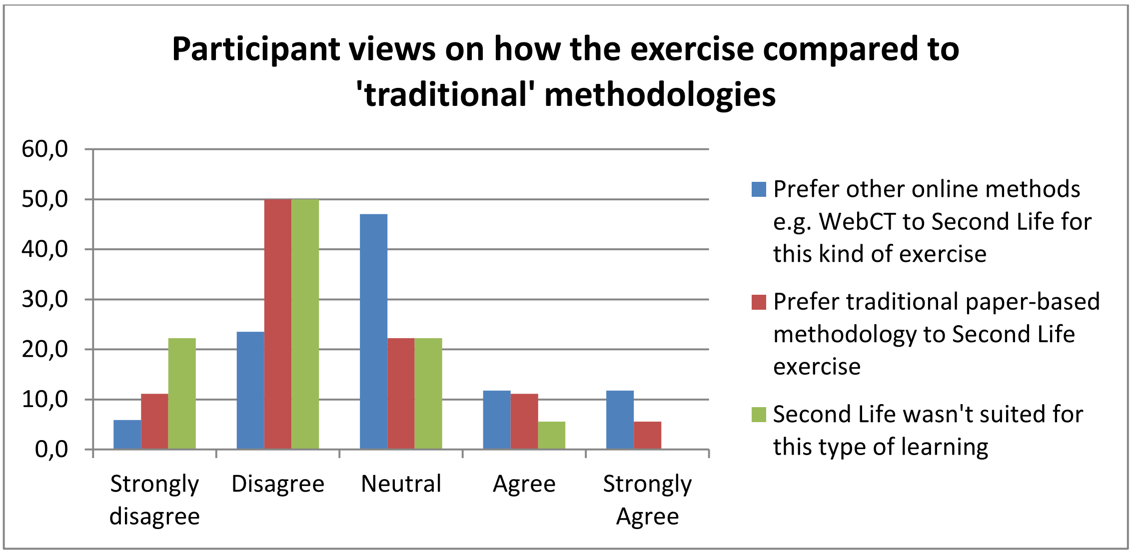

Figure 5: Participant views on exercise media (by percentage of participants)

The results suggested that a significant number of participants (greater than 60%) felt Second Life compared favourably with traditional teaching delivery and that an immersive virtual environment was an effective space to conduct this kind of exercise in. This was an encouraging result as the use of the iVLE did not detract from the success of the exercise. Also some sort of 'virtual' method is necessary if exercise participants are in different geographic locations.

The results were less conclusive however on how well Second Life compared to other online methods. It wasn't clear however which online methods were perceived to be better and why. This could have been influenced by technical issues on the day which meant not all students got the full intended experience. It could also have been influenced by the relatively basic graphics and visuals in Second Life (compared to the next generation of gaming consoles).

The high percentage of participants who felt Second Life was suited for this exercise is likely to be due to the realism possible in an immersive environment (and their perceived immersion in the environment and the task). This is supported by the fact that when the participants were asked how beneficial they felt the virtual world platform was in helping them visualise the concepts linked to the learning outcomes none recorded a negative response and 39% felt it was very good. This is also encouraging as many of the participants stated that they were unfamiliar with Second Life prior to participation in the exercise. This would indicate that participants who are used to different learning methodologies and pedagogy can meet on an equal footing in the iVLE.

6 Conclusions and Future Plans

These initial investigations would suggest that an iVLE provides an effective medium for subject learning and development of intercultural competencies. There is scope when using new media for the functionality to be either confusing or distracting. In this study, much of the available functionality in Second Life was restricted and this seems to have had a positive impact. Most participants were unfamiliar with this platform but were able to effectively interact with each other following the short orientation process.

Communication, and having opportunities to communicate effectively with others, is critical in the development of intercultural competence. Participants in this study felt they were able to communicate effectively with each other though further study is necessary to ascertain the most effective means of communication. Participants expressed preferences for both communication channels (voice and text-based) available in this study.

There were occasions during the pilots where technical issues impacted on delivery of the exercise. These were mainly due to University internet security arrangements blocking some of the functions of the platform. This was particularly an issue during the multi-university pilot as not all participants were able to interact easily with one another (some could only communicate via text whereas others were utilising voice chat). This presents an obstacle to interaction and as such development of intercultural competence. Experiencing technical issues can also lead to frustrations with the exercise and have a counterproductive impact on the rest of the exercise. It is important that technical issues are fully addressed before implementation of activities.

In summary the pilots conducted so far indicate that there is good potential for using iVLEs to facilitate internationalised student learning though a number of areas where further investigation would be useful. The multi-university pilot, despite technical issues, clearly indicated that this platform could be translated to an international context. The next step for this research will be to run this exercise with international partners.

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Peer review in PBL: a comparative case study in problem and project based learning

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Abstract

In this paper the authors report on a comparative case study involving two separate groups of postgraduate students in Sweden and Australia. Both groups were enrolled in a professional development program that used PBL as their main pedagogy. The Australian group comprised a mixture of tertiary educators, school principals and other professionals, returning to study to gain a one year Master of Education qualification. The Swedish group were lecturers at an Engineering University undertaking a ten week, in-service, Diploma of Education course which focussed on improving their teaching, learning, assessment and PhD supervisory skills. Most of the participants in both programs worked full time and, as a result, were enrolled as part time students. Participants in both programs undertook project based courses in which they were asked to identify a problem or issue in their own practice and investigate it in order to improve their professional knowledge and skills. The project course in Sweden extended over a year while the Australian courses were of one semester induration. Assessment was based on both oral and written reports. Students reported orally early on and towards the end of their individual projects. These presentations were followed by 15 minutes of peer review. It is the efficacy of this peer review process that is the focus of our research. We used action research as our methodology and collected our data via a pre and post survey, content analysis of written peer feedback sheets, written reflections and focus group interviews and anonymous course evaluations. The results of our study showed that a majority of students perceived the peer review process to have made a positive contribution to the quality of their PBL projects. In our conclusion we emphasize some of the key aspects of good peer review in PBL.

1 Introduction

In this paper we use the abbreviation PBL to refer to both problem and project based learning. In section two we explain some of the similarities and differences between these two pedagogical models. Throughout this paper the authors argue that both forms of PBL can complement and enhance each other. Our comparative case study concerns two postgraduate sets of students in Sweden and Australia. The Australian group was made up mainly of people in full time employment returning to study in order to complete a graded Master of Education program. Our study focuses on one course in that program, namely an action research project designed to improve professional practice, but students in other project courses were also surveyed . The Swedish group were lecturers at an Engineering University who were required to undertake a ten week, in-service, Diploma of Education program which focused on improving their teaching, learning, assessment and PhD supervisory skills. The program was made up of modules or courses and the one that is the subject of this study was called Pedagogical Project. Like the Australian course mentioned above, the Swedish course required students to undertake a piece action research in order to improve their own lecturing. Both Swedish and Australian groups were motivated intrinsically and extrinsically. For most of them undertaking the course was necessary if they wished to gain promotion in their jobs. There was more reluctance on the part of the Swedish group to return to study since they were engineering educators and as academics felt their PhDs qualified them to teach. Nevertheless 'pedagogical merits' was one of the promotion criteria and the clearest way of demonstrating that, apart from student evaluations and course development, was by possessing a Diploma of Education issued by the Teaching and Learning centre at their university. Although both the Master and the Diploma of Education programs could be pursued full time most were enrolled part time because of their other work commitments. Participants in both courses were asked to identify a problem or issue in their own practice that they wished to investigate in order to improve their professional knowledge and skills. This was in keeping with an open ended and self directed model of problem based learning. However, since students undertook a project, one could argue that the courses represented an amalgamation of the two PBL models. Written and verbal reports were the expected artefacts of the courses and they were judged on the basis of criterion referenced rubrics. The rubric was in the form of a matrix model along the lines of the diagram below:

Table 1: Matrix model. Source authors.

	Standard	Standard	Standard	Standard	Standard
Criterion 1	Standard descriptor	Standard descriptor	Standard descriptor	Standard descriptor	Standard descriptor
Criterion 2	Standard descriptor	Standard descriptor	Standard descriptor	Standard descriptor	Standard descriptor

For the graded Australian course the standards ranged from High Distinction, Distinction, Credit and Pass down to Fail. The Swedish group's results were ungraded but an integrated rubric was used by the examiner to give feedback on how well the criteria had been met and at which standard. In Australia the individual projects were carried out over one semester with oral reports at the planning and concluding stages of the projects. Our focus is on the concluding stage where 15 minute presentations were followed by 15 minutes of peer review and it is the efficacy of this peer review process that is the focus of our research paper. Our motivation for implementing PBL in our courses was that our 'students' were professional educators who would benefit from a model of pedagogy that could resolve many of the teaching and learning issues they faced in their own practice. Our research question was whether or not students perceived that the use of guided peer review during the verbal reports improved their learning experience and professional development.

2 PBL: problem and project based models

Engineering, Medicine and Economics are rather conservative disciplines so it comes as a surprise that they have championed two of the most influential pedagogical models to have emerged in Higher Education in the last half century. Although the opportunities to transform traditional pedagogies in Higher Education have existed for some time now (Baran, 2013) the lecture and tutorial system in social sciences and lectures supported by practical laboratory work in the natural sciences, persists. An integral aspect of this traditional pedagogy is end-of-course, closed-book exams as a main means of assessment. High quality traditional pedagogy can deliver excellent results, especially for students who take a deep approach to their learning. But when the quality is not high and lecturers encourage surface rather than deep approaches to learning, both the system and those within it can suffer. PBL, as an alternative system, has the capacity to revitalize and enliven higher education and provide authentic assessment for real life learning. For the purposes of this paper we use the abbreviation PBL to refer to both problem and project based learning because a key purpose of our research is to demonstrate how they complement and enrich one another (Christie & de Graaf, 2015).

In essence these two pedagogical variations of the PBL model have been around for thousands of years. Both Confucius and Socrates (c 500 and 400 BC) believed in stimulating learning rather than transmitting information. Socrates is famous for his dialogues that began with a problem and forced students to think, question and seek solutions. Confucius gave his students one quarter of a puzzle and if his students could not come back with the other three quarters he did not go on with the lesson. One of the earliest and best known varieties of PBL is the form that was introduced in the Faculty of Health Sciences at McMaster, a Canadian University, in 1969. It was soon adopted elsewhere including the medical faculties at the University of Limburg in Maastricht, Holland, the University of Newcastle, Australia, and the University of New Mexico in the United States. Today it is a worldwide phenomenon.

As is often the case, 'followers' of a new educational model can became more dogmatic about its practice than the founders (Christie, 2005). In 1996, nearly thirty years after the PBL movement started, Gwendie Camp was concerned that 'true PBL' was being watered down (Camp, 1996). She insisted that unless PBL was 'active, adult-oriented, problem-centred, student-centred, collaborative, integrated, interdisciplinary and utilized small groups operating in a clinical context' it should not be called PBL. She did, correctly, point out that if a PBL program was 'teacher-centred' rather than 'student-centred', the heart of 'pure' PBL would be lost (Camp, 1996). Although very few would cavil with the latter sentence there were many who objected to Camp's 'purist' approach. Ranald Macdonald (2001) and Savin-Baden (2000) both argued that PBL is an approach that should be characterized by 'flexibility and diversity in the sense that it can be implemented in a variety of ways in and across different subjects and disciplines and in diverse contexts'. Boud and Feletti (1980) pointed out that 'The principle behind PBL is that the starting point for learning should be problem, a query or a puzzle that the learner wishes to solve'. We argue, along with Camp's critics, that there can be a number of approaches and variations in the practice of PBL. Today a large number of disciplines use PBL, in various shapes and forms. In Business and Economics many Faculties design their architectural space to allow for 'syndicate rooms' where students can work on problems either as one-off tasks or as a connected series of problems that make up a whole subject or curriculum.

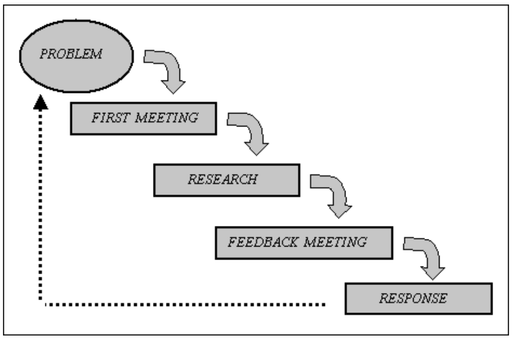


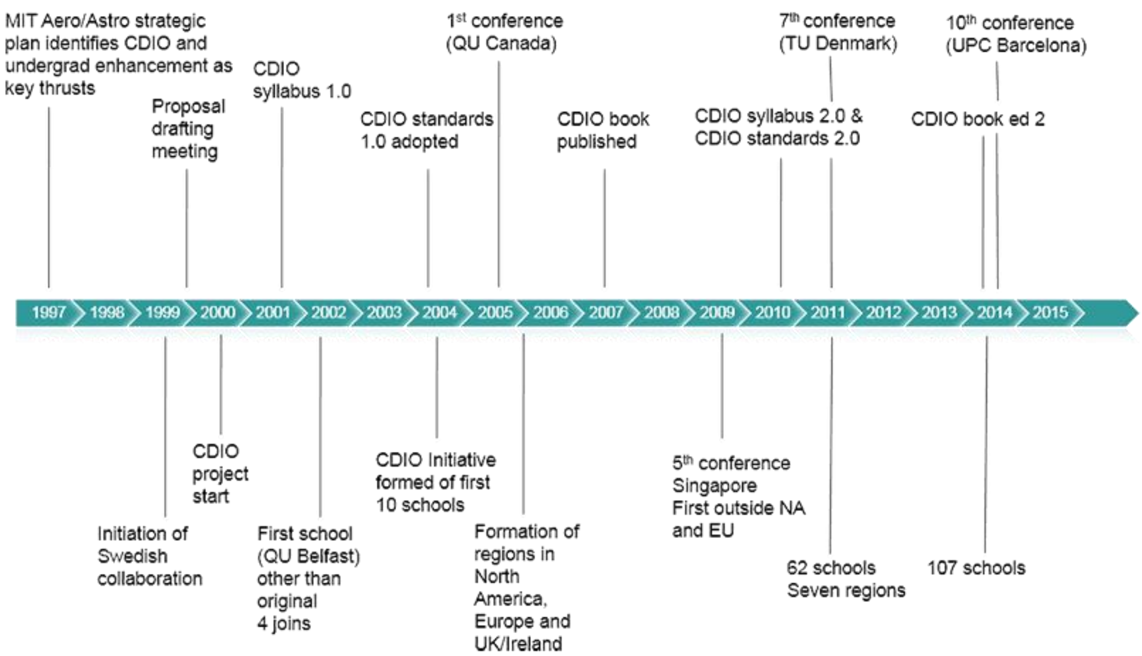
Figure 1. A simple model of PBL

The figure above, which provides a simple diagrammatic sketch of PBL is taken from the English Economics Network site that includes a handbook on PBL. See: http://www.economicsnetwork.ac.uk/handbook/pbl/21

Engineering educators who promote PBL argue, as the McMaster staff did, that good pedagogical models should emulate the way practitioners work in their own field. Doctors diagnose medical problems and try to find remedies. Engineers design, build and test products. It is the nature of PBL to adapt to different settings, cultures, curricula and circumstances. Camp did everyone a favour by clearly showing that PBL has its theoretical origins in the conceptual work of adult educators like Malcolm Knowles (1980), a constructivist epistemology (Savery & Duffy, 1995) and in the psychological principles of learning (Norman & Schmidt, 1992). However, while having an epistemological and psychological basis for PBL is important, we doubt that any of the scholars mentioned above, would espouse a dogmatic approach. PBL should not become a straitjacket for educators. It is a practical, pedagogical paradigm, robust enough to be adapted by a range of disciplines and for a variety of purposes. Both Problem and Project Based Learning enable educators to prepare their students for their future professional life as opposed to simply being able to pass exams.

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

Table 2: CDIO development taken from the official CDIO website.



PBL has become influential enough to affect the architectural layout of many business schools, and, in the case of Aalborg University, which has practiced Problem Based, Project Organised learning since 1974 the physical layout of the learning spaces in the entire campus are suited to their particular variation of PBL. We argue that the variations of PBL, that we mention above, complement each other. Problem based learning, as the name suggests, begins with an issue or problem that the students need to solve or learn more about. Loosely defined problems are often selected to ensure that the scenario or case study, if that is the format which is used, simulates real life complexities. In some instances the problems are actual problems that businesses want solved. Project based learning usually has the creation of a product or an artefact as a goal. Some tasks can be simulated, others require wider field experience in an actual workplace. Higher Education traditionally tends to default to pen and paper exams when it comes to assessment. Both problem and project based learning emphasize performance based, authentic assessment that can be reported on in a variety of ways. In our case study both written and verbal methods of reporting were used.

3 Methodology

Our methodology mirrors that used by the students in their projects, namely, action research. Action research is grounded in the philosophy of John Dewey (1916), adheres to the action research principles of Kurt Lewin (1946), and follows the main methodological recommendations of Carr and Kemmis (1983). Kemmis and McTaggart (1988) subsequently developed a model of participatory action research. The intention of all action research is to make changes for the better. In this sense it is both partisan and transformative (Mezirow, 1991). Since 1988 action research has become more and more relevant to educational improvement. The publication of a number of recent books and new editions (Spaulding & Falco, 2013 and McNiff, 3rd edition 2013) encourage teachers at all levels to instigate their own research as a way of improving the learning outcomes of their students. Action research, as the figure below demonstrates,

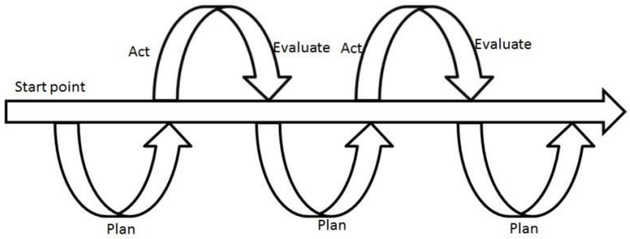


Figure 2: An action research spiral

involves a spiral process of planning, acting (implementing change), observing, analysing, reflecting and then evaluating. This completes one full cycle, which generally raises other issues that will be researched and acted upon in a new cycle. We used mixed methods to gather our data and these included a pre and post survey, content analysis of written peer feedback sheets, focus group interviews and anonymous course evaluations. The total number of participants for the Swedish group was 26 of which 16 were Swedish citizens and 10 came from other countries. The Swedish case took place during 2010 and at the start and end of the course students filled in pre and post surveys. In the pre surveys participants stated what they expected to get out of the course and commented on their attitudes toward and expectations of using peer review. The pre-course expectations form was sealed with an identification tag and handed back at the end of the course during their in-class evaluation. On the second occasion they were asked to write down if their expectations had been fulfilled or not. There was also space for them to explain their answers and comment on the usefulness of peer review.

