Designing an Engineering Laboratory Course for Problem Based Learning

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Abstract: This work presents a proposal for implementing a problem-based learning (PBL) methodology by means of a new specific engineering course. Using interesting and practical projects, this specific course integrates engineering courses of different. However, each involved engineering course maintains its respective syllabus and the methodological freedom of the lecturers. The lecturers can further explore the subjects by introducing methodological innovation. The selected projects will highlight how the topics learned can be used to understand the problem being studied and to find the solution. The proposed course will bring together the participants in the form of seminars to analyze the problems and the solutions, checking their mistakes and the possibility of them being implemented. The study object is the competition vehicle SAE Mini Baja developed by EESC USP Baja SAE team, which will provide case studies associated with practical needs in a competitive environment.

Keywords: Problem based learning, teaching engineering, management of projects.

1. Introduction

This paper presents an experience in Problem-Based Learning (PBL) being implemented in the School of Engineering of São Carlos (EESC) of the University of São Paulo (USP). It involves the design of a new course called Engineering Designs Laboratory linked to the Baja SAE-EESC USP Project. This Baja Project, which involves design, construction and improvement of a competition vehicle with standards established by the Baja-SAE, provides the problem cases for the application of PBL.

The PBL methodology proposes a learning approach based on the use of real problems, in one branch of activity, where students work in small groups under the guidance of an instructor. The idea is to stimulate students in their areas of interest, developing critical thinking and problem solving skills, and the learning of fundamental concepts in the area of study (Ribeiro, 2005).

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The PBL methodology was originated in the field of medicine in the late 1960s at the McMaster University in Canada, and applied over the years in other areas of knowledge, particularly in the area of Engineering (Taylor and Miflin, 2008).

The present work does not seek to perform a comparative study of PBL methods implemented and its specificities. Although there are different theoretical formulations and implementations of PBL methods, some concepts and perceptions of difficulties, advantages and disadvantages of the method are common to different experiences (Uden and Beaumont, 2006; Kirschner et al., 2006; Lord and Camacho, 2007; Haag et al., 2007). Many works on the implementation of PBL in engineering education have been published. Experience has shown that the acquired knowledge and its application do not respond adequately to the demands of production in different areas of engineering. In the traditional teaching, the subjects are treated sequentially and the students work passively and individually. The student performance is evaluated through tests that measure their skills to memorize formulas and procedures. The course syllabus presents the topics in a sequential and compartmentalized way and its contents are transmitted in a sealed manner. Students are thus left with the task of understanding the integration and meaning of the contents in their projects at the end of the course, when there are (Ribeiro, 2005; Lord and Camacho, 2007).

The traditional teaching does not meet the requirements of a professional activity that currently includes ability to analyze problems and search for solutions by working in a team, communication skills among professionals from different specialties and motivation for life-long learning (Ribeiro, 2005; Haag et al., 2007).

The PBL on the other hand starts from a real problem or by identifying a real problem to motivate the students and thereby leading them to knowledge. The purpose is the development of critical thinking and skills for solving problems through their contextualization, methods of analysis and synthesis, accessing the knowledge that the student already has and to develop the knowledge that the student does not have by researching or consulting experts.

One should also encourage the search of a real problem solution by means of a team discussion considering different points of view, exchanging information and sharing responsibilities. Unlike the problems in conventional approaches, a problem in the PBL is open-ended, which means that it does not carry a single correct

solution, but one or more suitable solutions, considering the constraints imposed by the problem itself and the educational context in which it is inserted (Ribeiro, 2005).
Given the complexity of the implementation of PBL, its application involves institutional commitment and collides with the complex institutional structure of ends and means: The engineering curriculum, departments, educational spaces (classrooms and suitable laboratories), etc. Also there is resistance of lecturers to pedagogical changes and the inadequacy of the educational background of the students accustomed to years of study in the traditional method. Hence, the proposal presented here is based on an integrating course which allows the natural application of the new methodology, gradually and spontaneously, with a buy-in of lecturers and optionally of students enrolled in other courses which are part of the proposal.

2. Background

Some expected difficulties have already been pointed out by many experts of PBL. Three of them are:

a) The first difficulty concerns the extra time and work the lecturers will need to implement PBL methods. Furthermore, they will have to deal with matters beyond their domain of expertise to guide the students in their cross disciplinary projects, which requires study and training.
b) Secondly, the students have to accept that they are involved with a new form of learning. They will have to seek knowledge in subjects not addressed in the program of the course in which they are enrolled in. Differing from the traditional approach to learning, the students have to perform simulations and tests which frequently will lead to the reformulation of the project or even of the problem conception.
c) The third difficulty concerns the pedagogic preparation that the lecturers need to deal with to implement a PBL proposal.

Anticipating these difficulties, the PBL was proposed in some subjects, particularly electronic instrumentation, transducers and digital systems and later on it will be extended to subjects of mechanical engineering. Regular meetings with members of Baja-SAE team for discussions and evaluations of the ongoing projects are part of the PBL implementation.

3. The EESC USP Baja SAE Team

The Society of Automobile Engineers (SAE) was established in 1904 in New York. In the 1970s the SAE began to motivate students in engineering and science by offering challenging projects consisting of the creation, design, manufacture and management of real engineering problems. Some examples of these projects are: SAE Baja, Formula SAE and SAE Aero design. The Baja-SAE Project offers engineering students the opportunity to apply in practice the knowledge acquired in the classroom, increasing their effectiveness for the job market.
The activities of the SAE Brazil began in 1991 and in 1994 the Baja SAE Brazil Project started. In 1995 the first national competition was organized in the city of São Paulo. Since 1997 the SAE Brazil has been supporting regional competitions.
Students participating in the Baja SAE Project must form teams to represent their institution of higher education. These teams are challenged to participate annually in the Baja SAE competitions, an event that brings together students and promotes benchmarking projects. Figure 1 illustrates a moment during a competition.
The EESC USP team is pioneer in Brazil and is committed to innovation and to be among the best teams in the country. For that, it brings together students of various courses of EESC-USP and is organized as a small business with administrative and execution positions, ensuring better performance in the areas of management, administration, project design and execution. To remain competitive, it demands efficient solutions for mechanical and electrical design, precision manufacturing, and use of new materials and devices. Modern 3D modeling and simulations software are used.

