APPLYING PROBLEM-BASED PROJECT-ORGANIZED LEARNING IN A TRADITIONAL SYSTEM

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ABSTRACT

Nowadays, PBL is considered a suitable methodology for engineering education. But making the most of this methodology requires some features, such as multidisciplinary, ill-structured teamwork and autonomous research that sometimes are not easy to achieve. In fact, traditional university systems, including curricula, teaching methodologies, assessment and regulation, do not help the implementation of these features. Firstly, we look through the main differences found between a traditional system and the Aalborg model, considered a reference point in PBL. Then, this work is aimed at detecting the main obstacles that a standing traditional system presents to PBL implementation. A multifaceted PBL experience, covering three different disciplines, brings us to analyse these difficulties, order them according to its importance and decide which should be the first changes. Finally, we propose a straightforward introduction of generic competences in the curricula aimed at supporting the use of Problem-Based Project-Organized Learning.

INTRODUCTION

The Aalborg Model (Barge 2010) describes a context where PBL in the central means of teaching-learning. It specifies the features that an organization should take into account to follow an approach to problem and project based learning similar to Aalborg University. This specification is divided into nine areas which cover the key dimensions of any university. This paper is based on experience at the Universidad Politecnica de Madrid (UPM). This university has a strong academic tradition. It is made up of 18 schools, it offers 41 degrees and has around 3300 teachers and more than 37000 students. It is a point of reference in architecture and engineering studies in Spain and around 5000 students graduate every year. Among the schools of the UPM, the Escuela Universitaria de Informatica (EUI) was chosen for including this experience. Recently, the EUI has started off two new degrees: Computer Engineering and Software Engineering. Both curricula are organized by semesters that contain around 5 subjects. EUI is composed by 6 departments which are in charge of designing and organizing a subset of the curricula subjects. Its main characteristics are: curricula organization by subjects, predominance of traditional lectures, use of traditional written assessment and predominance of individual student work against teamwork. Although we carried out several works to apply PBL in the academic curricula of the EUI, these experiences have been restricted to individual courses (Garcia *et al.* 2009). Consequently, the achievements obtained have been quite limited. During the year 2010, we have set out a new experience, where PBL is applied to a multidisciplinary context. More specifically, students carry out an ill-structured project that covers knowledge about three subjects: Requirement Engineering and Modelling (REM), Operating Systems (OS) and Statistics (St). These are three mandatory subjects out of five that constitute the third semester of the Software Engineering degree. The purpose of this experience was to achieve a larger number of PBL benefits than in previous experiences. In particular, we want our PBL course to be Multifaceted, Ill-Structured and based on Teamwork and Autonomy.

This study, applying the above mentioned methodology in a traditional frame, is aimed at detecting the main obstacles that a standing traditional system presents to PBL implementation. Then, these difficulties are analysed and ordered according to importance and this leads us to decide which should be the first changes to be introduced in our system. In next section, we highlight the main differences that we find between the Aalborg model and the UPM traditional model. Following this, the multidisciplinary PBL experience

provided in the year 2010-2011 will be described. Then, we present some results obtained in reference to academic performance and students´ response. In addition to this, we point out the most important deficiencies that have been detected in the traditional structure when an active learning methodology such as PBL is implemented. Finally, we deal with the issue of introducing PBL into an educative system with strong standing traditions.

Traditional system vs. Aalborg PBL model

The UPM establishes some general academic regulations. It has recently published the Modelo Educativo UPM (UPM 2009), an extent document which describes the challenges and changes that this University should carry out in order to adapt it to the new European university context. It gives a large number of proposals to foster these changes. On the other hand, departments are in charge of organizing the teaching activities and evaluation of a subset of subjects. This way, each department decides the teaching and assessment regulations. In some cases, subjects have a great autonomy to organize contents and methodologies, although continuous efforts are made to improve coordination among subjects. Table 1a highlights some relevant aspects of the Aalborg model related to 6 of the areas included in this model. In contrast, Table 1b describes the main characteristics of the traditional EUI Model related to the same areas.