Those who participated in the Australian research were students enrolled in MEd project courses in two semesters during 2014. The total number of participants who responded to a pre and post course survey on the efficacy of different sorts of peer review that had occurred in the semester long courses was 11 in semester one and 28 in semester 2. Some of the courses were offered in both semesters. This enabled two cycles of action research which meant that issues that arose in cycle one could be acted on in a second cycle. As a result of reflections made at the end of the first cycle changes were made to the tools used for data collection in cycle two, for example the peer review feedback sheets that were also in both the Swedish and Australian cases. These feedback sheets were used for the presentations that occurred late in the various courses. In the presentations students explained their projects, the interventions they had made, the data they had collected and their latest analysis and results. This occasion was the last chance for them to get feedback before submitting their written reports for grading. In the Australian case two of the courses were coordinated by the first author. The feedback sheets in those courses were collected and analysed in order to inform marking and provide information for this research project before being handed back to the respective presenters. Students were informed and agreed to this process. Ethical clearance was obtained for the conducting our research prior to sending out surveys. Data was further triangulated in the Australian case by conducting, with participant agreement, a focus group in the penultimate week of the course and looking at anonymous student evaluations that were administered centrally by the university. In the Swedish case analytical, critical reflections on the course were submitted by the Swedish participants and these provided an important additional data source on how peer review was viewed by students as well as assisting in the triangulation of sources. Ethical permission was obtained for this and other parts of the research process prior to the course.

4 Analysis and Results

The pre-course survey in both cases showed that students expected peer review to be a positive and useful experience if it was integrated into their project-based courses. In the Swedish case S1 wrote that ‘To deeply understand pedagogical improvement, and be able to use that knowledge, a personal involvement via active practice and peer review is needed’. This expectation was repeated by 80% of the group. S4 looked forward to hearing about the different projects his peers were engaged on and getting feedback on his own project. A majority (90%) of those who filled out the post survey in the Swedish case said their expectations had been met and that they were positive about the way in which ideas had been shared and feedback freely given. The participants not only commented on whether or not their expectations had been met but were also invited to write an analytical, critical reflection on the value of the course in bettering professional practice. S4, said: ‘It was interesting and very educating to see all the other projects, and to have the opportunity to interact, both giving and listening to comments about the work in progress’. S12 said ‘One of the key things that I have learned from doing a pedagogical project is how to use student self-assessment’. This comment referred to the requirement for student self-assessment in the feedback sessions. At the conclusion of the 15 minute presentation there was a two minute pause when both the presenter and the audience filled out a feedback sheet in silence. The presenter’s self assessment included both the quality of the presentation itself and any new ideas for improving the project. After everyone had filled out the feedback sheet there was a peer review discussion based on what had been written down. Colleagues could ask questions and make suggestions about both the presentation and the content of the project, including how it might be improved on before the final written report was submitted. At the end of the 15 minute feedback phase all sheets were collected and handed to the individual presenter. The post survey comments showed that this process was valued highly.

In the Australian example four surveys were conducted. Surveys 1 and 2 refer to the pre and post surveys sent out to students in semester one (first cycle). Surveys 3 and 4 are the pre and post surveys filled out by students in the second semester (second cycle). Not all respondents completed the form so the responses that are included in this analysis are completed responses.

Table 3: Response rates for the Peer Review surveys

Survey responses				
Survey No	Pre or Post	Incomplete	Completed	Total
Survey 1	Pre	4	11	15
Survey 2	Post	2	11	13
Survey 3	Pre	2	28	30
Survey 4	Post	2	17	19

Eleven people completed responses to surveys 1 and 2. The identification questions showed that 8 were students and 3 were lecturers. The numbers for the second cycle was twenty eight completed responses for the survey 3 and seventeen for survey 4. Again three lecturers participated in the surveys. Coded identifiers enabled tracking of respondents in all surveys. Because of coding it was possible to see changes in understanding and attitudes towards peer review over a semester.

The first four questions in the surveys were identifiers. The rest of the questions in the pre surveys asked respondents what did the term peer review mean to them; did they think peer review would be beneficial and if yes what could the benefits be; had they experienced peer review and if yes how did it operate; what did they learn from peer review in the past; did they think international interaction would be beneficial and could they explain their response; and, finally what advice did they have for the development of a peer review process for postgraduate studies. The post surveys asked the similar questions only this time they were couched in such a way that the students could reply by reflecting on the experience they had had over the semester with the peer review process. The questions were: this semester you took part in a peer review learning activity – what did it involve? What did you learn from your involvement in peer review? What would you describe as your most significant contribution to the peer review process? What motivated you to participate in the peer review process? Did you benefit from engagement in the peer review process? How did you feel you benefitted or did not benefit? Did you experience any challenges working with students in providing and receiving feedback? What were these challenges? What contributed to the success of the peer review project? Did your peer review process involve feedback a) from peers at your own university, b) from peers at an international university, c) from academic staff at an international university.

In the pre surveys (surveys 1 and 3) the term peer review was generally defined as giving feedback to one's fellow students or colleagues. Respondent #2 added that a review could be formative or summative, for example non graded feedback to other students or a reviewer's feedback on a journal article submitted for publication. An absolute majority (93%) believed peer review to be a positive process. A combined 68% had experienced peer review before and 78% felt that it had positive benefits. These included, according to #4 in survey 1 that peer review would lead to 'Ideas that I haven't thought of to better my work'. A number of respondents from the same survey (#6, #7, #8, #9, #10 and #11) all reiterated this benefit and included others such things as timely intervention that could assist in preparation for graded tasks, providing a benchmark for where a person was at (#9), cross-cultural input where the group was mixed (#8), and practical issues such as editing, refining a topic and collaborative learning (#6). A respondent (#5) from survey 1 who did not think peer review provided benefits said 'The process can be confrontational and strategies need to be in place to resolve deadlocks – e.g. have a chief moderator or peer reviewer whose decision is final'. The expectations from survey 1 were echoed in survey 3. One respondent in this survey (*4) provided a useful definition of peer review, namely, 'A review of work that offers constructive advice/criticism by others who may be studying in the same course or in a work environment at the same employment level'.

The post surveys (2 and 4) confirmed that many of the expectations at the start of the semester were realized by the time it concluded. In response to what format the peer review had taken participants identified a variety of formats and commented on the outcomes they experienced. In response to question 9 which asked respondents if they had benefited from engagement in the peer review process 73% in survey 2 and 94% in survey 4 said yes. The ways in which they had benefitted could be summarized as follows. Students saw that peer review had broadened their relationship with their fellows, increased their knowledge of the subject and developed generic competencies such as the ability to give and take constructive criticism. Those in survey 4 described other formative benefits such as developing ways of reflecting on their own progress, learning from others how to adapt their work, find new directions, focus their thinking, and develop pride in supporting and encouraging others. Many students were impressed by comments from their peers, and two respondents said they had realized that it was not only lecturers who could provide feedback; the three lecturers who filled out the post surveys spoke about how their intuitive judgments were vindicated by reading student feedback sheets. One of them wrote: 'I gained the sense that quality is tangible. Even if people cannot precisely say why something is of good quality they can definitely feel it and so when there is a clumping of opinion as I found in the sheets that were handed back (even though some tried to soften the blow of critique) I felt vindicated in my own professional judgment'. The different types of peer review covered by the above comments are given below.

Table 3: Categories of peer review format and outcomes.

Categories	Video	Online Discussion	Talk plus feedback	Informal discussions
Outcomes	Comparing different US & Australian styles and quality	Reflect and comment in groups in real time as well as later on	Guided feedback sheets with checklists plus free comments	Chance to brainstorm and cross-fertilize ideas and knowledge

This final point was borne out in the Australian courses that were taught by the first author. In the first semester students agreed to not only give their comments but also fill out the criteria assessment sheet, highlighting the areas that they thought were appropriate for the presentation that they had just seen. There were thirteen in the class and all but one (who was sick) submitted their feedback. The examiner awarded grades before he collated and looked at the students' feedback. The idea was that student judgements should be used to better inform his judgment and if necessary to adjust grades upwards. The lecturer returned each set of feedback sheets to presenters but also provided feedback about the overall quality of the peer reviews. There was remarkable consistency between the combined grading of the student peer reviewers and the examiner own marking. This was clearest with the outliers – those that received High Distinctions and Passes. No one failed this task which could be partly attributed to the fact that following the presentation students had time to improve on the written report, which carried a 75% weighting, before submitting it. There was often a high degree of consensus in feedback to individual presenters. For example almost all reviewers commended a presenter on enthusiasm and a passion for the chosen topic but questioned the academic rigour of the project in terms of how the aims, rationale and design of the project had been explained. Another result from the analysis of the individual comments on feedback sheets in both the first and second semester cycles was that those who gained the best grades also provided the best and most complete feedback. This touches on one of the main criticisms of peer review that was voiced by respondent (#5) from survey 1 and 2, who did not think peer review provided benefits. The reason given was that although fellow students might be peers in one sense (classmates) they were not necessarily peers in terms of their ability to provide informed feedback. For example that ability could be enhanced or limited depending on the professional, cultural, linguistic and academic background of the peer reviewer.

Written reflections, focus group interviews and course evaluations were used to triangulate the above results. In the Swedish case all those who completed the course were asked to write down a critical, analytical reflection of their experience. A number of common themes emerged. Learning from each other via peer review was one of the most important themes. UL wrote: ‘I have learned from the interaction with the other students in the pedagogical project course. It has been fruitful to give comments on each other’s projects and to share experiences with each other. The presentations of good examples have been inspiring for my own teaching and I got several ideas that I would like to try in my own course’. Another participant, SS, said: ‘The very idea of the course is definitely healthy – get together teachers and researchers to discuss and share their pedagogical experiences and problems and let everybody to work on a project (sic) directly concerning real-world pedagogical practice’. His view that ‘The course allowed me to meet colleagues from different departments’ coincided with RB’s comment that ‘It was very nice to meet other teachers and...very valuable to give each other feed-back on our projects’. A small focus group was held with participants at the end of the two Australian courses mentioned above. Since this course was repeated in term two feedback from the first group helped inform the second cycle of the research. Participants in the first focus group felt that peer review should not only be used to provide feedback to presenters but also used to gain a better understanding of the criterion based assessment sheet or rubric. This suggestion was acted upon in semester two. Another point was that some students felt uncomfortable about ‘grading’ their colleagues even though it was quite possible to simply leave the rubric blank and even though they knew it would not affect a final grade. This was also acted on in the second cycle and the idea of giving a ‘grade’ was scrapped. In the second focus group participants agreed that the formative nature of the peer assessment should be emphasized and that the facilitator must step in quickly if inappropriate or misleading advice it proffered. The course evaluations for both these courses were very positive towards peer review and feedback. A number of comments emphasized this, citing both the lecturer’s facilitation of class interaction and the organisation of clear and well defined process of peer review throughout the course. One student said: ‘both class interaction and peer review were done really well and helped me greatly in carrying out this mini project’.

5 Conclusion

Some of the most useful input concerning the efficacy of peer review in PBL projects came from dissonant voices in what was otherwise a very positive response to our surveys. In the final survey respondent #4, who had experienced peer review as a final exercise in the course, said: ‘I would rather have formative feedback…ongoing…than end-of-product feedback'. This response encapsulated a key finding for this comparative case study. In both the Swedish and Australian cases, students were more willing and more conscientious about engaging in peer review if they saw that feedback from others as well as the feedback they gave improved their project. If the peer review came too late in the process it was seen as a chore. 'I would welcome the idea of student support groups working together in the weeks leading up to a presentation…sharing ideas and feedback in a formative way', wrote #4, 'rather than sharing feedback at the end project. I would learn a lot more and the peer interaction would be more authentic'. Assessment, as we hinted in section 2 is a key driving force in Higher Education. However, as students move into postgraduate education and staff development courses, other, more intrinsic motivation weighs in. In our cases the desire to improve one's professional practice was a key motivator. When good quality peer review helped individuals fine tune their projects it was much appreciated. PBL projects, as figure 1 above indicates, lends itself to peer review. There are many manifestations of PBL ranging from individual to group variations. Our case studies focused on what were essentially individual projects. The peer review process, because it was, for the most part, embedded in the courses, acted like the feedback loop in our simple PBL model. Individuals got assistance in solving their particular problem via comments, suggestions, cautionary advice and practical assistance from their colleagues. When this occurred in an orderly, well organized fashion, where the facilitator took responsibility for filtering and augmenting peer comment, the process was both prized and praised.

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The impact of PBL learning environment and supervision of engineering faculty of Mondragon University in the student learning approach

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Abstract

Nowadays, universities offer its services to a greater diversity of students. During the 20th century, universities have become a mass university with a larger number of students. In the majority of the universities, there is a greater variety of students with different motivations and learning approaches. Nevertheless, the society is asking for students with high-level skills. Those skills go beyond understanding basic knowledge and acquiring basic skills.

From a theoretical point of view, it is well known that Problem and Project Based Learning (PBL) methodology is adapted to acquire such skills. From a practical point of view, it is conditioned by several factors. In our faculty, we are carrying out a series of research works in order to understand in which extend assessment and supervision sessions affect students learning approach based on a particular culture and PBL practice.

This is a first extension of a previous research work. In the previous research work, in Computer Science and Telecommunication degrees an experiment was carried out involving 18 students and 5 supervisors. In these experiment students' learning approach has been changed toward deeper learners. But the participant number was too small, and any bias in the process affects considerably the results. This is why we repeat the experiment in Computer Science and Telecommunication degrees and we extend it to a new degrees like Electronics, Bioengineering and Industrial Organization where there are 97 students and 20 students groups and 20 supervisors.

To collect information several information sources have been used: At the beginning and at the end of the process students' learning approach has been measured. In addition, two different non-structured focus group discussions has be organized: the first one with supervisors and the second one with students. In this paper, we show and discuss preliminary results.

Keywords: Reflection, formative, feedback, students learning approach, PBL

1 Introduction

The European Qualification Framework (EQF) for lifelong learning demands **high-level skills** for undergraduate level (EQF 2010) and tertiary education in general. In the recent OCDE rapport titled "Higher Education in Regional and City Development: Basque Country" they write following recommendation was given: The economic crisis, long term demographic change and worldwide competition **require a new economic transformation** in the Basque Country with greater emphasis on knowledge and continuous access to higher level skills (Puukka, Charles et al. 2013).

From our point of view this means that the knowledge and the skills used to produce technological goods in a production line are not enough; we need something else. We need to be critical with what we are doing. Take into a consideration a wide range of solutions, even the ones that sound strange. E.g., Steve Jobs did not consider the right solution for their smart devices.

Some years ago, when only academic students were present at universities, those students obtain **high-level skills** without any special help (Biggs, Tang 2007). However, that is not the case for **non-academic students.** John Biggs describe them as **academic and non-academic students** (Biggs, Tang 2007). Academic students are those that reach understanding, reflect on the consequences and applications of what they are learning. We cannot prevent them from learning; they tend to use high level cognitive process. On the other hand, non-academic students' goal is to obtain a degree and have a job. They are not **really interested in learning.**

Gross Enrolment Ratio (GER) in tertiary education is defined by the UNESCO as "*The total enrolment in a specific level of education, regardless of age, expressed as a percentage of the eligible official school-age population corresponding to the same level of education in a given school year* "(UNESCO 2009).

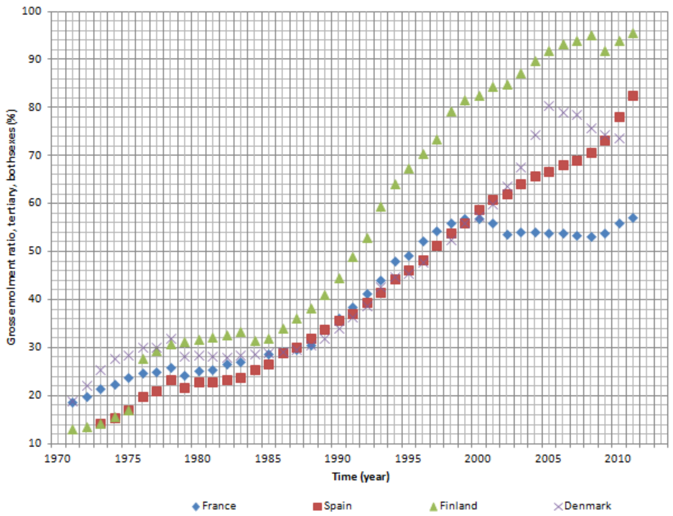


Figure 1: Gross Enrolment Ratio in tertiary education some European Countries (UNESCO Institute for Statistics)

As we can observe in Figure 1, in Spain the number of enrolment has increased from 8.6% of the population in 1971 to 82.6%% in 2011; in Denmark from 18.5% in 1971 to 73.5% in 2010; in Finland from 13.1% in 1971 to 95.5% in 2011;in France from 18.7% in 1971 to 57% in 2011. In this context, we can expect a higher number of non-academic students.

It is well known that Problem and **Project Based Learning (PBL)** methodology is adapted to acquire high-level skills (Pettigrew, Scholten et al. 2011). PBL has been introduced in various universities around the globe, like in McMaster University (Canada) in 1966, Maastricht University (Netherland) in 1969, Roskilde University (Denmark) in 1972 and Aalborg University (Denmark) in 1974. In our particular university, we started using PBL in 2002. This has mainly involved changes in the learning environment, supervision, etc. In this research paper, we would like to explore the impact of the learning environment and supervision implemented in the engineering faculty of Mondragon University on students' learning approach. The research question has been stated as:

• In which extent can the **PBL learning environment** of Mondragon University and the **supervisor** impact **students learning approach**?

2 Review of the literature

In this literature review we are going to focus on the main concepts of the research question: PBL learning environment and supervisor related activities. To understand the environment we are going to consider PBL types and learning outcomes emphasising on high-level skills. To define supervisor related activities, we are going to consider formative assessment and reflection.

Learning Environment – PBL type

Savin-Baden (Savin-Baden 2007, Savin-Baden 2000) has defined five basic PBL models organized in six criteria: type of knowledge, learning goals focus, problem scenario, students' role, facilitator role and assessment focus (see Table 1). In our PBLs, each student group can have different problem scenarios to solve (defined by the teacher or by the students), but a common technological framework and learning outcome (Arana-Arexolaleiba, Aldekoa-Anton et al. 2011) for all the students. At the end of the PBL, students are expected to build a complex technological system (know-how knowledge type). At Mondragon University PBLs are built so that all teachers are involved in PBL during a semester. Different teachers have different roles. Some of them work as experts, others as process supervisors or even as clients. Thus, the PBL implemented in Mondragon University can be classified as type II PBL "*PBL for professional action*".

Table 1: PBL models (Guerra March 2014).

	Model	Knowledge	Learning goals	Problem scenario	Students	Facilitator	Assessment
(I)	PBL for epistemological competence	Knowing what	Use and management of knowledge	Limited solutions already known	Receivers and problem solvers	A guide to correct propositional knowledge	Test of epistemological competence
(II)	PBL for professional action	Know how	Outcome focused acquisition	Real life situations	Pragmatics induced by professional culture	Demonstrator of skills	Testing competencies for work place
(III)	PBL for interdisciplinary understanding	Know what & know how	Synthesis of knowledge across disciplines	Knowledge to act and interact	Integrator of boundaries	Coordinator of knowledge and skills	Skills and contextual knowledge
(IV)	PBL for transdisciplinary learning	Reconstruction	Critical thought from subject positions	Resolving and managing dilemmas	Independent thinkers	Orchestrator of opportunities	Demonstrate an integrated understanding
(V)	PBL for critical contestability	Contingent, contextual & constructed	A hybrid imagination	Multidimensional and open	Explorers' of underlying assumptions	Commentator, a challenger and decoder	Open ended and flexible

Supervision - Formative assessment and learning cycle

Assessment can be used with different purposes. On the one hand, assessment can be formative, when there is potential for improvement. On the other hand, assessment can be summative, when there is a final judgement. There is also diagnostic assessment, which is used at the beginning of the process to assess students' initial level, but we don't take into account the diagnostic assessment in this research work.

