USING PBL WITH UNDERGRADUATE ENGINEERING STUDENTS

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Abstract: This paper describes the application of the new methodology of Problem-based Learning (PBL) in two undergraduate Materials modules for students of the Energy and Mining Engineering Degree at the University of Vigo and of the Civil Engineering Degree at the University of Alicante. This PBL system has been adopted by several universities in Europe because the students can acquire several skills (solving problems by themselves, self-directed learning, and collaborative work) which would be impossible to develop using other methodologies. Moreover, students assume responsibility for their academic education.

We have already been using the PBL system for 4 academic years in a final-year Materials Engineering (Metallurgy) module. The result has been satisfactory, although some corrections have been introduced in subsequent years.

This year, for the first time we have used PBL with younger students and the challenge has been how to motivate them to use this methodology. We have found three essential differences between using PBL with older or younger students. In the latter case, the formulation of the problems has to be clear and involve a restricted number of solutions. Secondly, the tutor needs to monitor the groups and the schedule of meetings closely in order to ensure the problems are solved. Thirdly, the method of assessment used has to be able to detect “bystanders”.

Keywords; Problem-based Learning, Materials Engineering, undergraduate students, Master’s students, tutor, skills.

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1. INTRODUCTION

Recent years have seen a complete overhaul of the degree system in Spanish universities. One of the disciplines affected is Engineering Studies (6 or 5 years), which has been combined with Technical Engineering (3 years), to create a Bachelor’s Degree of a duration of 4 years. In all cases, the student must reach a set of skills, specific to the discipline (specific) and generic (transversal) common to any field (MEC, 2010). The aim is also to attain the same levels of theoretical and practical knowledge associated with a particular discipline, and to acquire the
necessary skillset to analyze and solve problems, to work collaboratively, to communicate, to make decisions, to manage time, to master computer skills, etc. Whilst the traditional combination of lectures and practical labs can teach scientific, IT or specific skills, the acquisition of generic skills requires new teaching methods. Among these new methodologies, one of the most interesting and most successful in fields such as engineering, health and economics, has been Problem-based Learning and Project-based Learning, which both respond to the same acronym PBL (Moore et al., 2007).

Problem-based Learning (PBL) is defined by Barrows (1986) as a "learner-centered methodology, research and reflection that students follow to reach a solution to a problem proposed by the teacher." This system offers the student a series of problems which should be resolved, alone or in groups, with no background needed. The teacher is responsible for providing the student with the tools necessary for resolution. It seeks to help students acquire knowledge of a given subject by themselves, becoming responsible for their own education. Research has identified numerous advantages in this methodology; participants will develop various skills such as problem solving, teamwork, research and information management, communication skills, planning, critical thinking, etc. This objective will be achieved if the system is well organized but prior action is necessary to take into account the aims to be achieved.

Problem-based Learning can be used within a given area of knowledge acquisition, or at the macro level as part of the course (Direction of Investigation and Education, Monterrey). In some cases, it may include multiple subjects, which is the case for Engineering. It seems more appropriate to call the methodology Project-based Learning, since it challenges students to develop a project by applying the knowledge acquired from several disciplines. Due to the complexity of the new degree system, we have focused on the implementation of Problem-based Learning to see the results of the method and analyze the various difficulties resulting from its use.

The PBL methodology has already been used within a module of the Mining Engineering degree, which has changed in content and length under the new degree system. Although PBL has been used for several years, it has undergone gradual changes depending on the results; since the transition to this unconventional learning system has been complicated for both teachers and students. However, we will show in this paper that PBL leads to better results. It should be pointed out that, under the previous degree system, the module was taught towards the end of the course; therefore the students were effectively working at Master’s level.

The experience in this work has been the starting point for the introduction of the new PBL methodology in two undergraduate courses for students of the Energy and Mining Engineering Degree at the University of Vigo and of the Civil Engineering Degree at the University of Alicante. The module in both cases is Materials Science.