Educational Vision
Systematic framework for PBL approach. Ongoing commitment to its central principles
Problem/wonderings orientation
Multifaceted projects
Students make relevant decisions to complete the project
Integration of theory and practice
The institution has adopted learning objectives specific to the PBL approach
Team-work based
Students demonstrate understanding of framework and are prepared to identify and articulate the strengths
Curriculum
Credit-bearing academic work that introduces students to PBL and scaffold skills
Balance of orientation courses, study courses and project-related courses. Project supported by specific courses
Students´ project work comprise at least 50 percent of their academic credits
Assessment
Students´ group project work stands as the main assessment method
Forms of both formative and summative assessment are used
Students´ academic work is assessed according to clearly documented policies and

procedures and learning objectives
Students receive appropriately differentiated individual grades for their contribution to the project
Faculty
Faculty member demonstrate a clear understanding of and commitment to the PBL model
Faculty members have been introduced to the theoretical framework
Faculty are directly involved in the development and maintenance of program curricula
Faculty members demonstrate ability to incorporate best practices in supervising and advising student project groups
The institution has established the maximum of groups one faculty member is able to effectively serve as primary supervisor for in one team
Students
Students are able to identify the way in which the PBL approach shapes their academic work
Students demonstrate strong project management skills and collaborative work
Students play a meaningful role in the administration of degree programs. They participate in curricular development and implementation, term themes, course offering
Resources
The institution deploys resources in ways that consistently support the PBL educational approach
Each group is provided with its own private or semi-private work space
Classroom and laboratory space are provided as required by study courses and project courses
Materials required for completion of project work are provided for groups
The institution maintains an appropriate array of operational and modern technological resources. Resources which facilitate the collaborative work of project groups are central

Table 1a. Aalborg Model Abstract

Educational Vision
Students follow a number of independent subjects during the term
Each subject consists of a number of theoretical credits (50%) and practical credits (50%)
Traditional lectures predominate over other teaching methods, although new methodologies, such as oral presentations or case study have been incorporated to complete teaching activities.
Topics of practical tasks usually consist of well-defined tasks and are restricted to those matters studied in the subject
Individual student work has more weight than teamwork in the final mark
15 generic competences are specified in Software Engineering degree. Nevertheless, there is not a specific plan to reach them. Each subject chooses a subset of generic competences and tries to promote them
Students do not receive specific information or explanation about teaching-learning methodologies
Curriculum
There are not specific credits for teaching about generic competences
All courses are matter oriented and students register for them independently
The subject work is focused on reaching objectives related to a particular discipline
Assessment
Individual assessment predominates over group work

Teachers are not in the habit of using formative evaluation
Subject assessment is aligned to subject specific learning objectives
When group work is used, specific method to assign individual grades according to their contribution are not used
Continuous evaluation has been incorporated in the new curricula over the last years.
The assessment method is based on written tests.
Faculty
UPM foster the setting-up of educational innovation groups to engage teachers in new methodologies
UPM supports educational innovation projects to introduce the use of new methodologies
Some crash courses about educational methodologies are organized
Teachers are members of executive organisms where important decisions about curriculum are taken
Every teacher is in charge of one or several classes in which academic activities are carried out. This way, a teacher is responsible for teaching and assessing every student in those activities related with a subject
In the case of compulsory subjects, there is an average number of 40 students per class.
Students
There is a representation of students in each executive institution. This way, they participate in academic organization
Students are not introduced in teaching-learning methodologies
Regarding project development, students take a course about Project Management in the Software Engineering degree, where they acquire knowledge about project development. However, we cannot assert that they acquire long experience about this ability until the final semester, when they have to develop a final degree project
Resources
There is a Computational Centre where students can use some rooms at their convenience. Other rooms are dedicated to teacher-leaded sessions.
Departments have specialized laboratories to carry out practical sessions. In this case, laboratories have restricted opening hours, and there is no habit of using them at student convenience
Library has rooms dedicated to teamwork, student teams have not semiprivate spaces
Most of the subjects have Moodle platforms which offer learning material and some basic collaborative tools

Table 1b. Traditional EUI Model Abstract

All in all, we could conclude that the adaptation to the European Space of Higher Education points out the need of introducing new methodologies and it has produced the incorporation of some new practices. Nevertheless, there is still a predominance of traditional education and assessment. These features are widespread among most schools in the UPM.