Hassan suggests that "*Assessment tools should ... be designed to be based on tacit or explicit assumptions about how students learn*" (Wimpenny, Savin-Baden 2013). For example, on the one hand, traditional assessment is grounded in the belief that knowledge is universal and that students can take in knowledge as it is disseminated. From this perspective, assessment is objective and neutral and the supervisor is the authority and expert. On the other hand, authentic or alternative assessment "*... it is rooted in the premise that knowledge has multiple meanings that cannot be objectively measured; rather, knowledge must be understood through the subjective impressions of those who possess it*." This means that assessment takes into account not only the final product, but also how students carry out the learning process. In this case, the supervisor share a learning environment control with students (Wimpenny, Savin-Baden 2013).

Graham Gibbs points out that assessment can support students learning behaviour and learning outcomes (Gibbs 2003). Some of those conditions are linked to the quality of learning promoted by assessment activities. The other conditions are linked to how well feedback supports student learning. Other authors go deeper and they stress that assessment not only supports the learning process but it is also a part of the learning process. E.g. Torrance and Pryor (Torrance, Pryor 1998) highlight "*Vygotsky's theory of 'the proximal zone' as follows: the teacher must not only see and assess what the student has achieved, but what the student can achieve. The interaction between teacher and student is seen as part of the assessment process, which means that the assessment should have an integral role in learning* "(Hassan 2011). This idea helps the teacher to develop a co-construction process with the students.

High-level skills are beyond basic knowledge and understanding (QAA 2004). In order to achieve this level, the human being needs to go through a complex learning process. In this section, we are going to describe two relevant theories that can support this process from a social constructivism perspective: Kolb's and Dixon's learning cycles. Kolb (Kolb 1984) defines a cycle with four steps Dixon (Dixon 1999) proposes an organizational learning cycle based on Kolb's cycle. But each of the four steps is defined in a slightly different way listed in Table 2.

Table 2: Kolb's and Dixon's learning cycles

Kolb learning cycle	**Dixon learning cycle**
Each student generates concrete experiences.	Widespread generation of information.
Student carries out a reflective observation of his/her previous experiences.	Integration of new/local information into the organizational context.
Student generates an abstract conceptualization based on the reflections.	Collective interpretation of information.
Student actively experiment in the project with new concepts.	Having authority to take responsible action based on the interpreted meaning.

PBL team can be seen as a small organisation, where each team member generates his/her own information (from books, internet, experiences, etc.). Those information need to be integrated in the team and need to be interpreted collectively, during team discussion or supervision sessions. In this context, each student has his/her own source of knowledge, solution, arguments, etc. and they need to reflect, evaluate and select the most appropriate solution.

The supervisor can facilitate both. On the one hand, individual and group/information integration. And on the other hand, conceptualization and collective interpretation during supervision sessions using Kolb's and Dixon's learning cycles. This process can help students to construct more complex and rich mental schemes. The more mental schemes are restructured, the more relations are made between the concepts and, in consequence, the deeper learning or higher-level skills are acquired. During this process, supervisors can assess students' learning process and identify their difficulties to give them feedback about the learning process. In summary, we define a constructive supervision with the next statement:

3 Implementation context and Research Methodology

Once we have selected the research approach and suitable instruments to respond to each research question, in this subsection we are going to describe implementation context and research methodology.

Research methodology, data collection and data analysis

The purpose of this of this study is to explore the impact of the PBL learning environment of Mondragon University and the supervisor's role in students learning approach, to look for patterns and gain insight with the PBL model of Mondragon University. Thus, we place this work as an exploratory research that wishes to look for patterns. Because the number of participants is quite large, we have used quantitative research process.

To collect data we used two questionnaires: Biggs's students learning approach questionnaire R-SPQ-2F (Biggs, Kember et al. 2001) translated into Basque (García Martín, García Fernandez et al. 2011) and Garcia's learning environment context questionnaire CONTEX also in Basque (García Martín, García Fernandez et al. 2011). To measure students' learning approach change during the PBL, we collected data before and after the PBL (see Figure 2). To measure learning environment characteristics, we collected data only after the PBL was finished (after the PBL3 exam) as it is shown in the next figure. The data was collected using web tools, respecting the confidentiality of the students' responses. In order to relate data taken from both questionnaires (Contex and R-SPQ-2F) and avoid duplicated responses we also collected students' names.

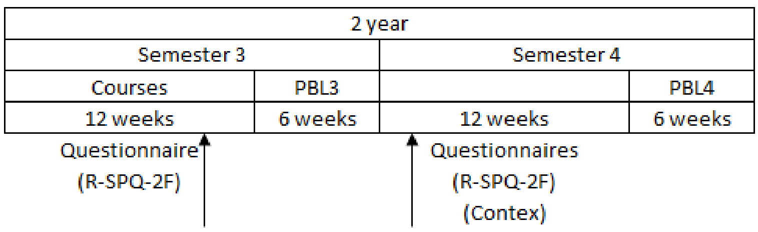


Figure 2: Data collection planning.

The data treatment was conducted on the students' responses to the questionnaire. It was quantitative by applying the frequency of the responses (Gall, Gall et al. 2006). We have used a descriptive method on the experienced reality.

Experimental context

The engineering faculty of Mondragon University has established a common educational model for all the degrees. It is a mixed model, where there are activities related to courses, at the beginning of the semester, and an interdisciplinary PBLs, at the end of the semester. There are 3-4 courses involved in each PBL. The PBL can take between 20% and 50% of all the ECTS (European Credit Transfer System) on each semester. In the previous years' semesters it took a 20% of all the ECTS but this percentage has increased until a 50% is achieved (see Figure 3).

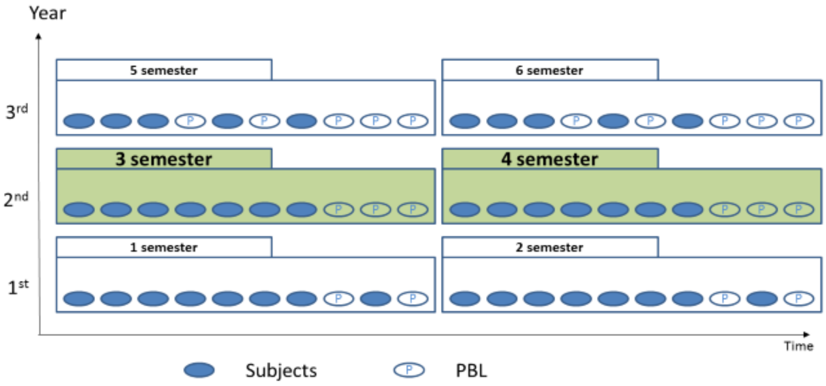


Figure 3: Curriculum structure of the engineering programs.

This research has been carried out in four different engineering degrees of Mondragon University (autumn term 2014-2015), in all the cases in the 3rd semester PBL. The 3rd semester is structured as follows: The first 12 weeks are course based, and the last 6 weeks PBL. This PBL has the next characteristics:

- In each course there are between 14-31 students.
- The project team are of 3-5 students.
- The students can create their own teams.
- Supervisors are assigned randomly.
- Each group can contact content expert when needed.

All supervision sessions are at least once a week. On the one hand, the first type of supervisors is focus on the next tasks:

- Facilitate project organization and project planning.
- Facilitate team-work meeting.
- Facilitate rapport writing.
- Facilitate students' team in everyday work.
- Verify that the team is on the track.
- Carry out summative assessment in collaboration with the content expert skills.

4 Results

In total, 72 students filled out the first questionnaire and 74 students the second questionnaire, giving an average response rate of the 77%. The average age of students when entering the programme was of 19 years (see Table 3). The study was conducted using web tools and respecting students' confidentiality in five degrees: Computer Science and Telecommunications (IT) which are merged in the same classroom, Biomedical Engineering (Bio), Industrial Electronics (Elec) and Industrial Organization (Organi).

Table 3: R-SPQ-2F responses – Before and after PBL.

	Students	Valid responses				Groups
		Before PBL	After PBL			
		R-SPQ-2F	R-SPQ-2F	Contex	%	
IT	14	13	14	14	93%	4
Bio	31	29	16	16	52%	6
Elec	29	11	26	26	38%	5
Organi	23	19	18	18	78%	5
Total	97	72	74	74	74%	20

Learning environment (CONTEX)

First of all, we need to measure the learning environment created by PBL in our institution and in each degree. To do so, we have used the learning environment questionnaire (CONTEX) which has four factors (García Martín, García Fernandez et al. 2011). The first two factors are constructive, in the sense that they help in the learning process, and the last two factors are non-constructive. The questionnaire translated into English can be found in the annexe. During the experimental process, the Basque version (students' mother tongue) was used.

Table 4 : CONTEX learning environment questionnaire factor description

Constructive variables	Factor 1 (6 items)	Variables related to the methodology and the educational community (intrinsic motivation).
	Factor 2 (7 items)	Variables related to the teacher, how assess and interact (assessment type as well as teacher).
Non-constructive variables	Factor 3 (3 item)	Non-constructive variables (didactic aspects that may hinder meaningful learning, such as short time, reproductive assessment and unrelated content-based academic program structure).
	Factor 4 (2 item)	Variables related to workload (to some extent also related to the previous factor, but in this case they point out to workload and the amount of content).

Table 5 and Figure 4 show collected data, mean and standard deviation of each factor, represented in the table and graph.

Table 5: CONTEX questionnaire results grouped in factors.

		Constructive factors		Non-constructive factors	
		Methodology and educational community	Assessment and interaction	Non constructive variables	Workload and amount of content
Factor		1	2	3	4
IT	Mean	3,75	3,72	2,83	3,11
	SD	0,79	0,82	0,96	1,07
Bio	Mean	3,67	3,62	2,95	2,96
	SD	0,95	0,76	0,76	0,96
Elec	Mean	3,78	3,76	2,64	2,77
	SD	0,91	0,86	0,95	1,04
Orga	Mean	3,50	3,48	2,89	3,06
	SD	0,97	0,86	0,92	0,95
	Mean	3,68	3,65	2,80	2,94

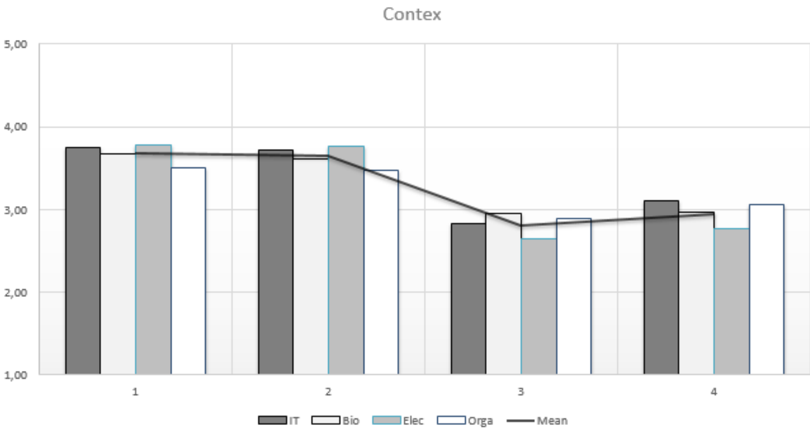


Figure 4: CONTEX questionnaire results grouped in the four factors.

As we can observe factor 1, related to the methodology and the educational community, and factor 2, related to assessment and relationship and feedback between teachers and students, are correlated. For example, the highest value in factor 1 and 2 corresponds to electronics and the lowest value in the factor 1 and 2 corresponds to Industrial Organization

If we refer to the factor 3, the non-constructive factor includes didactic content-based academic program structure. We note that the highest values in the factor 1 and 2 are those with the lowest values and vice-versa. We understand that low values in factor 3 reinforce the high values in factors 1 and 2; i.e., highly motivated students, a good relationship with the teacher and a perception of not content centred evaluation is consistent. There is the same relation with factor 4, but not in the case of Computer Science and Telecommunication. This is due to the higher workload and amount of content perceived by students (question 17-18 - see Figure 5).

Table 6: Detailed response of CONTEX questionnaire.

Factors		1						2							3			4	
Questions		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
IT	Mean	4,29	3,71	3,79	3,43	3,79	3,50	3,36	4,00	3,50	3,57	3,86	3,86	3,93	2,64	2,86	3,00	3,29	2,93
	SD	0,61	0,73	0,58	1,09	0,58	0,85	1,01	0,68	0,94	0,76	0,77	0,77	0,73	1,01	0,77	1,11	1,14	1,00
Bio	Mean	4,63	3,81	3,88	3,31	3,38	3,81	3,63	3,75	3,38	3,69	4,25	3,75	3,63	2,94	2,63	2,63	3,38	2,63
	SD	0,62	0,75	0,72	1,08	1,09	0,75	0,72	0,68	0,81	0,79	0,68	0,68	0,89	0,77	1,09	0,72	0,72	1,02
Elec	Mean	4,12	3,88	3,81	3,65	3,50	3,73	4,00	3,77	3,19	3,69	3,92	4,00	3,73	2,42	2,77	2,73	3,19	2,35
	SD	0,95	0,71	0,85	0,85	1,10	0,92	0,94	0,76	0,85	0,88	0,80	0,69	0,92	1,10	0,91	0,83	1,06	0,85
Orga	Mean	3,56	3,67	3,56	3,33	3,50	3,39	3,50	3,67	3,22	3,28	3,56	3,67	3,44	2,72	3,06	2,89	3,22	2,89
	SD	1,20	0,77	0,92	1,28	0,79	0,85	1,10	0,77	0,81	0,67	0,98	0,77	0,92	1,02	1,11	0,58	1,06	0,83
All	Mean	4,12	3,78	3,76	3,46	3,53	3,62	3,68	3,78	3,30	3,57	3,89	3,84	3,68	2,65	2,82	2,80	3,26	2,65

In Table 6 and Figure 5we can see detailed response of CONTEX questionnaire. First we remark that although the average of the values given by students of various degrees are different, most items answered will follow the same trend as can be seen in the graph.

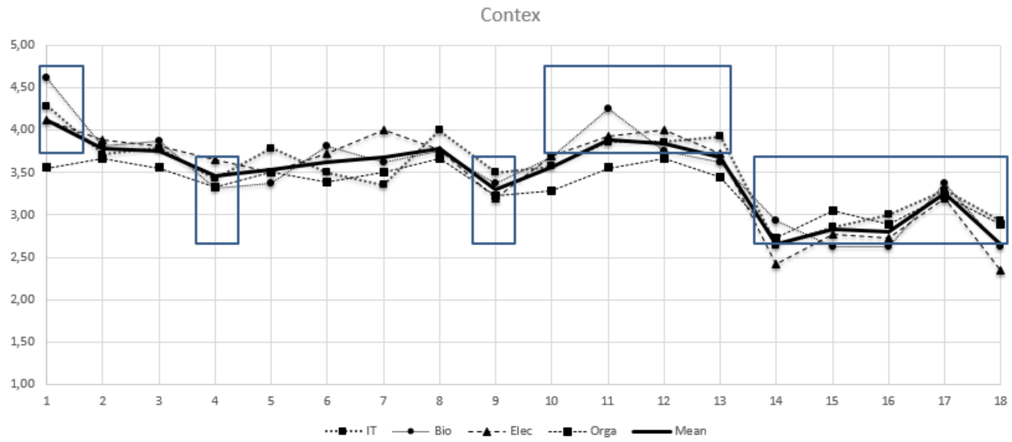


Figure 5: Detailed response of CONTEX questionnaire.

Observing constructive variables, we can conclude that first, the project increase students' confidence to share and exchange ideas with others (item 1). Second that quite how priority is given to deep learning (item9) and third that students highlight the relationship with teachers (item 10, 11, 12 and 13).

Observing non-constructive variables, we can conclude that first, the evaluation is not focused solely on learning by rote (item 14). Second that the contents that project has an equilibrated number of topics (item 18), and third that large workload is required by the project (item 16).

Table 7: Student's Learning Approach before and after PBL and the difference between them.

	Before PBL				After PBL				Difference	
	Deep Learning		Surface Learning		Deep Learning		Surface Learning		Deep	Surface
Degree	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	Mean
IT	3,29	0,99	2,31	1,06	3,39	1,01	2,25	0,81	0,10	-0,06
Bio	3,25	0,97	2,04	0,97	3,26	0,89	1,88	0,79	0,01	-0,17
Elec	3,24	1,14	2,12	0,91	3,43	1,02	2,20	1,05	0,19	0,08
Organi	2,95	0,93	2,25	0,89	2,98	0,89	2,22	0,76	0,04	-0,03
Mean	3,18	1,01	2,18	0,96	3,27	0,95	2,13	0,85	0,09	-0,04

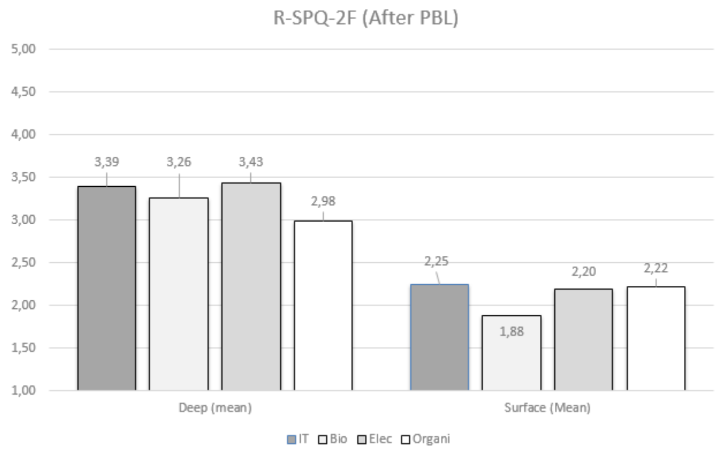


Figure 6: Student's Learning Approach after the PBL in each program.

Table 7 and Figure 6 show students' learning approach changes before and after PBL3. Deep learning after PBL is correlated with context constructive variable. In the case of Computer Science and Telecommunication and Industrial Organization students learning approach before and after PBL can be compared. In these cases the same number of students has participated in both questionnaires (see table

2). We have also observed that deep learning approach change is correlated with context constructive variables.