In this paper, we will discuss the differences we have found in using PBL with older and younger students.
2. PBL- PLANNING

This basic technique establishes learning objectives, which help to determine how to apply the PBL methodology (Amador et al., 2007). We have to bear in mind that the goal of this system is not only to resolve the problem but also it is useful for students to discover, alone or collaboratively, the process leading to the resolution. The PBL methodology is combined with other teaching techniques to form a single problem that encompasses one of the subject-specific skills. Under the previous degree system, the students used PBL to evaluate the energetic capacity of a plant to obtain materials from its raw materials. In the present study for the younger students, we chose a straightforward module taught towards the end of the syllabus, namely Composite Materials. The PBL activity starts at the beginning of the module, when knowledge about materials is limited. For this reason we consider that is a good module in which to apply PBL, because the students are forced to develop the following general skills to achieve success (Escribano and del Valle, 2008):

- Interrelate and interpret knowledge, accessing sources of necessary information.
- Propose practical solutions, using the information.
- Promote cooperative work, communication skills, organization, planning and personal responsibility for the completion of the work.
- Know the necessary sources for the continuous updating of all information, accessing current and future tools to search for information.

The last point was the most challenging for the undergraduate students because they are not used to looking for information in the library, their preferred source being the Internet. It is therefore of paramount importance to combine both information sources, Internet and real books, to acquire the knowledge. The main difference here in comparison with the older students is that we have to give younger students a list of books signposting them to where they can look for information to solve the problems.

The proposed problem must satisfy a number of features to make the students feel involved (Morales and Landa, 2004):

- The problem must engage and motivate learning and should be related to real cases.
- Students are required to justify their decisions, by defining assumptions made, identifying relevant information and outlining the necessary steps.
- For the completion of the work the cooperation of all students is needed, and it should not be possible to divide up the problem.

In our PBL experience under the old degree system, students required knowledge of previous courses, which were possibly linked to the newly acquired knowledge. We suggested they evaluate a real, operating metal plant. For the evaluation of the system, students required knowledge from modules they had previously studied, such as the fundamentals of energy, materials and also chemical thermodynamics. They were left initial assumptions and provided with a computer program, used by many companies, which they had to learn to manage, and which would serve as a basis for reflection and analysis on the new knowledge. The PBL was an
overall assessment of a plant, so, although initially students attempted to divide the work, progress was impossible because the same skills were required from all team members.

As mentioned above, knowledge of materials is poor under the new degree system (Amador et al., 2007), but we try to raise students’ interest through sports, as the composite materials are used in Formula 1 cars, tennis rackets, golf clubs etc. We give them different problems (Bao and Castresana, 2010) to solve, of several composite materials and guard against the division of the work; the presentation of the solutions at the end of the task is to be done by one student chosen at random.

3. DEVELOPMENT OF PBL DURING THE COURSE

In the Metallurgy module under the previous degree system, PBL was implemented in parallel to the teaching of the subject, without any specific hours for this methodology. On the first day of class, we explained the work and the methodology to the students, and they formed working groups of no more than five students. They also arranged a minimum of two meetings with the subject tutor. At the end of the semester, students presented their work to their classmates, and discussed respective solutions to the study of the plant. Work was assessed using self and peer evaluation. We then tried to transpose this methodology to the Materials Science module under the new degree system.

The first difference under the new degree system is that these new methodologies have been allocated some hours within the module timetable. At Vigo University, they are in the form of seminars and at Alicante University, they are group tutorials. At our University, five hours were divided as follows:

- In the first hour we presented the students with the work to be done in groups of no more than five people. At this point, we encountered our first problem: the tutor had to help the students to form groups because they were not able to do so. Then we distributed four different Composite Materials problems for each group to solve. We gave them a form to fill out, where, for each problem, they had to state the type of the composite, its use and its manufacture. We suggested they go to the library to find information in books, supplemented with a reasonable amount of information from the Internet.

- The next session was two hours; during this time the students in groups discussed the form with the tutor. They were expected to arrive at this session with all the information about the four different composites in the problems to be solved. The tutor had to observe the participation of all the students in order to detect any “bystanders”. Each group had to bring the different books and Internet sources where they got the information to fill out the form. They had to try to solve the problems within these two hours; it was difficult for them to finish in this short time. They had to propose a new meeting to finish the work and inform the tutor when it would take place. The tutor offered to help in his own office if they needed.