Method: The multidisciplinary PBL experience

As we have previously described, we carried out several projects to apply PBL in individual courses. In this experience, PBL is applied into a multidisciplinary context where students carry out an ill-structured project that covers knowledge about three subjects: REM, OS and St. Our purpose was to achieve a larger number of PBL benefits than in previous experiences, covering the main characteristics of problem-based learning (de Graaff *et al.* 2003). In particular, we established four specific goals: to make students: a) deal with ill-structured problems, b) develop a multifaceted project, c) improve their teamwork skills, and d) reach more autonomous work. REM, OS and St are three mandatory subjects out of five that constitute the third semester of the Software Engineering degree. Students registered independently in each one of these subjects, therefore, only students who were registered simultaneously in the three subjects could participate in the development of the project. These students attended a special theory class in OS and REM, where lessons were aimed at supporting the project. On the other hand, St followed the usual lessons. The topic given to the students was related to an ill-structured problem. More specifically, students had to develop a study to compare two operating systems, Linux and Windows, from the performance point of view. To reach this goal, they had to specify formally the system requirements, carry out a software benchmark and develop a statistical analysis to explain the results. Before starting the project, students followed a two-session seminar about team-working, project development and problem solving. The project was carried out by groups of four students for fifteen weeks. Students of the three disciplines were required to implement a solution. The project was divided into three phases. Each subject has one two-hour laboratory session per week. REM and OS sessions were dedicated to project development. This way, teachers of both subjects have a close monitoring of student work. Statistics laboratory sessions were dedicated to practical tasks related to subject disciplines. In this case, students attended teacher office hours to consult about project technical doubts. Also, the OS teacher had a twenty-minute individual meeting with every group every fifteen days. These meetings were focused on helping students to solve problems related to general orientation and scheduling of the project. As far as assessment is concerned, each phase had a preliminary evaluation in order to give feedback to the students prior to the final submission. Each project phase gave three grades corresponding to each one of the three subjects. The project had different value in the final grade of every subject: 60% in REM, 50% in OS and 20% in St. The complementing grades were evaluated individually in every subject through written tests.

Now we describe the sources of information that have been used in the study to gather information.

(1) At the end of the term we did a five-point Likert scale survey to obtain the students' opinion on the usefulness of different aspects such as subject organization, kind of project developed, assessment and resources.

(2) The report that students should hand in at the end of every project phase included several questions about the procedure. Among them, we have analyzed the number of work hours and a description of the main difficulties that students had found.

(3) Teachers took advantage of individual meetings with every student team to take directly their opinion and explanation about their decisions.

(4) Two tests were used in order to measure generic competences: the Team Work Behaviour Questionnaire (TWBQ) (Tasa *et al.* 2007) and the Problem Solving Inventory (Heppner 1988), which were filled in by the students at the beginning and at the end of the term. TWBQ test has two parts: one in which students have to assess their own ability, TWBQ (Self), and another in which they assess the ability of the group as a whole, TWBQ (Others). In each item (statement), participants have to evaluate the statements on a 7 points Likert-type scale (1= not at all; 7 = very much). The purpose of the PSI test is to assess the students´ perception of their own problem-solving behaviours and attitudes. Participants have to evaluate each item (statement) following a 6-point Likert-type scale (1= Strongly Agree; 6 = Strongly Disagree).

(5) 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 questions: "I have improved my starting level, regarding the competences established in the course", "The teacher assistance is effective to learn", "The volume of contents and tasks included in the learning activities is proportional to the credits attached to this subject", "The assessment method shows relationship with the kind of tasks that are developed". This survey follows a Likert scale of 6 points (1=strongly disagree, 6=absolutely agree).

(6) Figures related to participation of EUI teachers in Innovative Education Groups and Innovative Education Projects.

(7) Opinion and conclusions of the teachers that have participated in this experience, which were gathered in a meeting at the end of the term.

Results

First of all, we would like to highlight some administrative issues that directly affected this experience. The first intention was to have all students who participated in this experience included in a specific group. Nevertheless, as we have described previously, REM, OS and St are individual subjects in the curriculum, and students register for each one independently. Students are free to choose the group according to their time-table preferences. These facts, along with some problems with registration software did not allow us to include all students who were going to participate in this experience in the same group. Eventually, the student participation in the PBL experience was voluntary.