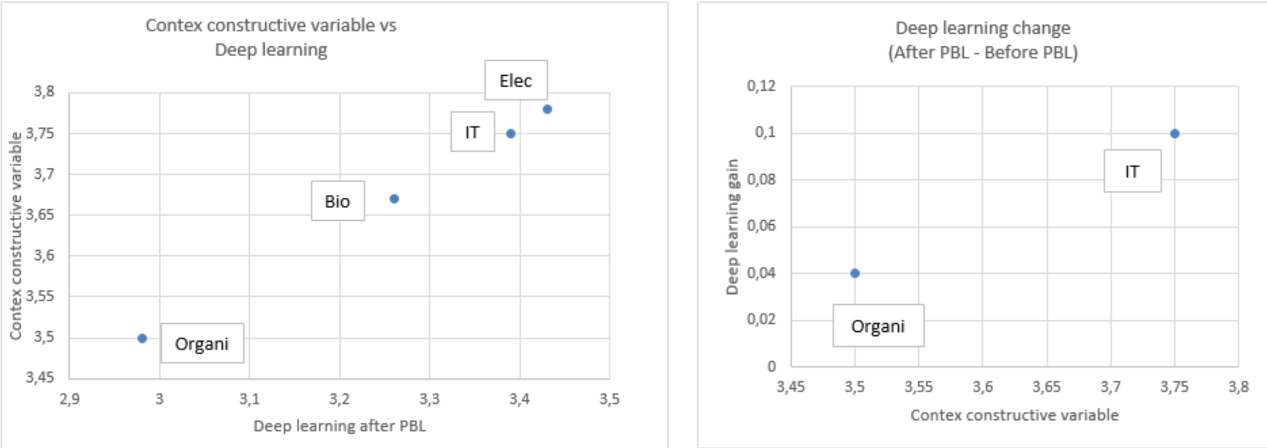


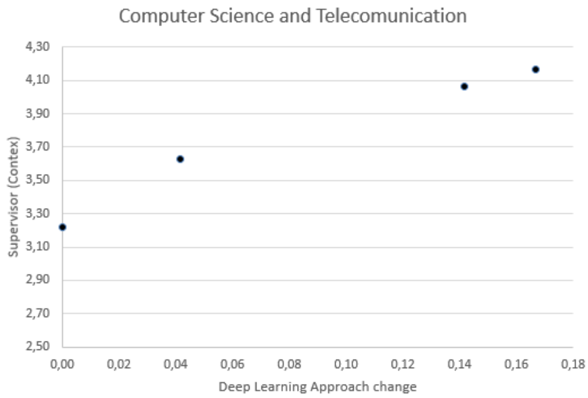
Figure 7: Students learning approach correlation with constructive context variables.

In Figure 8 (a) and (b) we can see a zoom of what happened in the degree of Computer Science and Telecommunications. Collected data allows us to analyse more deeply the impact of four supervisors in deep learning. Table 8 and Figure 8 (a) show the relation between each groups' deep learning approach and the perception of each about the supervisor (CONTEX - item 10, 11, 12 and 13). This figure shows that there is a correlation between them. The closer the relationship with the tutor and his intervention with the group becomes more reflective, the deeper the learning acquired by students is.

Table 8: Student's Learning Approach of PBL groups in Computer Science and Telecommunication degree.

	Before PBL				After PBL				Difference		Supervisor (Contex)	
	Deep Learning		Surface Learning		Deep Learning		Surface Learning		Deep	Surface		
Group	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	Mean	Mean	SD
1	3,53	1,07	2,33	1,06	3,68	0,89	2,20	0,99	0,14	-0,13	4,06	0,77
2	3,40	0,93	2,50	1,11	3,40	1,19	2,70	0,75	0,00	0,20	3,22	1,65
3	3,23	0,86	2,33	1,12	3,28	0,78	2,00	0,64	0,04	-0,33	3,63	0,88
4	3,00	1,05	2,07	0,94	3,17	0,95	2,20	0,66	0,17	0,13	4,17	0,24

The data collected during two consecutive academic years (13-14 and 14-15) in the same PBL and with the same supervisors, allow us to see if there is any relation between supervisor and deep learning change (Table 8). In both years supervisor 2 had been used it as a reference. We can see that the supervisor 1 and 4 create greater change in both cases. Supervisor 3 creates lower change in the second year. In a focus group carried out last year we found an explanation of changes in the case of supervisor 1, 2 and 4 but not in the case of supervisor 3.



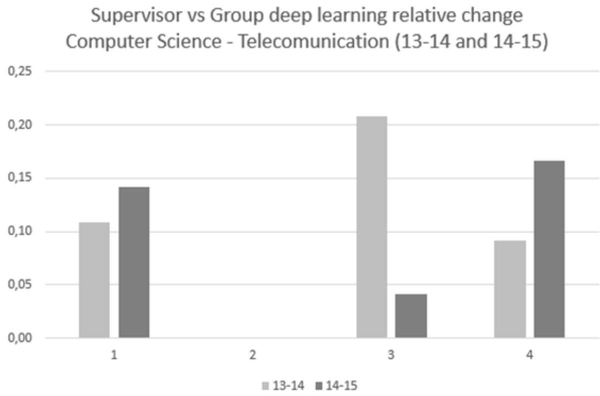


Figure 8: (a) Relation between supervisor related questions (CONTEX - item 10, 11, 12 and 13) and deep learning approach. (b) Deep learning approach change vs supervisor in PBL3 of Computer Science and Telecommunication in two consecutive academic year (13-14 and 14-15).

5 Conclusion

All PBLs considered in this study are focused on professional action and on know-how type of knowledge. All PBLs show a similar pattern in terms of constructive and non-constructive factors. Therefore we can conclude, that there are small differences among the programs, as there is an institutionally shared culture.

In all the cases constructive variables (related with methodology, educational community, teacher perception, adequate assessment, etc.) are more highly valued than non-constructive variables (non-meaningful learning, reproductive assessment, workload and amount of content).

The learning environment created around those PBLs promote students' deep learning approach. A correlation has been found between the learning environment and students' deep learning approach. In those environments with higher constructive variables students have deeper learning approach.

Supervisor seems to be a relevant actor that promotes trough reflection and formative assessment (feedback) deeper learning approach. This is what has been observed not only this year but also last year in a similar study.

As a result, considering the quite modest score given to constructive variables, we think that there is a room for improvement in the learning environment reinforcing all the constructive variables and particularly the priority given to deep learning. Regarding non-constructive variables, they can be made by the relationships between the topics and less priority to cover all the topics. Regarding the non-constructive variables related with **workload**, authors are critical. The questionnaire classifies its variable as a negative aspect, but authors claim that this can be a positive indicator related to the effort made by students.

Research team is aware that, although the collected data is bigger than in the previous works, it does not allow us to have statistically significant data, this is why this work needs to be with caution. In the close future we expect to extend to this work to all the degrees of the engineering school.

6 Summary and Acknowledgments

We would like to acknowledge all professors and staff of Mondragon University that have directly or indirectly participated in this project.

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Annexe – CONTEX – Learning environment questionnaire

Factor 1	1. The project work has encouraged and reinforced in me the confidence to share and exchange ideas with others. 2. The used method generally ensures the achievement of the proposed learning objectives. 3. Instead of explaining mere information, teaching seeks to elicit an active response from students by questioning or giving problem. 4. I feel part of the school. 5. I feel that this school has stimulated a desire to learn. 6. Assessment primarily assess links between the ideas and the personal production done by students.
Factor 2	7. Adequate assessment methods are used to assess that the objectives set at the beginning of the project are achieved. 8. Priority is given to assessment methods that encourage students to work every day. 9. Priority is given to deep learning rather than to the topics' coverage. 10. Teachers show interest on the students and the difficulties they could be facing. 11. Teachers support / guide / provide feedback during the learning process. 12. Teachers show interest and appropriate training in the subject. 13. Teacher's teaching style creates a positive work environment, where students were able to make mistakes and learn from them.
Factor 3	14. Priority is given to assessment methods that encourage learning by rote. 15. To work on the project a lot of data are presented, and not the relationships between the topics. 16. Priority is given to cover all the topics; therefore, they is not enough time for all of them.
Factor 4	17. The project has too much work to do. 18. The project has too many topics

The Influence of Problem-Based Learning Environment on Law Students' Learning Strategies and Academic Performance

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Abstract

Problem-based learning, a student-centered educational method, is believed to stimulate high quality learning in students. High quality learning can be described as students' use of effective learning strategies, specifically deep processing (i.e., connecting different study topics to a whole) and self-regulation (i.e., taking control over one's own learning). Several aspects of PBL are believed to encourage deep processing, such as stimulation of connecting course material to real-life situations as a result of working with realistic problems. Similarly, self-regulation is assumed to be encouraged in PBL, because students need to self-select literature and plan their self-study time in between tutorial meetings efficiently. The present study investigated the influence of PBL on learning strategies by comparing third-year law students of a PBL curriculum to third-year law students of a traditional, non-PBL (i.e., control) curriculum on their learning strategies. Results showed that PBL students reported to apply deep processing, self-regulation, and external regulation more frequently than their non-PBL counterparts. PBL contributes to the use of effective learning strategies, but PBL students also seem to depend their regulation more often on external sources, such as teachers, course material, and assessment. This might indicate that teachers, despite their coaching role in PBL, still provide too much instruction to students.

Keywords: Problem-based learning, deep processing, self-regulation, legal education

1 Introduction

1.1 Learning Strategies

Time investment in self-study is referred to as the *quantity* of learning. Some students spent more time than others on studying course material. However, whether this quantity of learning plays an important role in academic success is debatable (Doumen, Broeckmans, & Masui, 2014; Plant, Ericsson, Hill, & Asberg; 2005; Van den Hurk, Wolfhagen, Dolmans, & Van der Vleuten, 1998). One could argue that rather the *quality* of learning, which is focusing on how students learn, matters with regards to understanding and academic performance. The quality of learning in turn might be influenced by the learning environments students are in, because some learning environments aim to encourage high quality learning. Problem-based learning (PBL) can be considered such a learning environment that attempts to stimulate high quality learning. The present study will investigate whether PBL indeed influences how students learn.

The quality of learning is described as learning strategies students apply. Vermunt (1998) distinguishes learning strategies in cognitive processing strategies and regulatory strategies. Processing strategies are thinking strategies needed to process the material to be learned (Vermunt, 1998; Vermunt & Vermetten, 2004). When students relate different study concepts together and link course material to their own experiences and real-life situations, they study in an effective way. This is called deep processing and results in a deep understanding of information. Less effective processing strategies are, for example, rehearsing the learning material till it is memorized, as this results in only a poor understanding of the material. Therefore, processing strategies such as memorization are often labeled as surface or stepwise processing strategies (Newble & Entwistle, 1986; Vermunt, 1998).

Regulatory strategies are strategies students use to regulate the processing strategies (Vermunt, 1998; Vermunt & Vermetten, 2004). There is a difference between self-regulation, in which students take control of their own learning process, and external regulation, which holds that students depend for this control on external sources, such as teachers, course material, and assessment. Self-regulated learning (SRL), which is a skill that includes active engagement of students on metacognitive, motivational, and behavioral aspects (Zimmerman, 1989), is considered more effective than external regulation, since students with SRL skills are able to set goals, monitor, and motivate themselves to achieve those goals (English & Kitsantas, 2013). These learning strategies, processing and regulatory strategies, can be influences by the applied educational method. Some of these methods, such as PBL, aim to stimulate high quality learning (Mattick & Knight, 2007).

1.2 Problem-based Learning

Problem-based learning (PBL) can be considered an instructional method that aims to stimulate high quality learning (Mattick & Knight, 2007), and therefore aim to foster more frequent use of deep processing and self-regulation by students. PBL is a student-centered educational method which emphasizes collaboration on realistic problems under guidance of a tutor. Students' intrinsic motivation is aimed to be enhanced as well as their knowledge construction (Hmelo-Silver, 2004; Loyens, Kirschner, & Paas, 2012). PBL stresses the importance of an active role of students in their learning process, meaning that students need to construct their own knowledge rather than passively receiving information (Barrows, 1996; Hmelo-Silver, 2004).

The process of PBL can be divided into the pre-discussion, the self-study phase, and the reporting phase (Loyens et al., 2012). In the pre-discussion, students start the learning process by working in groups of ten to twelve on a realistic, ill-defined problem, which describes a situation that can occur in real life and elicits discussion in the group. Since students receive the problem at the beginning of their learning process, before they have acquired any knowledge about the topic of the problem, they activate their prior knowledge when thinking about the problem. Students try to come up with explanations and possible solutions, based on their experiences and common sense. The advantage of this prior knowledge activation is that new information can become connected to one's already existing knowledge, which is referred to as the process of elaboration (Schmidt, 1983) and which has shown to be beneficial in terms of knowledge retention (e.g., Dochy, Segers, Van den Bossche, & Gijbels, 2003). Because prior knowledge is limited, several aspects of the problem stay unclear and students collaboratively formulate questions (i.e., learning issues) about the aspects of the problem that need further investigation and explanation. These learning issues guide students during their self-study period in which students individually select and study different literature resources in order to answer the learning issues. After a few days of self-study, students gather again for the reporting phase, where the studied literature is discussed and the learning issues are answered in the group. The tutor, who is present during the pre-discussion and the reporting phase, facilitates the learning process through providing feedback and encouraging students to think more deeply about the studied material (Hmelo-Silver, 2004; Loyens et al., 2012; Schmidt, 1983).

The focus of PBL lies on the tutorial meetings and the amount of lectures is usually limited in a PBL curriculum. Because of these curriculum characteristics, sufficient time for self-study is available. It is argued that more time available for self-study is beneficial, because students have more opportunities to apply effective learning strategies, which require much time investment. More time available for self-study is argued to be beneficial in terms of graduation rates (i.e., higher graduation rates) and study duration (i.e., shorter study duration), because of the use of effective learning strategies (Schmidt et al., 2010).

1.3 PBL's Influence on Learning Strategies

It is believed that several aspects of PBL stimulate students' use of deep processing (e.g., Mattick & Knight, 2007; Schmidt, Dauphinee, & Patel, 1987) and self-regulation (e.g., English & Katsintas, 2013). Because PBL students are encouraged to connect course material to their experiences in the pre-discussion, deep processing of information is stimulated. Further, information is learned in the context of a realistic situation (i.e., the problem), making that students connect the learned knowledge to practice. In addition, students need to connect different concepts to each other in order to complete and understand the answers on the learning issues discussed during the reporting phase. A tutor can stimulate this by asking in-depth questions. Despite these encouraging components of PBL, studies investigating the effects of PBL on deep processing show mixed results (Loyens, Gijbels, Coertjens, & Côté, 2013). Some studies demonstrate more deep processing of PBL students and more surface processing by non-PBL students (e.g., Newble & Clarke, 1986), while other studies found no effects of PBL on deep learning (e.g., McParland, Noble, & Livingston, 2004).

PBL is also believed to stimulate self-regulated learning (English & Katsintas, 2013; Mattick & Knight, 2007). One of the goals of PBL is developing self-directed learning skills (Hmelo-Silver, 2004; Loyens et al., 2012), meaning that students should take initiative to participate in learning activities, rather than needing stimulation by a teacher (Schmidt, 2000). Self-directed learning is to a certain degree similar to self-regulated learning, however not identical (Loyens, Magda, & Rikers, 2008). While self-regulation can be seen as a learner's characteristic, self-directed learning is assumed to be both a learner's characteristic as well as a learning environment's characteristic. Self-directed learning is therefore broader and contains self-regulation learning. PBL can be considered a self-directed educational method which stimulates self-regulation in students, because students need to self-select their literature, prepare themselves for every tutorial meeting, and monitor and plan their own time during self-study. Moreover, the role of the tutor can enhance self-regulation in students, because the tutor only facilitates the learning process by scaffolding, but students need to take responsibility for their own learning (English & Katsintas, 2013). Previous studies aimed to investigate the effects of PBL on learning strategies by comparing PBL medical students to medical students of a traditional educational method (Lycke, Grøttum, & Strømsø, 2006; Van der Veken, Valcke, Muijtjens, de Measeneer, & Derese, 2008). It was found that PBL students show less surface learning, make more use of multiple resources, and show more self-regulation compared to their non-PBL counterparts. The present study will investigate whether PBL also influences learning strategies in law students and therefore try to generalize previous findings. Moreover, since PBL students have more time for study available (Schmidt et al., 2010), it was studied whether PBL students spend more time on study.

1.4 Present study

Since deep processing and self-regulation strategies are considered effective in terms of understanding and academic performance, the present study will investigate whether students in PBL show different processing and regulatory strategies compared to students in a more traditional learning environment. PBL is assumed to stimulate deep processing (e.g., encouraging students to connect different study topics) and self-regulation (e.g., students need to self-select literature). In order to study PBL effects on quality of learning, learning strategies of students in a PBL program will be measured and be compared to learning strategies of students of a traditional educational method (which serves as control group), where no explicit stimulation of deep processing and self-regulation is present. It was hypothesized that PBL students show more deep processing and self-regulation and less ineffective learning strategies as surface processing and external regulation, because PBL carries several design characteristics outlined above that can stimulate high quality learning.

Additionally, as students in PBL are provided with ample time for self-study, the present study will explore whether PBL students spend more time on self-study compared to students in a more traditional program, where more lectures are provided and less time for self-study is available. It was hypothesized that since PBL students have more time for self-study, they also invest more time on study.

2 Method

2.1 Learning environment

The educational program of the Faculty of Law of a Dutch university in which the current study took place, consists of a three-year bachelor program and a one-year master program. At the start of the academic year in September 2012, a PBL curriculum was implemented. In the former educational method, the academic year consisted of four semesters with a total of eight courses. During each semester, two courses were offered parallel and multiple lectures were provided each week and some courses offered a weekly workgroup, where a teacher discussed a particular law case. Four exam weeks took place during the academic year, in which several courses were assessed.

In the new applied PBL program, a total of eight courses each academic year are offered sequentially, taken five weeks each and they all end with a course test. In PBL, the focus lies on tutorial meetings that occur twice a week. In these meetings, the pre-discussion (i.e., collaborative discussion of a realistic problem prior to self-study) and the reporting phase (i.e., discussion of the studied literature) take place. Students have ample time for self-study in between these meetings. Lectures (i.e., one or two each week) and practical courses are offered next to the tutorial meetings and serve the purpose of extending students' understanding of course material and teaching students how to apply the learned material in real-life law cases.

2.2 Design and participants

Third-year Dutch law students of the non-PBL, control program and the PBL program participated in this study. The students of the non-PBL, control group enrolled in their first year of study Dutch law in September 2011, before the switch of the educational program to PBL. Students in the PBL condition registered their first year of Dutch law in September 2012, after the implementation. A total of 338 students participated voluntary in this study. Participants of the non-PBL, control group were 180 third-year Dutch law students (38% males) with a mean age of 22.5 years (*SD* = 2.60). In the PBL group, 158 third-year Dutch law students (36% males) participated. Mean age was 21.5 years (*SD* = 1.82). The gender distribution in both conditions is common for law study programs in higher education in the Netherlands (Central Bureau for Statistics, 2014).

2.3 Material

2.3.1 Learning Strategies

The Inventory Learning Styles (ILS; Vermunt, 1998) was used in order to measure students' learning strategies (i.e., processing strategies and regulatory strategies). The ILS is a self-report questionnaire in which students rate statements on a scale of 1 ("I never or hardly do this") to 5 ("I (almost) always do this"). Items regarding processing strategies are distinguished in: A) deep processing (11 items), which focus on relating topics, structuring, and critical processing, B) stepwise processing (11 items), in which the use of memorization, rehearsal, and analyzing is measured, and C) concrete processing (5 items), which measures whether learning material is concretized and personalized by the student. Further, items on regulatory processes are divided into D) self-regulation (11 items), which measures to what degree students control their own learning process, E) external regulation (11 items), which measures to what degree students depend on external resources (e.g., a teacher) for steering and controlling their learning process, and F) lack of regulation (6 items), which measures the inability of students to regulate the learning process. In total, the questionnaire contained 55 items. Table 1 provides an overview of the subscales with example items and Cronbach' alphas. The Cronbach's alphas can be considered acceptable, with exception of the scale 'external regulation' (α = .64), which has a rather low reliability compared to the alpha's of other scales. Results on this scale should be interpreted with caution.