- In the last session, also lasting two hours, each group presented one of the problems. The presentation was given by a student chosen at random. This is important because applying this system all the members of the group are involved in doing a good presentation on the
day (a part of the mark at the end depends on this collaboration). The other students in the class had the opportunity to ask the student questions about the method used to solve the problem. The student had to explain the composite material in the problem, the properties, the possible uses and the manufacture.

- In this last session the evaluation of the work is decided. We used the Rubric System (RubiStar Home) for the evaluation. Each student evaluated himself, his teammates and the other groups. The transversal skills are assessed (ability to propose practical solutions, use of information, cooperative work, communication skills, organization…).

We have to say that with these students the work of the tutor was more important because he had to be in control at all times so that the students managed their time and their work effectively. It is necessary to point out that their knowledge of materials at the beginning of the module was very limited.

4. EVALUATION OF PBL

At the end, it is necessary to evaluate the work. Literature (Escribano and del Valle, 2008) discusses different evaluation methodologies. All are concerned with the method used to solve the problem, regardless of whether the solution is correct or not. It is necessary to evaluate the transversal or generic skills. We have tested some of them and we think that the most appropriate is co-evaluation, as illustrated in Figure 1. The acquisition of specific skills is evaluated by a test at the end of the course, not forgetting that the methodology is applied in one part of the module, the rest being taught by the traditional methods of theory, problems and laboratories. The generic skills are allocated a mark not exceeding 20% of the overall assessment of the module. This mark is obtained from the average provided by: the self-assessment undertaken by the student, the evaluation of the peer group and the tutor. The same questionnaire is employed in all three cases, based on obtaining generic skills and abilities. In addition, the student is asked for feedback on the methodology and the role of tutor after the course. This is of great importance since it has served to keep improving the system, year after year.

![Figure 1 Evaluation System.](image-url)
5. RESULTS OF PBL

The PBL methodology has been used in the teaching of the traditional subject of Mining Engineering. Despite the introduction of several corrective measures in subsequent years, the results have been satisfactory, as Figure 2 shows. Year after year the number of students who have passed the subject has increased. The results have been different in the core module of Materials Engineering, both at Vigo University and Alicante University.

The main problem is that few students are accustomed to these types of evaluation and teamwork. It appears that the result of the assessment does not correspond to the actual acquisition of the skills. For example, some groups did not acquire the skills because there was poor evidence of collaborative working. Yet in the self and peer group assessments, they gave themselves the highest marks. Figure 3 compares the result of the co-evaluation process with the result of the test at the end of this part of the course.

As shown in Figure 3A, the co-evaluation system without any correction for the tutor mark allocates high marks to all the students. The experience at Alicante University was the same in the first year, and for this reason they introduced marks from the tutor, as depicted in Figure 3B. However, this factor forces the students to do the work only for the mark rather than for the learning. But we consider that, at present, it is absolutely necessary not to use to new assessment methodologies with younger students.

Figure 3C suggests that the PBL system is beneficial not only in order to acquire the generic skills; at both Universities the result of the test from this part gave better marks than the rest of the subject. The PBL system also contributes to the acquisition of specific skills. It should be pointed out that Alicante University is in the second year of the new system of a 4-year Engineering Degree, whereas at Vigo University is the first year and we hope that the result will improve over time.
Figure 3 Results of the PBL application for the undergraduate students in the Basic Materials Science module for Engineers. A) Result of the co-evaluation system at Vigo University for the first year 2011/2012 (maximum mark is 4). B) Result of the co-evaluation system at Alicante University for the second year 2011/2012 (maximum mark is 4). C) Students who passed the text at the end of the semester course.

6. CONCLUSIONS

We had to try to integrate the PBL methodology in the basic module of Materials Science within the new Engineering degrees, and we had some problems related to the behavior of the students not accustomed to this system. The result in the specific skill of the exercise, namely knowledge of composite materials, has been good when compared with the other parts of the subject. However in order to acquire the transversal skills some changes are required, especially in the evaluation method. In order to avoid the poor organization of the work, it is necessary to include the tutor’s feedback on the sessions in the evaluation.
7. REFERENCES