Students: Regarding the information described in point (1), students who followed the PBL course gave a good opinion about learning by development a project, obtaining an average mark of 5.5 over 7 points. Although the best valued aspects were the continuous evaluation system against the traditional final exam (6.3) and the lectures used to support the project (6.2). On the other hand, the difficulties described by the students in the information included in the reports, point (2), were arranged in the four categories displayed in Table 2. This table shows the percentage distribution of these kinds of difficulties related with the two first phases of the project. These data have been complemented with the same measures taken during the year 2009-2010 in an Operating System course based on PBL as well. The figures show that students find more difficulties that are linked to dealing with unknown information at the beginning. On the other hand, in subsequent phases their attention is mainly focused on technical problems.

Kind of difficulties	2010-2011		2009-2010	
	Phase 1	Phase 2	Phase 1	Phase 2
a- Scheduling and approaching the problem	16.6%	11%	4%	10.1%
b- Looking for and dealing with unknown topics	58.3%	9%	68%	40.5%
c- Technical and specific problems	8.3%	70%	28%	48.6%
d- Lack of resources	16.6%	10%	0%	0%

Table 2. Kind of difficulties found by students

As far as UPM survey is concerned (5), Table 3 displays the results of the four questions selected for this study. First column shows the appraisal related to OS group that

followed the Multifaceted PBL course, whereas the second and third columns correspond to the average range of the remaining OS groups (which followed traditional lectures) and all the subjects of the school. Whereas there are not significant differences in questions c and d, PBL shows better scores in questions related to student improvement and teacher assistance.

	PBL OS group	Not PBL OS groups	School
a- I have improved my starting level, regarding the competences established in the course	4.60	4.12	4.32
b- The teacher assistance is effective to learn	4.85	4.14	4.28
c- The volume of contents and tasks included in the learning activities is proportional to the credits attached to this subject	4.08	3.83	4.13
d- The assessment method shows relationship with the kind of tasks that are developed	4.28	4.34	4.35

Table 3. UPM survey

Teachers could gather some interesting opinions of students during the individual meetings (3). Among them, students showed some initial doubts about the convenience of following the multifaceted PBL alternative. The main reasons seemed to be that they do not feel sure about the difficulty of the work that they had to carry out and the low weight of the project in Statistics. Moreover, they perceived the lack of organization described above. These facts, along with the voluntary participation above mentioned, resulted in a high dropout rate in the multifaceted project experience. Initially, there were 30 students who could participate in the PBL experience, but a half of them decided not to participate due to administrative issues. 17 students were organized into 4 groups that started the project. Nevertheless, 2 groups gave up the multifaceted project because of insecurity and convenience. Eventually, only 2 groups took part in the experience. Related to this, we highlight that all OS and REM students should develop a team project in any case, although only these 2 groups carried out the multifaceted project. Finally, the PSI and TWQ tests (4) indicate that there is not significant improvement in the problem solving and teamwork skills during the semester (Table 4). An analysis of the items included in both tests, along with the information obtained from the individual meeting, reveal some deficiencies regarding both skills.

Generic Competence	**Mean (SD) beginning**	**Mean (SD) end**
TWBQ (Self)	4.98 (1.095)	5.14 (1.169)
TWBQ (Others)	4.50 (0.864)	4.70 (1.322)
PSI	85.38 (20.250)	87.43 (23.329)

Table 4. Mean and Standard Deviation (SD) in generic competences in OS PBL group

Curriculum: Although the analysis of the information included in the reports and the surveys shows us that students spent a number of hours similar to the number of hours that were foreseen in the PBL course, students complained about the overall workload that they had to tackle taking into account the five compulsory subjects. Continuous evaluation has been incorporated recently in both degrees with limited experience, especially in those aspects related with the work load. Consequently, some work overload was detected in several weeks during the term.

Assessment: Subject regulations determined that students who developed the multifaceted project had to reach the same specific objectives as students who did not participate in the project, and they were evaluated with the same written test. This fact had a special importance in the Statistics´ case, since the project value was merely 20% of the final grade. The third semester of Software Engineering degree consists of five subjects. As we know, deadlines in the development of a project are more flexible than in short practical tasks and written tests, and consequently students tended to give the project a secondary role, paying more attention to written tests and shorter deadlines of other practical tasks. As a result, students had some delays in the project implementation. Table 3 displays that students do not appraise the assessment method used in PBL course better than in other courses.