Table 1. Example items and Cronbach's alphas of subscales of learning strategies measured in the ILS

Learning strategy	Subscale	Example item	Cronbach's alpha
Processing	Deep processing	'I try to combine separately discussed concepts to a whole'	.82
	Stepwise processing	'I rehearse important topics of the learning material till I memorize them'	.79
	Concrete processing	'I use what I learn on a course in my activities outside the study'	.72
Regulation	Self-regulation	'When I'm having difficulties with parts of the course material, I try to analyze why it is hard for me'	.80

	External regulation	'I study according to the instructions provided by course materials or the teacher'	.64
	Lack of regulation	'I confirm that I find it difficult to determine whether or not I sufficiently mastered the course material'	.75

2.3.2 Self-study time

Students were asked to give an estimation of their weekly time investment in self-study (in hours) prior to the ILS, by the question: "How many hours an average do you spend each week on self-study?"

2.4 Procedure

Students of the non-PBL cohort participated in the given course in January 2014 and students of the PBL cohort participated in the current study a year later, during the given course in January 2015. The teacher (i.e., in the control condition) or tutor (i.e., in the PBL condition) handed out the questionnaire on paper during a regularly study week and students took about 15 minutes to fill it out.

3 Statistical Analyses

In order to investigate the effect of PBL on learning strategies, a MANOVA was conducted with educational method as between-subjects factor (i.e., control vs. PBL) and the scores on the subscales of processing strategies (i.e., deep, surface, and concrete processing) and regulatory strategies (i.e., self, external, and lack of regulation) as dependent variables. In order to study the effect of PBL on time spent on self-study, a One-Way ANOVA was conducted with instructional method (i.e., PBL vs. control) as independent variable and self-study time as dependent variable.

4 Results

Before conducting the analysis, assumptions were checked and met. After excluding two outliers on the subscale deep processing for the analysis, the total number of participants was 336. Mean item scores on the processing and regulation strategies for participants of both conditions are given in Table 2. The MANOVA showed a significant effect of instructional method, Pillai's trace $V = .06$, $F(6, 329) = 3.27$, $p = .005$, *partial* $\eta^2 = .06$. Separate univariate ANOVAs on the subscales of the ILS showed that students in the PBL cohort reported more frequent use of deep processing ($F(1, 334) = 4.15$, $p = .042$, *partial* $\eta^2 = .01$), self-regulation ($F(1, 334) = 7.41$, $p = .007$, *partial* $\eta^2 = .02$) and external regulation ($F(1, 334) = 7.39$, $p = .007$, *partial* η^2 = .02) than students in the control cohort. No differences between conditions were found on stepwise processing, concrete processing, and lack of regulation, respectively $F(1, 334) = 1.42$, $p = .054$; $F(1, 334) = .27$, $p = .820$; $F(1, 334) = .64$, $p = .285$.

As a result of missing values on self-study, the number of participants included in the One-Way ANOVA analysis was 325. Mean scores on time spent on self-study are given in Table 2. Results on the ANOVA with self-study time as dependent variable showed no significant differences between students of the PBL program and students in the non-PBL program on time spent on self-study, $F(1, 324) = .80$, $p = .371$.

Table 2: Mean item scores on all subscales of the ILS and reported self-study time for both conditions (standard deviation in parentheses)

		Condition	
		Control	PBL
Processing strategies	Deep processing	2.89 (.67)	3.03 (.59)
	Stepwise processing	2.90 (.62)	3.03 (.60)
	Concrete processing	2.93 (.74)	2.91 (.71)
Regulation strategies	Self-regulation	2.43 (.66)	2.62 (.60)
	External regulation	3.08 (.50)	3.23 (.49)
	Lack of regulation	2.45 (.77)	2.36 (.73)
Self-study time		12.67 (7.44)	11.99 (6.09)

Note. Scores on the subscales of the ILS could range from 0 to 5.

5 Discussion

The current study investigated the influence of PBL, a learning environment that aims to stimulate high quality learning, on students' processing and regulatory strategies by comparing law students in a PBL cohort to law students in a traditional, non-PBL (i.e., control) cohort.

With regard to the processing strategies, it was showed that PBL students reported more use of deep processing more frequently than their non-PBL counterparts. An explanation lies in the aspects of PBL, which aim to foster deep learning (e.g., Mattick & Knight, 2007; Schmidt et al., 1987). In a PBL curriculum, students need to formulate answers to the learning issues, based on self-selected literature sources. In order to construct coherent and complete answers to the learning issues, PBL students are required to relate different study topics together. Moreover, tutors can ask students in-depth questions during the pre-discussion and the reporting phase, making that students elaborate more on the material. While previous studies indicated mixed results on the effects of PBL on deep learning (Loyens et al., 2013), this study found a beneficial effect of PBL on deep processing.

No differences between students of the PBL group and control group were found with respect to stepwise processing, which is inconsistent with previous findings (i.e., Van der Veken et al., 2008). This finding might be explained by the content of assessments used in curricula and the discipline of study (Baeten, Kyndt, Struyven, & Dochy, 2010). It might be that assessments used in both curricula under study do not always require deep processing in order to receive a sufficient grade and can be managed with stepwise processing only. Since stepwise processing is applied frequently in both cohorts (see Table 2), this might be the case. Further, the use of deep and surface learning appears to differ between disciplines of study (Baeten et al., 2010). Previous studies are often conducted in medical education (e.g., Lycke et al., 2006; Van der Veken et al., 2008), while the present study investigated learning strategies in law students. Both the content and student characteristics between legal and medical education differ (i.e., medical students are often assumed different than the average student because of the strict selection procedure) and this could explain why no difference on stepwise processing was found in the present study, while this was found in previous studies (e.g., Van der Veken et al., 2008).

Regarding regulatory strategies, the present study showed that PBL students reported to be more self-regulated compared to students in the non-PBL control group. This result can be explained by elements of PBL that encourage self-regulation in students, such as the need for self-selecting literature, planning self-study time carefully because of required preparation for tutorial meetings, and evaluation of formulated answers on the learning issues after the reporting phase (English & Katsintas, 2013; Mattick & Knight, 2007). Results also indicated that PBL students reported to be more externally regulated compared to students of the control cohort, which means for the regulation of processing strategies PBL students depend often on external sources such as the tutor, teacher, course material, and assessments. The more frequently reported use of PBL students on external regulation was unexpected and contradicts to earlier studies (i.e., Lycke et al., 2006; Van der Veken et al., 2008) in which no effect of PBL on external regulation was found. This result might be explained by the fact that the PBL students under study were students of the first PBL cohort after the implementation of PBL. Due to unfamiliarity with and novelty of the PBL method, teachers might have provided students with too much information and instructions, making them depend more on external sources, despite the fundamental idea that PBL is student-centered. It should, however, be noted that reliability of the subscale external regulation turned out rather low (α = .64) and findings on this subscale should therefore be interpreted with caution.

In addition, the present study investigated whether PBL students spend more time on self-study, since more self-study time is available for them. Results indicated that PBL students and non-PBL students invest an equal amount of time on self-study. Apparently, more time for self-study available does not result in more participation of self-study.

The present study used the ILS, a self-reported questionnaire in order to measure learning strategies. On one hand, this can be considered a limitation because not actual learning behavior is measured. Nevertheless, the use of self-reported learning strategies might be more accurate than observation and the majority of previous studies on learning strategies also make applied self-reported questionnaires. This provides the opportunity to compare results with previous finding. However, future studies could measure learning strategies in multiple ways, such as a self-reported questionnaire and interviews. Self-study time was also measured by self-report and was asked in general. However, time spent on learning can differ between courses, because of for example the content or amount of workload required in the course. Therefore, it is possible that the representation of self-study in the present study does not provide a clear image of their actual time spent on studying. Follow-up studies could measure self-study time on multiple occasions or by diaries. In addition, it has been shown that how students perceive the learning environment influences the use of learning strategies (e.g., perceiving the environment as student-centered fosters the use of deep processing; Baeten et al., 2010). At this point in the present study, it is unclear whether students' perceptions of the environment are in line with the fundamental ideas (i.e., student-centered). Therefore, further studies should include more factors like students' perspectives of the learning environment.

In sum, the present study investigated the relation between PBL and Dutch law students' learning strategies and it was found that PBL students reported more frequent use of deep processing, self-regulation and external regulation. Several aspects of PBL contribute to high quality learning in law students. This study shows that previous findings on PBL and learning strategies in medical education can be generalized to legal education.

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Changing to PBL: the students' perspective

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Abstract

Processes aimed at creating change from the bottom up usually require experiences and analysis before institutional leaders can become involved. Normally, a small group of highly motivated teachers starts by testing PBL through several different experiences, with the conviction of success, in an attempt to motivate other colleagues and encourage their involvement. However, the task of putting these experiences into practice is usually more complex than that of directly applying the educational theories involved in PBL. Frequently, students demonstrate the apathy associated with traditional learning and tend to concentrate their efforts on just passing exams, especially during their first year. This produces frustration in teaching staff lacking experience, which leads to the conclusion that successful PBL experiences depend on the students' reactions and attitudes.

From the students' perspective, PBL is not an easy way to learn, especially when they are first exposed to loosely structured problems. Students feel stressed, caused predominantly by their lack of knowledge and skills, and also because of their lack of teamwork experience. Even when they are intrinsically motivated to solve the problem itself, many of them tend to give up at the first hurdle as soon as they encounter difficulties as they are more used to focusing their efforts on the results rather than on the problem-solving process itself.

This paper analyses students' perceptions of PBL at the end of the process, and studies which obstacles are perceived when introducing this learning method in an engineering education.

Keywords: Changing to PBL, student motivation, processing skills, student social networks, student engagement.

1 Introduction

The new structure imposed by the Bologna Process has led to major changes in higher education institutions. However, in the case of engineering qualifications in Spain, professional associations have reported that recent university graduates appear to have a lower educational level than older pre-Bologna graduates (IIES, UPCI, FEDECA, 2014). In our experience, the transformation process has been predominantly focused on the acquisition of knowledge, but not on the acquisition of skills required by wider society and the labour market. In fact, the Bologna Process adaptations that were performed involved subjects and content, rather than using intended learning outcomes as a starting point; perhaps this is because social competences do not require specific courses and the traditional orientation of faculty staff (Heitmann 2005).

We have observed that this structure tends to drive the students more towards trying to attain the highest possible grade than towards the applied use of their acquired knowledge. The result is that knowledge is not being thoroughly assimilated, mainly because it is easier to forget than to use, as a result of a lack of emphasis being placed on developing problem-solving and transferable skills.

The attitude and previous skills held by students also have a deep impact on their learning process. Based on our work with students entering the university for the first time, we have experienced several issues in line with this observation:

- Students are used to being passive, so they tend to merely act as receptors of content. Only a few individuals actively participate in the classroom on a routine basis.
- In traditionally taught subjects, students tend to select their seating arrangements in the classroom in relation to their grading. We think that this is directly related to their attention, their self-perception and their motivation.
- Generally speaking, teamwork is not a key factor in their learning process, possibly because of the influence of previous educational stages prior to university. When they do undertake such tasks, the concept of *teamwork* equates to *traditional teamwork*, that is, working individually and posteriorly joining all the parts together to build a full text. When doing this, plagiarism and freeriders are also often present.
- Students prefer traditional exams. Other assessment methods are avoided if at all possible.
- Students struggle to understand real-life problems. They do not associate simple concepts to real evidence. Concepts tend to be memorized and later dropped out during the exams. Students tend to avoid real-world problems, and prefer to solve problems by following a step-by-step procedure.
- The structure of their curriculum is difficult to understand. They tend to build barriers within subjects and do not understand how knowledge interacts with the real world.
- Students have serious difficulties when trying support concepts, especially when they have to put into words their ideas or conclusions.
- Mobile devices are not generally perceived as work tools, but rather for pleasure and communicating within their social networks.

We have adopted active learning while trying to solve these problems because it fits with the Bologna precepts (Huber 2008). PBL has proven effective in decreasing the dropout rate, increasing students' motivation and the integration of knowledge, professional skills and process skills. But the integration of PBL in a traditional learning institution implies a change in process that affects all educational stakeholders, including students (De Graaff & Kolmos 2007, De Graaff 2013).

Students who are used to traditional teacher-centred learning processes may encounter difficulties when trying to adapt to PBL (Yusof et al. 2004). As such, our team has focused on testing several PBL strategies in order to gain experience in PBL and to observe the students' reactions, but also to support our process of switching to PBL that uses scientific evidence. With regards to overcoming other difficulties i.e. financial support, proper infrastructures, and organisational facilities, we believe that an increase in students' acceptance of PBL is the first step towards implementing active learning.

2 The context

Our institution —the University of La Laguna, Canary Islands, Spain— has grounded its learning in the traditional learning approach. This fact is reflected in our infrastructure because it is quite clear that the classes and shared spaces have not been designed for teamwork. The current curriculum for all engineering degrees is designed to deliver a four-year course and provide 240 ECTS credits (European Credit Transfer and Accumulation System). Students learn theoretical concepts during the initial stages of the course, which should then be applied during the fourth year of the course during compulsory internships and in a final project, which used to be performed individually. Lecturers are heavily influenced by this traditional inertia, and usually focus the whole learning process on lectures and individual practical sessions.

A major proportion of the students entering this institution come from traditional teacher-centred learning environments. Before entering the University they have to pass an exam, which in our opinion is too focused on knowledge (a theoretical understanding), and does not always reflect their real skills (the ability to apply their knowledge). In our specific case, we have observed a steady and continuous decrease in level of basic skills in successive cohorts of students, with especial emphasis on an elementary understanding of basic sciences, reading, problem-solving and teamwork. This is coherent with PISA results from students in the Canary Islands, which indicate that students here were awarded the lowest results for competences in reading, maths and sciences when compared to the rest of Spain, which is equivalent to one year below the average for OECD countries (OECD 2012).

3 Student motivation

Motivating students positively can lead to benefits in terms of their learning process (Kirn & Benson 2013). Low motivation levels will hinder the learning process and will lead to frustration in the faculty staff (Savin-Baden & Major, 2004). PBL will not only increase student motivation, but it will also increase their problem-solving skills through facing new problems, prioritizing and analysing (Bouhuijs & Gijselaers, 1993). However, we have encountered some resistance from our students when faced with a loosely-structured problem for the very first time, especially from those coming from traditional learning environments. Savin-Baden and Major advocate giving support to the students from the beginning so they are able to get used to PBL during the initial stages. However, even once used to this learning method, their interest should still be stimulated. For these reasons, it is necessary to understand what motivates and what frustrates students who are new to PBL.

Intrinsically motivated students tend to perform well, but intrinsic motivation is not always present in higher education and depends on the previous experiences of each and every student (Ryan & Deci, 2000). By contrast, extrinsic motivation is closer to the learning process in higher education. Motivational theories highlight the role of identification and integration in boosting extrinsic motivation, and recognise the importance of feeling competent when carrying out extrinsically valued activities (Ryan & Deci, 2000). The use of a student-centred learning environment encourages students to claim the learning process as *theirs* (Yusof et. al. 2004), which comes as the result of empowering students and enabling them to have the feeling of being able to control the process (Jones 2009).

Consequently, to be extrinsically motivated, students have to recognise the importance of their behaviour, and then assimilate that their learning process is a way to build themselves up in a professional and personal sense. In this regard, the feeling of being competent is a key factor for boosting students' motivation. The MUSIC model (Jones 2009) fits this purpose perfectly and can be used as a decision-making platform to improve PBL experiences. To monitor our experiences of student motivation we opted to use Jones' model, which is based on five components: empowerment, usefulness, success, interest, and caring.

4 The target group

This experience involved 199 students (15.3% women and 84.7% men) from three degrees. All students were enrolled in a common target subject that is both technically and vocationally oriented. The selected subject is taught at the Polytechnic School of Engineering (University of La Laguna) during the first year of the degree programs in the first and second semesters. Student distribution according to degree is not uniform: 58% of participants were students enrolled in the degree Maritime Transportation, 28.5% in the degree Marine Engineering, and 13.4% in the degree Marine Radio-Electronics.

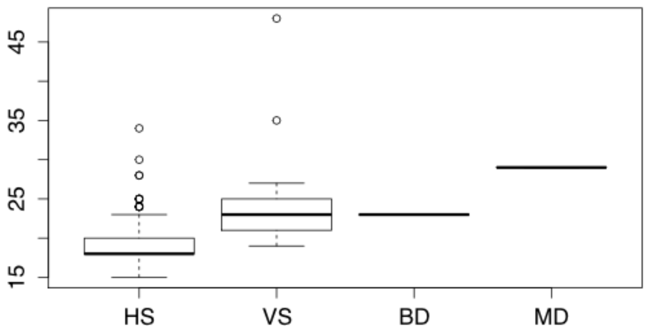

Figure 1: Distribution of ages depending of the students' previous education

The majority of these students (82.6%) came from high school (HS) and had entered university for the first time, but there was a significant rate of more experienced students (13.4%) who had come from vocational schools (VS). A smaller proportion of the students (4.1%) held either a previous bachelor or masters degree (BD, MD). Overall, most of the students were quite young. At the time of enrolling 75% of the students were aged between 17 and 21 years old; however age groups are distributed differently depending on whether students aleady held higher education qualifications, as seen in Fig. 1. The median age of the students coming from high school (18 years old) is significantly lower that the median of students from vocational schools (23 years old), probably because the latter has already entered the labour market prior to entering university.

5 The organisation of PBL

It is not easy to reorganise the actual structure of the curriculum to separate active learning activities from subjects at this early stage. Our first approach was to readapt the target subject to accommodate PBL, given that its vocational nature makes it a perfect choice for active learning.

Before the PBL experience, the subject's weekly schedule was organised as follows: 1 hour for conventional courses, 1 hour for problems, 1 hour for practical lessons in reduced groups, and 4.5 hours for autonomous learning. During PBL it was rescheduled as follows: 1 hour for conventional courses, 1 hour for short problems, 1 hour for meetings with the facilitator, and 4.5 hours for PBL work. Therefore, the main difference consisted in the use of the time after classes: before the experience, students used this time mainly for studying and preparing exams whereas during the experience, this time was more used for teamwork and project work. As a result, the subject was split into two parts: active learning through PBL, and conventional courses and short problems to support PBL; both tutored separately.

Only four lecturers attempted to participate as facilitators, two of whom also had teaching responsibilities in the target subject. Consequently, it was necessary to establish large groups of students in order to be able to schedule weekly meetings. Students were free to choose between twelve available groups and the resulting group sizes averaged seventeen students per group. This had an initial negative impact in the efficiency of students and facilitators, given that this enabled freeriders to avoid participating and hampered the labour of facilitators. To overcome this limitation and resolve this issue, and also to help the students in their organisation and self-control, students were told to choose a team leader and to write their own rules.

Not all the participating facilitators had the same level of experience, but all of them had experimented with PBL before. Groups were assigned to facilitators based on their previous experience and their availability (Table 1). Facilitators were responsible for guiding the students, monitoring their progress, dynamizing the group, or intervening in the event conflicts arose. In addition, facilitators also resolved doubts, with the exception of specific technical issues not related with the facilitator's experience, in which case the students were redirected to the appropiate tutor. Consequently, the role of the facilitator was more "tutoring for the process" than "tutoring for the subject".

Table 1: Students assigned to each facilitator.

Facilitator	Groups	Students
Facilitator A	5	86
Facilitator B	4	71
Facilitator C	2	31
Facilitator D	1	11

Students were free to organise their workload with instructions that they must avoid exceeding the maximum time allowed per week (4.5 hours for this experience). Students were also allowed to schedule their own meetings and to use any online platform for videoconferences, document sharing or social networks. However, one online platform was mandatory: Trello (http://www.trello.com). All student groups used this platform to share ideas and brainstorm, publish a weekly video blog, ask questions and organise tasks. Each facilitator had access to the platform's content for monitoring purposes.

Regarding group meetings, each group of students had to write up the minutes of each meeting and submit them to their facilitator. This document had to reflect the names of the assistants, their conclusions and next actions to be performed. Attendance at meetings with their respective facilitator was also mandatory. During these meetings the facilitators helped the students to find their issues, monitored their progress, established milestones, discussed the following objectives for the next meeting, and helped to resolve conflicts.

6 The problem-solving process

The problem, which was common to all groups, was designed so as to occupy a whole semester. During this period, each group of students had to develop a project to solve the problem.

For better comprehension of the PBL process, during the initial weeks students were instructed about the basis of PBL, the problem-solving process, and the assessment procedures. With the aim of guiding the students well, we developed a five-step problem-solving process (Table 2), which was inspired in the seven-jump problem-solving process at Maastricht University (Perrenet & Bouhuijs, 2000): a) Initial Clarification, b)

Establishing Learning Objectives, c) Brainstorming, d) Research and Development, and e) Final Synthesis and Checking.

After finalising the process, each group of students sent a final report to their facilitator and passed a group exam that consisted of a group presentation, an open discussion, and the answering of specific questions. Faculty members and external professionals assessed the students individually without the participation of the facilitators. Peer-assessment was also used to measure individual performance.

Table 2: Five steps PBL, project-oriented process.

Initial clarification	Students must understand the problem. The facilitator asks questions about the problem, which should be related to the previous knowledge and skills. The research for answering these questions helps the students to clarify the problem. During the rounds of questions, the facilitator dynamizes the group. One useful strategy during this step was *one-student one-idea*: the facilitator presents the problem and asks each student to formulate a question or add something relevant. All questions and ideas have to be discussed later without the facilitator, and students have to do their own research and try to answer all items before a deadline.
Establishing learning objectives	After the initial clarification, students will discover that the proposed problem is more complex than initially thought. When the initial doubts are answered, they have to organise their learning objectives and think about what they consider necessary, or not. This requires previous research and a certain amount of trial and error to find the right objectives. During this stage, students tend to accumulate a large amount of information, but they may not be able to process it. The role of the facilitator consists of supporting the students through this process, helping them to discard irrelevant information.
Brainstorming	Students have to discuss how to solve the problem. In an engineering environment the problem is usually technical and requires a project. Brainstorming increases their participation and their creativity. Facilitators support the students during this stage dynamizing the group and observing their discussions to correct any deviations from their learning objectives. Initially students will present naive ideas, or projects that are too complex, so the facilitator has to give feedback to encourage better focus.
Research and development	During this step, students perform their research to reach their learning objectives and, simultaneously, start to develop their project. To increase their motivation they have to feel that the process is theirs; in order to interiorize their responsibilities they should auto-impose their own tasks. On the other hand, teamwork is an important strategy, but groups of students tend to work individually and not to share information within the group. Facilitators must promote leadership, and give the students organisational and proper teamwork strategies.
Final synthesis and checking	Before sending the final report students have to check the project. Teamwork is also relevant during this step given that the students must share their responsibility. They have to establish whether the project answers the question, or has any gaps that still need to be covered. Students also have to synthesize what they have learnt. Facilitators help the students in the more formal aspects, and also to identify any potential gaps and establish whether the learning objectives have been reached.

7 Analysis methodology

The five components of the MUSIC model were analysed using an open-ended questionnaire at the end of the experience. This questionnaire consists of 21 questions, many of them inspired by the questionnaire developed by Jones, Epler, Mokri, Bryant, & Paretti (2013). The questions were discussed and adapted to our experiences to answer our research questions: *Do students feel that they control their learning process? Does PBL increase the interest of the students? Do students perceive the usefulness of what they learnt? How do the students perceive the labour of their facilitator? What is the perceived workload of students? What are the issues of big-sized workgroups?*

To evaluate the impressions of the students the data was qualitatively analysed using an open coding approach. Two different researchers extracted an initial two-level hierarchy by reading the answers of the students several times. The coding was performed afterwards by successive scannings for increased detail and to dynamically alter the initial hierarchy when necessary. This process was independent for every question. Finally, the hierarchy-related iterations were quantified to map the opinions of the students for each question.

8 Results

A total of 153 students reached the end of the experience and answered the questionnaire after their exams. The values of the analysis do not represent a specific number of students, but quantify the iterations of each code. This enables us to establish tendencies, relations, or highlight any issues. For clarity, the first level of the hierarchy is marked in bold. In some cases the total number of the first-level code is not equal to the sum of the related second level codes. This is caused because not all answers give further explanations or details.

- ***1 Sense of control: Which aspects of the project have you been able to control?***

Part of the answers **(26)** quantified their feeling of control: 2 affirmed not to have any control, 5 controlled "just a few aspects", 3 controlled "some aspects", 5 controlled "nearly everything" and 14 affirmed to have controlled "everything". A larger number of answers **(53)** were related to the control of different parts of their project: components (31), calculations (13) and drawings (8). Another section of student answers **(26)** was related to their freedom to manage their team (15) and organise their own tasks (11).

A significant proportion of the answers **(50)** simply did not understand the question: they confused the term "control" with the idea of being able to understand or dominate the project.

- ***2 Freedom for taking decisions: Which decisions were your team able to take regarding its functioning?***

The answers to this question reveal that students felt free to take decisions linked to their own organisation **(36)**, and the assignment of individual tasks **(24)**. About one fifth of the answers **(32)** referred to the possibility of taking decisions related to technical aspects of their project; an analogous amount of answers **(35)** simply quantified their sense of freedom as "none" (2), "few" (5) and "many" (28).

- ***3 Results of the team decisions: What have the results of the decisions taken by your team been?***

The biggest proportion of the answers **(105)** quantified the answer. Most of them referred to "satisfaction" with their decisions (67), or felt them as "acceptable" (10). A smaller amount answered "some decisions were good and others not" (20). Only 8 answers quantified all their decisions as "wrong". Other answers **(15)** revealed that taking their own decisions derived into self-improvement, the delivering of a good project, and an improvement in their learning process.

- ***4 Decisions taken by the facilitator: What decisions did the facilitator take?***

Regarding this question, a significant number of the answers **(51)** revealed that the facilitator took decisions related to the technical aspects of the project. A similar amount **(64)** answered that the decisions taken by the facilitator were more related to guiding tasks (53) and organisational aspects (11). The rest of the answers **(17)** quantified the amount of the decisions taken by the facilitator: 11 said that the facilitator "did not take any decision", and 6 quantified them as "few".

- ***5 Need of more control: Would you prefer the facilitator had more control?***

About one half of the answers **(73)** correspond to students that do not want more control from their facilitator. Just some of them (3) clarify that not having such control "permits gaining more autonomy".

Roughly the other half **(66)** would prefer to be more controlled, but a representative part of these answers (15) specify that "only at the beginning", and a similar part (12) revealed that they "needed more information". One of the answers manifested "disorientation".

- ***6 Knowledge and skills usability: How will what you have learnt be useful during your studies and your professional life?***

The biggest proportion of the students' answers **(58)** finds their knowledge and skills to be relevant for their professional life. In decreasing interest, they found the following aspects relevant: teamwork **(25)**, easier knowledge acquisition **(22)**, easier understanding of technical aspects **(21)**, easing of their learning process **(20)**, and making it easier to face future problems **(17)**. Other less mentioned aspects were related to their own personal growth **(7)**, individual work **(6)**, communication **(3)**, and resources managment **(2)**.

- ***7 Feeling of being competent, overwhelmed or bored: Which aspects made you feel competent, overwhelmed or bored?***

The analysis of this question reveals that students felt competent **(94)** especially when they were able to understand concepts by themselves (32), reached their goals (31), and were able to make valid contributions (16). On the other hand, they felt overwhelmed **(76)** mainly by difficulties in understanding concepts (18), the complexity of the project (15), and the absence of previous knowledge (14). They also felt overwhelmed by initial disorientation (8), not being able to reach their objectives (7), the face-to-face presentation (4), and an overload of work (4). A minor proportion of the students felt bored **(15)**. This affirmation was caused principally because of repetitive work (7), the lack of productivity in their team (4), or the inefficient sharing of tasks (2).

- ***8 Received help from the facilitator: What help did you receive from your facilitator?***

Most of the answers describe the perception of receiving support in the form of orientation to solve the problem **(65)**, and knowledge **(49)**. Other aspects perceived by the students were group dynamics **(7)**, and the "human aspect" **(2)**. A smaller group **(26)** quantified their perception of the help received from their facilitator as: "none" (5), "poor" (2), "just the necessary" (2), "much" (4) and "a lot" (13).

- ***9 Received help from the group: What help did you receive from your team?***

The students affirm that they received help from their team in the form of knowledge **(54)**, teamwork **(33)** and also companionship **(18)**. One of the students stated "feeling protected" by his team. Part of the answers **(47)** quantified their perception of the help received as "much" (27), "enough" (3), "poor" (8), "none" (8), and one of them manifested explicitly repulsion against teamwork.

- ***10 Team learning: Do you think you have learnt more due to working as a team?***

Students felt that teamwork has a positive impact in their learning. The biggest proportion of their answers **(109)** is aligned with this idea. They think that most of it is caused by the effects of collaborative learning (67), but also because they have been able to organise their own work (21), and also by being able to discuss ideas or concepts (10). Some of the students (7) think that teamwork has a positive effect on individual work. Students that felt a negative impact **(16)** said that it was caused by the size of the groups (4), too much specialisation of their team members (4), and the irresponsibility (2) and individuality (2) of some students.

- ***11 Initial interest: Describe your initial interest.***

A significant proportion of the students' answers **(74)** affirmed them to be previously interested in the subject. A smaller proportion **(38)** were not interested previously. Some of the students **(3)** stated a passing intereste in the subject. Part of their answers **(89)** quantified their initial interest as "none" (15), "poor" (17), "medium" (10), "much" (31), " very much" (13), and "the same as other subjects" (3).

- ***12 Final interest: Describe your final interest.***

Nearly half of the students' answers **(73)** manifested an increased interest. They recognised a positive effect caused mostly by feeling competent (21), relevance to the real world (16), the novelty of this way of learning (8), or because they had reached their objectives (5). A more reduced number of answers **(26)** stated feeling the same level of interest than at the beginning, mostly because it was still high (11) and they still wanted to learn (2); others because they felt disappointed (2), just wanted to pass the subject (2), or simply were not interested at all (1). The rest of the answers **(16)** recognised a reduction in interest, most of it because of conflicts within their own team (5), excessive workload (4), a sense of disorganisation (3), not feeling competent (2), or just because of a preference for the traditional learning method (2).

- ***13 Teamwork effects over interest: Do you think that teamwork boosted your interest? Why?***

The analysis of the answers to this question shows that many students **(101)** perceived an increase in interest caused by: receiving help from others (21), being able to assume their own responsibilities (8), collaborating and contributing to their team (7), feeling entertained while learning (5), being able to discuss ideas (4) and reaching objectives (4), learning by themselves (4), and even making new friends (4). Other factors that may contribute to an increase in their interest are the sharing of difficulties (3), the ability to do new things (3), feeling the enthusiasm of other team members (2), or feeling important within their team (2). However, a significant number of answers **(37)** show a reduction in interest, especially motivated by conflicts (6), irresponsible team members (5), too many team members (4), indifference and individualism (3), too much workload (1), inexistence of companionship (1), or feeling ignored by other team members (1).

- ***14 Learning value over future learning: How will what you have learnt affect to your interest in other topics related to your project? Why?***

Nearly all respondents **(147)** think that what they have learnt has increased their interest in future topics, caused principally by the acquired knowledge (36). Part of their answers relates to an increase in their curiosity (32), some recognise a "practical orientation" (11) and others manifest an increased interest caused by the acquired skill (10). Other causes are related to their feeling of competence (5), professional interests (5), transversal knowledge (4) and improved critical thinking (2). Only a small number of the answers **(6)** do not describe an increase in interest, but of these, most of them (5) manifest a lack of previous interest or even amotivation.

- ***15 Interest in the problem: Did you feel interested? What made the problem interesting or made you feel indifferent?***

Practically all the answers **(141)** describe a feeling of interest in the problem for different causes: it was close the real world (31), eased their learning (12), it was a challenge (12), it was something new (11), it was orientated towards teamwork (11), it represented something different and new (11), the solving process was attractive (10), it was something complex (9), and it was a goal to reach (6). Other causes stated by the students included transversal learning (4), certain level of stress (3), the research process (3), the assessment method (2) or the contact with experts (1). Only some answers revealed a lack of interest in the problem **(10)** motivated by the difficulty of the problem-solving process (5), boring (2), inexperience (1) or simply because the individual wished to abandon their studies (1).

- ***16 Teamwork organisation: Please describe your group's dynamics. How did you interact with your partners?***

The answers of the students were categorised in organisational aspects, social aspects and negative aspects. Regarding organisational aspects, students described the use of mobile devices and the Internet **(44)** and face-to-face meetings **(41)** as key organisational factors. Other relevant organisational aspects were the sharing of opinions and ideas **(19)**, "good organisation" **(15)**, companionship **(8)**, a hierarchical organisation **(6)**, the subdivision of groups and specialization **(2)**, discussions **(2)** and polls **(1)**.

Regarding social aspects, students recognise the importance of respect **(6)**, mutual help **(5)**, compromise **(3)**, a calm attitude **(2)** and leadership **(1)**. As negative aspects, students highlighted "ups and downs" in their organisation **(6)**, the neglect **(6)** and indifference **(3)** of some team members, the shyness of some students **(2)**, some disorganisation **(2)**, the lack of recognition by some team members **(2)**, obligations between team members **(1)**, irregularities **(1)**, discrepancies **(1)** or even the rejection to teamwork **(1)**.

- ***17 Suggested changes in your team's organisation: What would you change about your group's performance?***

A big proportion of the students would not change anything **(39)**. In decreasing relevancy, other students would change aspects to improve their organisation **(23)**, and would impose sanctions on non-compliant students **(16)**. Other proposed changes are relative to improving implication **(9)**, the scheduling of the meetings to reduce conflicts with other subjects **(9)**, reducing team-size **(8)**, improving leadership **(6)**, limiting individualism **(2)**, improving the responsibility of some team members **(13)**, increasing dialog **(4)**, and imposing more control mechanisms **(4)**.

- ***18 Use of the Internet: How did social networks, mobile devices and the Internet influence your group's dynamics?***

In their opinion, ITs and mobile devices offer many advantages **(160):** they boosts communication (53), improve organisation (21), permit the sharing of information and ideas (21), avoid unnecessary travel (17), ease the search of information (9), improve productivity (8), and help support the integration of team members (3). On the other hand, the students perceived some drawbacks **(9)**: merely using these technologies does not increase levels of interest (3), "worked worse than expected" (3), can cause conflicts if not used properly (2). In the opinion of one of the students, ITs are less effective than face-to-face communication.

- ***19 Perceived caring from the facilitator: Did your facilitator show concern for your group?***

The majority of the students' opinions **(110)** showed that their facilitator was concerned for them. Most of their answers linked this feeling with actions like guiding (17), reorienting (13), pushing (13), correcting (11), observing (11), or clarifying (10). Other comments mentioned ideas like supporting (5), questioning (5), informing (3), advising (3), limiting (3), motivating (3), warning (2), giving options (1), interesting (1), intervening (1), criticizing (1), giving ideas (1), or even striving (1). However, some of their answers **(16)** stated they were disappointed because they felt that their facilitator did not help them with their problem much (5), he or she was not interested in their troubles (2), showed a lack of knowledge (1), did not strive (2), required the team to resolve their own problems with "non-compliant team members" (1), had too much work-load (1), was not concerned (1), assumed a high knowledge level at the beginning (1), ignored their difficulties (1), was only concerned about formal aspects (1), and seemed chaotic (1).

A total of **119** of their answers also quantified their answer: 110 manifested that their facilitator was concerned about them, (6) "just a bit", and only 3 affirmed that their facilitator showed no concern.

- ***20 Suggested changes in the facilitator's role: What would you change in the role of your facilitator?***

An important proportion of the answers **(58)** explicitly affirm that they would not change anything. Other students would like more help **(11)** especially at the beginning **(7)**, more control **(9)**, more concise answers **(9)**, more information **(6)**, more feedback **(4)**, more meetings **(4)** and more concern **(2)**. Other ideas appeared only once in their answers: "less questions", "specialised courses", "being more enjoyable", "courses about teamwork", "less criticism", or "more contributions".

- ***21 Workload: Do you think that workload has been too high?***

Most of the answers **(91)** were linked with the idea of it being very time-consuming, but 14 of them thought that it was worth it. Interference with other subjects was also an issue **(14)**. A few stated that poor organisation caused a high workload **(3)** and complained about their lack of previous knowledge **(3)**; others associated high workloads with the idea of complexity **(6)**, the challenges presented by the learning method **(2)**, conflicts within the group **(1)**, or because the group being oversized **(1)**.

9 Conclusions

Students perceived the concern of their facilitators, but the role of "tutoring the process" initially caused some confusion and frustration among the students. This confusion and frustration was the result of certain preconceived expectations about receiving classes, whereas they were being asked to be responsible for researching, discussing and driving their own learning process.

However, the PBL process empowered the students and increased their interest which was seen in the fact that they were satisfied with their decisions, even though in some cases they may have been wrong. Although the facilitators guided the students through technical and organisational aspects, students did not perceive this as excessive external control. On the contrary, they would have prefered more control and support at the beginning of the process.

PBL created a positive impact on students and changed their perceptions, despite the complexity of its nature and perceptions of a high workload. Due to its relevance beyond the classroom in real life, and as a result of linking directly to their sense of competence, PBL boosted student motivation and interest. Interest levels were show to increase as a result of the following factors: the mutual help they received; the sum of emotions experienced when they felt integrated in their team; the shared burden of responsibilities and problems; and enthusiasm. With regards to competence, the more successful they were in reaching their objectives, and the greater the sense of their ability to contribute, the greater their feeling of competence.

It has been identified that those students who do not perceive themselves as competent have principally felt this way as the result of having a weak background. It seems that this fact has not affected their interest, but it appears to be the motivating factor behind the request for more support at the beginning of the PBL experience. Students that reported a decrease in their interest do not associate this effect directly to PBL, but rather to the conflicts caused principally by irresponsibility, being ignored, indifference or individualism.