Faculty and Educational Vision: In general, there is some resistance to the use of new educational methodologies among the EUI teachers and a limited number of them participate in seminars and courses about this topic. Regarding the point (6), 20 EUI teachers out of 130 are involved in 2 educational innovation groups. The number of educational innovation projects developed in 2010 was 3 and in 2011 it has been 5. These figures are lower than the average rate in the UPM. The final conclusions of the three teachers (7) who participated voluntarily in this experience point out some failings. Although they showed a keen interest in the PBL course, the lack of previous experience in this kind of multifaceted project pointed to some aspects that should be improved in future experiences. In particular, there were two aspects that were detrimental to REM subject. Firstly, teachers decided to give the project specifications in an incremental way to facilitate the project planning. This fact did not allow students to tackle conveniently some matters related to REM, where a global view of the project would have been more appropriate. Secondly, teachers perceived that matters related to each subject were too much differentiated in the project requirements, so we will need the specification of a global project that combines better the different areas as a whole.

Discussion

This experience has been part of an educational innovation project with limited institutional support. Problems in the registration process produced some organizational troubles that have made the experience more difficult. Moreover, due to the perceived resistance to the introduction of new teaching methodologies, in some cases there was a significant lack of support from some teachers involved in related subjects and departments. These facts point to the need of a change of mentality and a direct involvement of the institution, which represent one the most important drawbacks.

EUI students are not used to dealing with ill-structured problems and they show some insecurity when they have to tackle some important decisions. Moreover, teachers perceived some inefficiency related to team-work and problem solving strategies. Nevertheless, surveys described in points (1) and (5) indicate that, despite the initial doubts, the PBL methodology is well received by students. Results of Table 2 indicate that they assimilate satisfactorily the new methodology. So, this lack of experience does not represent a strong drawback, but points to the need of specific training. Besides, some instruction about learning in PBL could be really helpful for student performance.

The curriculum structure establishes strict technical objectives for every subject and a large part of subjects are evaluated according to these objectives. This fact constitutes an important drawback when students have to deal with an ill-structured problem, since they tend to pay more attention to written tests than researching activities. Therefore, some changes are needed in assessment methods and regulation, as they seem to be quite strict and not adapted to active learning. Related to this, the uncoordinated working of the subjects that make up a semester, their strict technical objectives and their established assessment rules do not help at all the development of multifaceted projects. These drawbacks related to the curriculum, along with the resistance to the new methodologies make us conclude that changes related to new methodologies should be introduced in a straightforward and gradual.

To sum up, students, despite their lack of experience, have shown enough ability to adapt to new challenges and they do not represent the main obstacle. Changes in teacher´s mentality seem to be more difficult and they would be necessary to overcome the current resistance. On the other hand, the strict structure of the curriculum and the assessment

regulations represent the strongest drawbacks to implement the multifaceted PBL course. These aspects should become more flexible according to active learning methodologies. Related to this, more institutional support seems to be central to achieving better results in the application of methodologies such as PBL.

Conclusions and future work

In conclusion, we highlight the changes that, from our point of view, should be made to overcome the main difficulties found in the introduction of a methodology as PBL. In the first place, some changes in teacher and student mentality about learning methodologies should be introduced. This will allow subsequent changes in academic regulation and practices. At the same time, some credits should be spent on teaching general competences, since currently there is no specific training about them and they are central to achieve success in PBL methodology. Moreover, students seem to have some important deficiencies in basic skills. Secondly, we propose the introduction of new assessment methods in tune with active learning, since traditional ones mean an important barrier to PBL success most of the time. Changes in the curriculum could come later, once the institution and a majority of teachers are in favour of supporting these methodologies.

Certainly, the best situation to introduce the PBL model is the inception of a new school or at least a new curriculum, since it affects the key dimensions of the university. Unfortunately, this is not the real situation of most schools, where the only choice is to apply this methodology to already existing structures. In these cases, a short-term application of the Aalborg model is not viable. Therefore, based on our experience, we outline some proposals to start a gradual introduction of Problem and Project based learning in our school. In future years we will suggest the integration of some general competences in current curricula. This integration will be done such a way that it affects the current organization as little as possible. The proposal will consist in developing a map that distributes general competences among semesters in a balanced way. Subjects which make up a semester will spend some practical credits in order to teach about the general competences selected for this semester. Then, subjects will require the students to show enough ability related to these skills according to the training they have received. Related to this, some new assessment methods will be suggested. The first term will deal with basic competences, among them teamwork, problem

solving, written expression or time management. Once students have acquired some basic competences, Project Based Learning will be introduced in subsequent semesters.

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