Students valued teamwork because it eases the acquisition of knowledge and helps them to understand the technical aspects. They also valued what they learnt with regards to their curiosity, the practical aspect and the skills acquired. However, transversality and critical thinking are not still recognised by students after just one PBL experience.

In spite of the size of the groups, the organisation of their work has been possible thanks to the specialisation and the use of ITs. Big groups are not the best solution as large group sizes may cause conflicts and a lack of interest as the result of freeriders. If reducing the size of workgroups is not possible, leadership becomes a crucial factor in their success, although in the students' perception it should be more socially focused than just organisationally driven. The training of team leaders seems to be a key factor in improving PBL when working with oversized groups of students.

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“Are they ready?” – The technical high school as a preparation for engineering studies

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Abstract

Are they ready? - the technical high school as preparation for engineering education
In a Danish context admission to engineering school requires an exam from a high school. The question addressed here is, do the high schools equip the students with competences necessary for an engineering education? In Denmark there are several ways of acquiring the admission exam – The names of the different exams are stx, hhx, htx, hf and admission course (a special one-year course for people with other qualifications). In this paper the The Higher Technical Examination (htx) is examined, as it is targeting directly at further education in the fields of the natural sciences, healthcare and engineering. The question addressed here is whether the future students can acquire the study competences necessary for studying engineering, through the three-year program that is HTX. This question will be dealt with in the following way. First I will give a short sketch of the concept study competences. Secondly I will show some empirical results from a study of the activities at the HTX, especially the PBL projects that are at the centre of the education. Thirdly I will describe some first-year student projects from the Aalborg University engineering education and compare them to the activities of the HTX. Finally it is concluded that the activities of the HTX really do provide the students with the competences necessary for studying engineering in a PBL environment.

Keywords: curriculum design, evaluating active learning, new active learning strategies, PBL and learning theory, PBL implementation, PBL model and approaches, PBL process and student engagement, research in active learning method, teacher role in PBL.

1 Introduction – the technical high school _ HTX

Admission to Danish universities is for students having graduated from one of the high school educations (general upper secondary school) or from similar educational institutions. The majority of Danish university students have a background in the ordinary high school called STX. This high school offers a broad general education in classical fields such as modern languages, math, physics, etc. In 2013 app. 27,000 students were enrolled in the STX. In addition to the STX the Danish educational system also includes the business high school, HHX, the technical high school HTX.

The purpose of this paper is to investigate the technical high school and analyse the content of the HTX and this education’s ability to equip the student with the study competences necessary. That is, will the HTX prepare the students for a future as e.g. engineering students?

The purpose of all high school education in Denmark is to equip the students with study competences and with a general formation of character (Bildung) (the ministerial order §1). In this portrait study competences will be described as students 'knowledge of the tradition’, that is, knowledge of the discipline, theories and methods, the students' formation (Bildung), i.e. the students change through the meeting with the school's challenges and the students’ 'ability to produce new knowledge’, that is, the students' ability to apply theories and methods in practice. This means that the requirement for study skills or study competences require both the Bildung and the ability to solve problems using theories and methods learned at the school. In the process that equips the students with the necessary study competences, different forms of knowledge are included. They can be summarized as episteme, techne and phronesis, or, roughly translated to the theoretical, practical and social knowledge, all of which are necessary for students' study competences (Gallagher, 1992; Henriksen, 2013, pp. 49).

The following sections examines whether it is the case in HTX program. With a special emphasis on what is known as ‘profile subjects’. Profile subjects are subjects offered only by this specific program. In the case of HTX the profile subjects are ‘technology’ and ‘technical science’. In addition to the profile subjects the ‘study area’ (called SO) and the ‘study direction project’ (called SRP) are described. The study area is an interdisciplinary collaboration between the subjects and is here described separately, partly because of the profile subjects are included in the study area activities, partly because the study area in its foundation is interdisciplinary and problem-oriented and therefore central to the development of students' study competences.

The empirical basis for this paper is partly ministerial orders and guidelines, curricula and other written material related to the study program, and interviews with teachers and students, teaching observation and observation of exams, and the students' written work. The study does not include all schools and all students and not even a representative sample of schools and can therefore only provide a glimpse of what is possible. The question is therefore not whether all students in all schools achieve the required study competences, but whether it is possible, within the current framework, to implement an education that allows the students to achieve the required study competences. This means that this study's purpose is to investigate whether it is possible to achieve the required study skills - not that all students, in all cases achieve them. The study program provides opportunities, but other issues can get in the way of the desired results. Such is not included in this study - only a look at what is possible.

2 The HTX program – Background

The technical high school was inaugurated in 1982, first as an experiment, later, from 1995, as a permanent education at the same level as the ordinary high school. The education started out as a supplement to the technical colleges' apprenticeship programs and the idea was to have a high school education especially aiming at science and engineering and a new type of high school combining theory and practice in a new way. The study program was very much influenced by the PBL principles of the new universities – Aalborg and Roskilde - and therefore interdisciplinarity and project work was part of the curriculum right from the beginning.

3 The HTX – Content

In the ministerial order for the HTX program, the objectives are stated as:

> § 1. The program for higher technical examination is a three-year secondary education, which is targeted at young people interested in knowledge, depth, perspective and abstraction. The program represents a whole and is concluded with an examination after the national standard.

If we look at the ministerial order in the light of the study competences described above – tradition, Bildung and the ability to produce new knowledge, it is clear the ministerial order is asking for exactly that. The preamble describes the purpose of obtaining the 'study competences' that is 'to prepare students for higher education' (§ 1.2) the purpose of education is clear, then, they need to prepare students to further education at universities or engineering schools. This will be achieved by introducing students to the tradition: 'Knowledge' and 'breadth and depth' (§1.2), develop professional insight (§1.3) and 'professional and educational progression' (§1.3).

The education should 'form' the students (Bildung): 'general education' (§ 1.2) 'professional and educational progression' (§1.3) 'The program must have an educational perspective with emphasis on students' development of personal authority' (§1.4). The education and school culture as a whole should prepare students for active participation, joint responsibility, rights and duties in a society with freedom and democracy (§1.5).

Finally, the programs should enable the students to produce new knowledge: 'Competencies' (§ 1 paragraph. 2). They should become familiar with the use of various forms of work and have the ability to function in a study environment, where the demands are independence, cooperation and to seek knowledge and the training should also develop the students' creative and innovative skills and critical thinking (§1 section 4).

In all the ministerial order is fully consistent with the description of the study competences above - tradition, Bildung and production of new knowledge. This is supported further by the order's descriptions of the program's scope and duration (Chapter 2) and the structure and content (Chapter 3) and especially in the description of the ‘study areas’ identity and purpose (see below).

Therefore the ministerial order fully supports the idea of developing study competences as described above. Of course, one could say, it was basically the whole purpose of any high school education, but the ministerial order is quite explicitly mentioning knowledge of the tradition, Bildung and the ability to produce new knowledge as the purpose of the education.

In the following I will examine the subjects 'technology' and 'technical science' as these subjects are the so-called profile subjects, which mark the difference to other secondary educational programs. I also examine the ‘study area’ (SO) and ‘study project’ (SRP), as these activities are specially targeted at the formation of study competences.

HTX has a basic course and a study direction. The basic course has a duration of six months and is common to all students – first half of first year. The basic program consists of compulsory courses and the study area.

The compulsory courses includes Danish A, English B, Mathematics B, Physics B, Chemistry B, technology B, communications and IT C, civics C and biology C. A is a three year course, B a two year course and C a one year course.

After the basic course, the students choose one of the offered ‘study directions’. Study directions are combinations of subjects and runs over the program's remaining two and a half years. The ministerial order states that:

'Study directions consist of compulsory subjects, and continued teaching in the study area, subjects, electives and a study direction project' (§13).

Each study direction must include three electives and in practice this means that the school offers different packages that ensure interaction between electives (§14). Individual schools offer their own core modules and use these to profile specific interests and efforts.

For HTX the examples could be core modules in biotechnology, chemistry of nature, the world of physics, and so on. An example of one such module could be the world of physics (Aalborg HTX). The package includes profile subjects (Physics A, Mathematics A, History of Ideas B) compulsory subjects (Technology B, Danish A, English B, Chemistry B, Communication/It C, Civics C, Biology C) Technical science A, where there is a choice between three directions; design and manufacturing, construction and energy, and finally, process, food and health. In addition, an elective in this package can be selected, for example Innovation C, German C and B, Information technology B, Psychology C.

There are a number of constraints on the composition of the core modules, precisely to ensure coherence between the subjects and the possibility of interdisciplinary projects.

4 The Profile Subjects HTX: Technology and Technical Science

HTX's profile subjects are technology and technical science. The education's profile subjects are the subjects that distinguish this education from other upper secondary education, that is, the courses are only offered at the HTX or offered only marginally on other secondary education – e.g. technology in the ordinary high school.

4.1 Technology

The subject 'technology' is concerned with the relationship between technology and society in the broadest sense. The subject's goal formulations are all characterized by a socio-technical concept of technology (Sad & Bamford, 1951; Müller et al, 1984; Larsen et al, 2014, p 6), i.e. technology described as composed of knowledge, organization, technology and product. The subject thus takes its starting point in social issues and analyses technology development, community development and the interplay between technology, knowledge, organization and product. In the analyses, social science, technical and scientific knowledge are combined with practical work in workshops. The course is in its outset interdisciplinary and problem-oriented.

The project also aims to provide students with technological Bildung, e.g. they acquire an understanding of the interplay between technology and society.

In addition to these general objectives the course in technology should provide the students with understanding the relationship between science, technology and society; a critical approach to technological development and social conditions; knowledge and understanding of technology as a solution to problems; knowledge and understanding of technology, which creates problems; knowledge and understanding of the need to involve actors and stakeholders in technology development; experience working with the connection between scientific theory and practical training in workshops and laboratories; knowledge of and experience with the choice of production processes; knowledge of various technologies used in business; knowledge of the development of ideas and innovative and creative processes important in the development of products.

Finally, it is an objective that the students get experience with problem-based learning (PBL) in larger projects, including independent work, both individually and in cooperation with others, as well as study and work methods that are relevant in higher education.

The technology course contains a number of specific topics, including materials and machining processes, technology and environmental assessment, product development, production and marketing. The course also aims at developing the students' understanding of project work and their skills in documentation and presentation. However, with the difference that Technology A also includes the company perspective and the manufacturing process, i.e. that of 3 years with subjects like quality and environmental management, strategy, marketing, logistics, costing etc.

In al, it is clear that the objectives of the subject ‘technology’ are to achieve study competences, and this is an integral part of the course objectives. Technological literacy is explicitly mentioned and the students' own ability to create new knowledge through independent projects is also a central element in this. However, the subject technology’s own tradition pose a particular challenge. Technology is a relatively new subject, only about 20 years old in a high school context and has not, in the same way as other upper secondary school subjects, many years of experience to build upon. The tradition must first be established and the content of the technology subject is so broad that it is open to many interpretations. The ministerial order and its supplements are all based on a socio-technical approach, a socio-technical technology concept, which in itself can be very sensible, because it is useful and manageable in a secondary school context, but in principle, other approaches could be selected. Therefore, it may also be difficult to talk about 'tradition' in the subject technology, since it is open to interpretation to a degree that does not exist in exactly the same way in other upper secondary school subjects and programs. Yet, it seems that it has been possible for teachers in the subject technology to establish a tradition for the subject, based on project and problem orientation and in the above-mentioned socio-technical approach.

A typical course in technology includes both classroom teaching, workshop courses, group work, all organised in a number of projects whereby various topics are processed.

A course might look like this:

First year, basic course, the themes are project processes (how to work in projects), technology history, design of playground equipment (a practical design task), workshop courses and working environment. The subject work is made in collaborates with the subject Danish, Civics and Chemistry and the course is part of the study area (see below). In the study direction, still 1 year, the topics are project processes, workshop courses, as well as ‘climate and environment’ carried out in collaboration with the subject English and included in the study area. In the last project processes is the topic ‘a bike light’, this topic is carried out in collaboration with physics and is also part of the study area.

Study programs continue in the second year, and here the topics are project processes, systematic product development, participation in science cup (Young Enterprise Competition), technology assessment carried out in collaboration with Danish and English and included in the study area. Fourth course is ‘science and technology’ in collaboration with chemistry, physics and mathematics, the course is part of the study area. Fifth course is called ‘technological development’ and carried out in cooperation with the history of ideas and is also part of the study area. Finally the second year is completed with an exam. Those students who have technology level B complete the course at the end of the second year.

Technology in its third year is for students who have chosen technology at A level. The difference to the B level is that students at A level also includes manufacturing processes and business in the analyses of technology. A typical third-year project course could look like this: Integrated product optimisation of waste of resources, re-design of existing products carried out in collaboration with design and the technical science subject, urban design, again in collaboration with technical science and Design, Danish and an external company. The process included in the study area and is part of a competition. ‘From idea to business’ in collaboration with the subjects design, chemistry, technical science, mathematics, included in the study area. Integrated product development phase 4. ‘Design 3rd world’ in collaboration with the subject design. ‘Concept Design’, continuation of the design for the 3rd world. Business Building, in collaboration with an external company. CreaCamp in collaboration with an external company. ‘Product development and manufacturing’ as the last part of the student's One Year Project. At the end of the year the students will complete a program where they gather work don in the third year in an examination report.

For each of the mentioned projects the teachers describes learning objectives, work methods, content and scope.

As shown in the plans, the teaching of the technology subject is most often organised as projects. The education therefore also has an emphasis on projects as the guiding principle and projects, group work, individual project work and teacher-led classroom training forms the basis of the activities in the subject ‘technology’. This means that project work largely allows students to actively shape the content of the courses and even make suggestions for how projects should be approached.

The students are very positive about the subject technology and consider their own ability to shape the projects as an advantage, as they, as several of the students expressed, found that there was great freedom to 'do things' and even to control the process themselves. Several students said that they saw this freedom as a major reason for choosing the HTX. They had heard about the projects from friends or had heard about it from visits to HTX while still in primary school.

The lectures I have observed in the subject technology can best be described as an organised creative chaos. The students sat in groups discussing loudly with each other, they visited other groups to ask for their solutions or they sat very concentrated and wrote or calculated on their PCs. Everything seemed very focused on the projects itself. Even when two students came back from a passed theory test for their drivers licence, there was only congratulations and high-five for about 5 minutes, after which the group work resumed. The teachers were highly engaged in discussing projects and guide students when they had specific questions for their work.

Example 1: Conversation between a girl and her teacher. The group was engaged in a design task where they have to develop a product in relation to some external requirements.

Girl: 'Why should we look at the requirements again – we have already looked at the requirements under the point x?

Teacher: You should compare your product with the requirements – does your product meet the requirements?

Girl: Well, I do not understand, we have been working on the requirements and we have not made our finished product yet. How can we see if we meet the requirements when we are not finished (with the product)?

Teacher: Well, you can go back and look at the requirements and use them while you are designing your product.

Girl: Oh, yes, of course, that's what we do, we can of course use the requirements, so we are sure that it is in line with the requirements.

Example 2: Four boys are working on a project on the filtering of rapeseed oil. They want to make an installation that a car owner, whose car runs on rapeseed oil, can have in his garage. They have made a sketch of a filtration plant, but are not happy because they think their plant is too tall to fit in a garage. They discuss, whether there is something they can do. 'Think out of the box' says the teacher. One of the boys asks whether the existing filters can fit into a PVC pipe. The teacher picks two filters that the boys can investigate. Another boy asks if the filter can lie down, so they could make the system fit into the garage. They continue the discussion and try to make sketches on paper with a pencil.

Example 3. Two girls and two boys are working on a project on disability aids. They have made an experimental setup with an actuator. Unfortunately the actuator does not work and they turn to the teacher with the problem. The teacher picks a new actuator in the workshop and students can continue to study the actuator.

Generally, the students are very satisfied with the technology subject is organised. 'The best thing is the way we work, the projects, it is all very relevant what we learn'. 'The practical part is good too - you can touch the things and many company visits, it has all been applicable what we have made'. 'This is not what is normally understood as a school such as writing essays - we got that freedom. Much of what we do, we can see the purpose of, rather than that we just have to fill in some student hours'.

The students also mentioned the group work. 'For me it (the best thing) is group work – one hundred (per cent). We meet outside the school and on weekends, now in technology. We work well together socially, and then we sometimes do something else, it is sometimes some long days, but it will also be some pleasant days ... than if you just sit and nerd it all day'. 'There are many things we must do alone - but we have helped each other - we are good at working together'.

'If someone does not do something then they get a earful'. 'So they get a kick in the behind!'. 'The teachers were good at, in the first year, you have to work with many different (class mates) and those who are not doing anything is automatically excluded, they know it very well. Those who want to make something go along, those who make 'in between' go together so ... it happens quite naturally '. 'In the large project (Third year technology project), we work together with those class mates we prefer to work with'. 'You learn something by being together ... so at different levels, some are good at writing, some are good in the workshop ... learning from each other, we pull each other up by being different'.

Much of the work in the technology course is focused on students' projects. In the third year, Technology A, the students carry out a major project where they, in groups or individually, work on a chosen project. In the project, students work with a technological problem, analyse the problem and construct a solution, a product and at the same time relate their solution to the technology's societal importance. The work is documented partly in a report, partly as a tangible product. The project work is the basis for that year's exam in the subject. Exams can be individual or in groups with individual assessment.

Examples of projects:

Example 1. Two girls and a boy works with a project where they will find solutions to the problem that many cyclists are injured, or even killed, in right turn accidents. Through an analysis of the number of accidents they conclude that a problem still exists, despite the fact that there has been a reduction of the number in recent years. The solution will be to develop a sensor that can be placed on the bike and a receiver that the truck driver has in his cab. In the preparation of the project, the group has worked with a local Carlsberg depot, where the group has interviewed the drivers about the problem and their proposed solution. The report itself is structured as a business plan for a company that manufactures and sells sensors to avert right turn accidents. The report includes the following: problem analysis, line of business, business structure, market description, business strategy, mission, vision and goals, technology analysis of another product, production, product development and manufacturing and engineering drawings for the product. In addition to the report, the students made a sensor and a receiver and made a model showing that the product actually works.

The report is well composed and shows that students are able to handle project work and enable them to use the methods and techniques they have met in technology course. At the same time they have contacted actors outside school in order to solve their problem and thereby demonstrate a degree of maturity. In all the project shows, from idea to implementation, that the students have been able to handle project work by themselves and they are able to plan, implement and document their work.

Example 2. Four boys have discovered that they have difficulties getting down to work with the technology project. They are therefore interested in work and working conditions and therefore they initiated a project on work organisation and motivation. The project report is structured as a description of the company 'Communication Matters', i.e. the boys have been working on a specific issue - organisation of work - and made their solutions into a business concept. The report has the following content; problem and a problem statement, generating ideas, method, theories of work, business description, including vision, mission, goals and actions and technology analysis of the planning tool the boys had developed.

The project is very interesting, as it shows a very high professional level, both in choice of subject, analyses, use of theories and methods, and finally in the chosen solution. Furthermore, the report is very well composed and very well written in a good and mature Danish language. But the boys have had to produce a physical product that actually had not been necessary. Technology project requires the preparation of a physical product (Ministerial Order, Section 28 paragraph. 4.2). But in this case the students worked with a process and it had been smarter to make the physical product as a piece of computer software. Therefore the description of the physical product also seems somewhat overdone, something that just has to fit into the requirements and not something that is made to make the project better. Working with the improvement of work processes is a classic engineering discipline and should provide the basis for a technology project, without it had been necessary to produce a physical product - software had been more appropriate here. Work processes, and issues related to it, is a central discipline in engineering and the students had therefore already begun to look into that in their technology project.

In the spring of 2014 representatives of four HTX schools and the consultant from the ministry gathered for a meeting in the city of Slagelse. Common to the four schools was that their students scored significantly higher grades in the subject technology than the national average of HTX schools. The purpose of the meeting was to discuss what is special about these schools, if they are doing something different in the subject technology. The results of the discussions can be summarized as follows:

The management of the schools take the subject seriously as a profile subject and has placed it on an equal footing with other subjects. The course is led by a group of teachers who collaborate on the subject. When making schedules the subject is taken into account, so it can be placed in the study area and it can cooperate with other subjects.

The cooperation among the teachers is important and it is important that different disciplines are represented in the teaching staff and the various disciplines are utilized and can complement each other.

It is important that teaching is based on ambitious goals, ensuring progression in the core substance and goals of the projects. Participation in competitions and business collaboration is very motivating and gives the students something tangible to aim at. School facilities must allow for workshop instruction, and there must be room for group work.

As a special or very concrete thing all schools said that they work very consciously with the students' written work in connection to report writing.

The subject technology contributes significantly to the students’ development of study competences and can help to prepare them for their future conduct in the education system - especially for those students who later choose natural sciences, health sciences or engineering studies. The subject aims especially at developing awareness of methods that develop students' understanding of and ability to work in a project- and problem-oriented education system. Compared to study competences, understood as tradition, Bildung and knowledge production, it is the emphasis on production of knowledge that comes into focus. Technology is as relative new discipline and as a tradition, it is still under development and not yet rooted in the same way as other subjects in upper secondary school.

In order to achieve the subject's objectives, and for the students to develop the required study competences, it is vital that the school management and the school's teaching team work together to organise and implement the teaching necessary. This requires ambition, serious planning, management’s support and teaching staff's cooperation.

4.2 Technical science

The technical science subject is a compulsory subject at A level. Students have to choose between three courses:

Design and production, which is about the technologies used in the manufacture and development of products, including design and materials.

Construction and energy, which is about planning processes in construction from concept to finished design. The themes are therefore planning, production and development of structures, that is, knowledge of construction, installations and materials.

Process, food and health, is about health, disease and the environment. The themes are physiology, genetics, disease and environmental sciences.

Technical science contains a number of mandatory key themes and additionally two themes of the student’s own choice. Each school determines how to distribute the different subjects. The course provides a final grade for the year and there is a mandatory project exam defended at an oral exam.

The ministerial order describes the subject as follows:

"The course deals with the development and manufacture of products and related issues. The course consists of the relationship between technology, knowledge, organisation and product, with a focus on technical and scientific knowledge integrated into product development and manufacturing process and combined with practical work in workshops and laboratories. "

The ministerial order's description of the subject's identity and purpose is virtually identical to the technology subject. Again we see the socio-technical base - technology, knowledge, organisation and product. But in the technical science course, in the description of the subject, there is a much greater emphasis on practical work in workshops or as formulated in the notice: 'The course helps to make the HTX program realistic, contemporary and relevant' and 'The subject contains process and manufacturing of product at a level reflecting commercial professionalism within the chosen subject area '.

Teaching is like in the technology subject geared to projects and problem orientation, but again with an emphasis on practical work in the workshops.

One example. A group of students and their teacher have contacted a company on cooperation on a project. The company has a problem with their packaging line. There are too many single operations and they would like the packaging of their products to be simplified and therefore more effective. Through analyses and design suggestions the students find out that four operations can be reduced to two and the company can save time and money.

The project looks very much like the projects students at engineering studies are doing in the first year at the engineering school. Therefore the course is entirely up to the task of developing study competences.

When asked directly, the students are expressing enthusiasm for the subject, technical science. 'That's where we can do something' with regard to the practical work in the workshop. 'That's where we can do something … they do not have anywhere else', with reference to the difference between the various secondary schools. Students thus see the possibility of working in the workshop as technical science's main contribution, as it differentiates their education from other secondary schools.

This does not mean that technical science is without its problems in relation to the other subjects. First of all it seems that the subject is sort of left alone among the other subjects. According to the students as a bit of a practical 'rock' or playtime that does not really have anything to do with the other subjects, but is a place where one does something practical and can be active. The idea of a socio-technical base does not seem to have reached the students I spoke with. Thus, it also seems the technical science subject's cooperation with the other subjects, does not work exactly as described in the ministerial order. The students had a completely practical explanation for the lack of cooperation. Three students in a technology group that worked with their technology report, was asked why they had not included technical science in their work? The answer was simple. The three students had three different lines of courses in technical science and therefore they could not find a common topic. When I asked if they could choose to be with someone from the technical science class that had the same subjects in technical science, the answer was that it could not at all be possible – because they would not work with class mates from the technical science class, and therefore it was not possible to make an integration of the work of the subject technology and the subject technical science.

Whether this can be the whole explanation is doubtful. Teachers can come up with a somewhat different explanation. In the spring of 2014 a group of teachers, consisting of teachers in both technical science and technology, along with the consultant from the ministry in both subjects wrote a report that would come up with suggestions for how to achieve progression in student learning. This report included concept development, material selection, product requirements and evaluation forms (Kaltoft et al, 2014 p. 1). The Group considers that although the description of identity and purpose are very similar for the two disciplines (technical science and technology), there is to a high degree large difference between the subjects' description of the academic and professional content. So much so, that the difference in itself would provide problems when the two disciplines have to work together. That does not mean that it cannot be done (which plans for technical science also shows), but according to the report, it is necessary to develop the cooperation in a way that will better secure the progression in both subjects. E.g. by developing a set of uniform concepts for the two subjects, for example by developing a common 'engineering' concept, and ensure that it is clear that the technical science course builds on the technology course, with the difference that technology is based on social issues, while the technical science subject has a more narrow technical focus.

Perhaps it is here that the two subject's real difference is. They work with each their own 'engineering' concept? Where the subject technology, throughout, is true to its socio-technical base and are working on a technology concept in which social, organization and project management is an integral part of 'engineering', so it seems that technical science has chosen a very narrow product focus and thus left its socio-technical base. An example; from the goals of technical science class, design and production, it is clear that it is the product that is in the centre and society, organization and project management plays a minor role (Ministerial order, Annex 26, 2.1). That is, the engineering concepts behind the technology subject and the technical science subject are very different and this difference can be traced to a quite classical debate about the content of the engineering profession itself. The same conflict between technique and technology can be found in debates about the engineering profession and engineering training and content and status of both (see e.g. Henriksen, 2014).

Based on a study competence concept containing students 'understanding of the tradition, their formation (Bildung) and their own ability to produce new knowledge', it can be stated that the subjects technology and technical science play an important role in developing the students' study competences. The courses are particularly important for the development of the ability to implement major projects and to work together in groups. The courses are very popular with students and offer a great alternative for those students who prefer other forms of teaching than the traditional classroom and teacher centred teaching.

At the same time, there are potentials in cooperation between the subjects that are not fully utilized, partly due the fact that schedules are difficult to arrange in a manner securing the cooperation and partly because of uncertainty about the underlying ideas, like the concepts of technology and engineering. The working group's proposal for the development of a common engineering concept seems therefore to be very well chosen.

4.3 The profile subjects in the study area

In addition to the compulsory courses, the HTX program also includes a so-called 'study area'. The study area is collaboration between the subjects, the ministerial order states for HTX: 'The study area is a technical cooperation based on the technological and scientific fields of study and with the involvement of the humanities and social science disciplines. The study area deals with the interaction between theory and practical work, and included experiments and workshop work individually and in combination'.

And, 'The methodical element includes the subjects study techniques and work methods. The element of science and forms of knowledge includes knowledge production and scientific methods of subject areas as well as the thoughts and theories behind'.

It further reads: 'Furthermore, the aim is that students gain insight into the relationship between natural sciences and choice of production processes through working with theory and practical workshops and laboratories. Innovation and entrepreneurship are part of one or more themes with the aim to develop students' creative abilities and give them insight into entrepreneurship'.

Language and communication are part of the study area with the aim for students to develop their language and communication skills and experience, orally and in writing, in order to acquire knowledge and disseminate results, attitudes and values (HTX, Appendix 2).

The purpose of the study area is described very explicitly in the ministerial order. The purpose of the study area is to develop students' study competences. It is also formulated as the purpose is to make primary school students to high school students in the basic course and make high school students ready to begin a third level education. This is done through interdisciplinary project.

The ministerial order's instructions for HTX states that students must acquire knowledge and skills in the areas of learning, reading strategies, writing, planning, working (collective and individual), projects work, information retrieval, assessment methods, use of references, science and forms of knowledge (HTX, instructions).

The study area do not have separate lessons allocated, but the learning objectives are to be achieved within the compulsory subjects, so that what is learned in one subject, for example project work, is used in other subjects. The study area at HTX is also part of the compulsory subjects and here it is also supposed that what is learned in a course is used in other subjects. Example: In the study area, in the second year, the students are working with the following topics: learning theory and learning processes, work methods, including project work, information retrieval, scientific methods, communication theory and evaluation theory. In practical terms, this takes place through a so-called SO-course (study area course)(Lund and Moller, 2009, pp. 103). Here the different subjects together in short courses where students work on projects that cut across the curriculum. The projects are most often finished with a written report that can then be included in the final sample folder. The sample folder collects all projects in a final report that is used at the final exam. The final exam consists of a 30-minute individual oral examination on the basis of the sample folder. The sample folder consists of selected works from the whole process and must meet the academic goals in the study area. The sample folders content is selected on the basis of guidelines formulated by the teaching staff. In addition, the sample folder includes a short description of the selected works, as well as a documentation of the student's academic and personal development. The oral examination consists of the student's presentation of the works, 15 minutes, and a conversation with the teacher and examiner, 10 minutes.

When students were asked about the SO, as they call the study area, they responded mostly with some surprise. 'What do you mean? – oh, well, SO, yes, it's OK', without really taking position either for or against. Just noticing that the SO exists and that it pretty much is good enough. This may be due to the fact that the study area does not have its own lessons, but are collaborations between the compulsory subjects. Therefore, the students might not even discover that they have the SO. Another student said, 'Oh, well, SO, well, that's fine, because that is where we learn to use what we have already learned'. It is evident from the written work included in my analysis that the objectives of project work and problem orientation are reached.

The study area has, quite explicitly, the aim to prepare high school students to become university student - the purpose is to develop study competences.

My conversations with students about the study area showed an overall positive attitude towards the study area, although some students had not noticed that they also had SO, as they called it. This means that the study area’s integration of the subjects is successful - to such an extent that the students do not even realise that they are engaged in the study area? Other students, however, was aware of the activities in the study area and when they say that 'the study area is where you learn to use what we have already learned', then it must be their way of saying that they have actually acquired some study competences, understood as the ability to independently to produce new knowledge.

5 Study Direction – and the SRP project

Study direction contains a major assignment called the study direction project. The study direction project is described in an annex to the ministerial order (Appendix 5). This section states the purpose of the study direction project in HTX:

'The purpose of the study direction project is that students work independently to explore and present an academic problem within a chosen area related to their field of study. By combining different disciplinary approaches and disciplines that enhances the academic work, students must demonstrate that they are able to independently select, integrate and use relevant background material, and that they are able to conduct a critical assessment of a professional and methodological basis. Through the work with the study direction project the students strengthen their study competences because they, through written presentation, must demonstrate that they are able to work on and present an academic and complex subject'. (The Order Annex 5)

As seen in the formulation of the purpose it is again independence, concentration, communication, interdisciplinary, critical assessment, application of methods and, as they say in the formulation of the purpose, in all to strengthen the students’ study competence. It is also the case if the description of the objective is to develop study competencies described as tradition, Bildung and problem solving - it's all there. The study direction project becomes an exercise in implementing a major independent piece of work, that is a foretaste of what awaits students in higher education; independent production of knowledge, based on tradition and thus study competence.

The study direction project has a scope of 30 hours, often an entire week, called project week, in the third year and must be prepared in two subjects, starting from a field of study subjects at A level and another subject of at least B level. The written report has to be app. 8-12 pages. Already in October the subjects must be approved together with a preliminary assignment for the task.

Annex 5 states: 'One mark is given, based on an overall assessment and based on an assessment of the extent to which the candidate's exam paper meets the objectives of the study project. If the task is written in only one subject, it is also included in the assessment, the extent to which the reply demonstrates the student's mastery of a specific academic subject'

Example of SRP project.

SRP, HTX, Social Studies B and Physics A. Title: Ship Stability. The report is app. 30 pages including annexes. It describes the importance of ship containers for globalisation and the problems dealt with are partly questions about globalisation (social studies) and partly how it is possible using containers to carry large amounts of cargo on ships (Physics), which in turn is seen as a prerequisite for globalisation.

The idea of looking at the material conditions for globalization seems obvious. From physics the student finds theories about the centre of mass, buoyancy, etc. and this is assembled in the section, 'How is a force analysis of a container ship made?', where an analysis of the physical conditions for container traffic on ships is made. From social studies the student finds theories of globalisation; 'realistic' and 'neo Marxist' theories. The discussion of globalisation is found in the chapter 'Denmark, the late modern society and globalisation'. Finally, it is concluded that even if a container is a simple box, it has been able to change the world economy completely. The project is very well organised and the whole idea is interesting. The somewhat brutal materialism expressed in the conclusion is not problematised, for example in relation to the neo Marxist theories. But that would probably have been too much to ask at this level?

The tasks are generally well laid out and one can see there are a lot of work put into seeking information, organise and write the project report. This shows that students are actually able to formulate a project, find information, structure the information and finally solve the problem statement.

The students' own perception of the study direction project varies widely. A boy said that 'it was wildly exciting, you can choose whatever you want, you know the freedom, you can do what you want', while a girl had a more nuanced relationship with study direction project. 'It's great! to help to solve a problem for a company with the theory we have learned. You become like seduced when you are in a business company, so it should just be done properly, it is not just nonsense. But the actual writing of the report, ... to put it bluntly, then it's a hell a sit in ... because you know it's going to count much on one's diploma and it's hard for you not to have a teacher who constantly sit and breathe you down the neck. It is something you have to find out, even finding its conclusions. Well do I explain this properly; do I reach a point where I tell what I want to tell? '.

As the girl, there were many students that found it hard to write the report, but on the other hand there were students who had already completed the study project, who were very proud to have been able to complete the study direction project, as it is a very large and demanding assignment.

The study direction project is thus also the place where the students study competences really are going to stand the test. The projects that the students are doing, all point to that they are ready for the task, even though they probably think that the project week had been tough to get through.

6 Conclusion

Above study competences were described as knowledge of a tradition; here understood as the subject's tradition and not only as cannon or curriculum. Bildung or as it was described, a process through which the students are 'Gebilded', changed, formed, becoming an able person. Finally, the aim is to develop the students' ability to participate in the production of new knowledge. This means that the students are in possession of the tools and methods necessary to be able to formulate and solve problems. The question was then whether the HTX high school program is able to achieve such goals, are the students able achieve the desired study competences? The answer is clearly that it can be done. That does not mean that all students in all schools also achieve the desired competencies, but just that it can be done within the limits as study subjects and other school activities.

The ministerial order and its supplements are to a large extent able to constitute a framework that can develop the students' study competences. There is not much here that prevents that. Looking at the profile subjects – technology and technical science, it seems that it is possible to develop study competences within the current framework, but at the same time it is possible to develop these subjects even further. The profile subjects, technology and technical science do not, in the same way as other upper secondary school subjects, have a long tradition to build on. It seems that the underlying technology concept in both subjects is still up for discussion. The socio-technical concept of technology may be sufficient in a high school context, but the teachers should be aware that the subjects technology and technical science, should not end up in a fixed form, but should be a vehicle for debates of the content of the subjects. Thereby, the subjects can create the academic breadth necessary in order to achieve the goals. But the technology concept becomes a problem when technical science in the description of the academic content abandons the socio-technical technology concept and focus only on a narrow product-technical technology concept. Here, the working group (Kaltoft et al, 2014) has a point when they recommend the development of a common engineering concept. There is a further potential in the cooperation between the subjects technology and technical science that are not fully exploited today and it will, as the working group also recommends, require in-depth discussions of the subjects' basis, content and methods to realise this potential.

The profile subjects technology and technical science are important for the development of students' study competences. Especially the study methods - project work, problem orientation and group work - are important elements and also very popular among the students. The discussion of the profile subjects' basis could be supplemented by a similar discussion of the future pedagogical development of the subjects. Here, a discussion of the cooperation between the subjects could be particularly helpful. That is, a discussion of the degree of problem orientation, project organisation and student centeredness. HTX has the potential and has already come a long way in making up with the teacher centred classroom training as the only valid activity, but there seems to be room for taking that one step further within the current ministerial order and guidelines. The technology course is in its outset interdisciplinary and problem-oriented and could be the nucleus of a real PBL-based education. The discussions could focus on the technology subject's place in the curriculum and the other subjects’ role in the entire program.

Besides discussing the profile of the subjects' basis - a discussion of a 'engineering' concept - and a discussion of the degree of PBL, there are a number of more specific measures that can be set in motion. The study of the best schools identified the following: It is important that the school management has a focus on the profile subjects. They should be placed at the centre of the education and be, as profile subjects, taken seriously as just that. This means that the school management provides the necessary resources to the subjects and at the same time formulates some very ambitious goals. The technology subject is problem-oriented and interdisciplinary and as a consequence, collaboration between teachers is an absolutely necessity. Therefore the technology subject needs a team of teachers who have the required professional breadth and in cooperation ensures problem-orientation and project organisation.

Report writing is a big part of the technology subject. Students spoke with almost awe about study direction project. Understandably, since the study direction project is a big challenge. It appears, however, that students are able to meet this challenge and are actually able to write projects at a high level and thus demonstrate that they possess the necessary study competences. The projects show that the students will be ready to continue studies at the university. This is also confirmed by my conversations with the students at the university. The HTX education features many larger written projects and it seems that this is a good foundation to bring into the university and there is thus a fine progression from the HTX high school projects to the university’s basic year.

Study competences do not come by themself. The ministerial order and its guidelines outline the framework, but these must be completed. If schools will exploit opportunities in the profile subjects - interdisciplinary and problem orientation - so there are good opportunities to develop the students' study competences, but the individual teacher cannot handle the job alone. In sum the recommendations for the HTX could look like this:

• A discussion of the basis for the curriculum, the HTX' should consider the concepts 'engineering' and ‘technology’ and their role in the curriculum.

• A discussion of the pedagogical basis, where students' qualifications for working with interdisciplinary and problem orientation are developed even further.

• A management focus on the profile subjects, so that these will be the focus of the education.

• Teacher Collaboration, so each teacher is not faced with the responsibility of developing the students' study competences alone.

• An increased focus on writing reports for the projects.

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