Fig. 1 Mini Bajas race

4. The integrating engineering course design

A. Engineering Projects Laboratory

The integrating course, called Engineering Projects Laboratory, is offered by the EESC. Enrollment in this course is made available to all students committed or involved with projects related to the Baja SAE. The faculty members supervising these projects are lecturers of the Electrical and Computer Engineering, Mechanical Engineering, Mechatronics Engineering and Production Engineering courses.
The course is administered in an equipped laboratory with suitable space for group work, meetings and seminars. The activities consist of discussion and supervision of projects every two weeks and, when necessary, workshops are organized and experts are invited to give seminars.

B. Related Topics and Areas

Ten problems/projects were pointed out in this first phase of the Laboratory Engineering Project Course implantation, selected in meetings with the actual Baja-SAE team. They are:

- engine rotation measurement
- fuel level measurement
- motor starting via chokes

- brake force distribution
- data telemetry-development of communication protocols
- vehicle velocity measurement
- utilization of GPS
- odometer implementation
- engine oil temperature measurement
- structural stresses measurement

Some of these problems have already been solved but need some degree of rectification; others are yet to be worked upon. Others have been suggested problems of capstone projects.
The requirements for the development of projects are guided by the rules of the Baja SAE Project and limitations of cost, space, weight, robustness to vibration and ease of maintenance.
Three of the problems have been cases of study for the PBL and allocated to the courses of SEL0358 Transducers, SEL0435 Electronic Instrumentation and SEL0384 Laboratory of Digital Systems:

- fuel level measurement
- engine oil temperature measurement
- engine rotation measurement.

The main contents of the engineering courses involved in this PBL proposal are still presented in the sequential and traditional way. However, compartmentalization among contents should be minimized, which requires skill, criticism and creativity.
Figure 2 illustrates the structure of the PBL proposal and Fig. 3 the simplified case used to start its implementation.

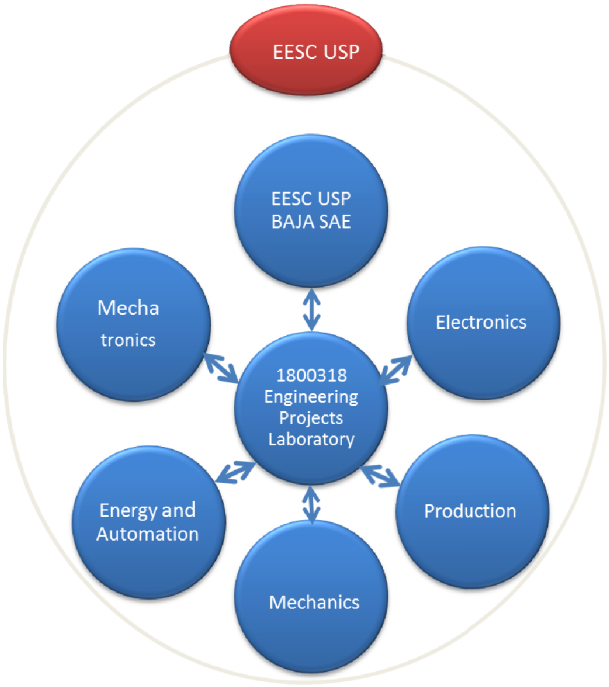

Fig. 2 PBL proposal and related engineering degrees in EESC-USP

C. Students Assessment
The credits for the course in which the projects are being developed are independent of the credits offered by the integrating laboratory course, and thus their assessments are independent. The assessment of the integrating laboratory course is based on the students' participation in assigned projects, discussions and seminars. For this assessment, indicators have been proposed by the participants and teaching staff. The self-assessment procedure is also included.

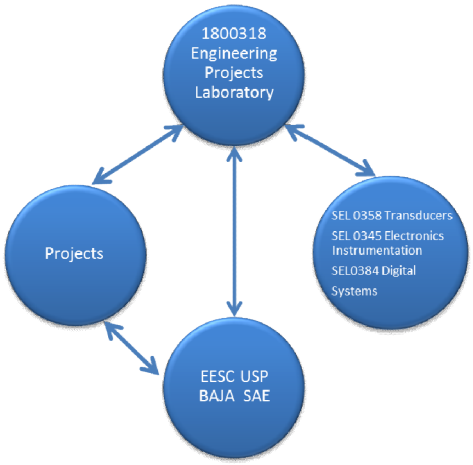

Fig. 3 illustrating a simplified case

D. Course Assessment
The assessment of the effectiveness of the Engineering Projects Laboratory course contains three components. The first concerns the improvement of the academic performance of students participating in the projects, and can be accounted for at the end of each school year. The second will be evidenced by the performance improvement of the Baja SAE Team during the competitions every year. The third form of assessment will be through open questionnaires answered by the students and teaching staff every academic semester.

5. Benefits and Challenges

A. Benefits
The implementation procedure here presented brings a number of benefits which follows:
a) There is a possibility of immediate and continued interaction among the participants of the projects.
b) Allows real interdisciplinary problems to be addressed, with the possibility of short-term implementation and testing.
c) Allows, easily, the inclusion of other existing competition teams existing in the EESC-USP.
d) It is easy to incorporate interested faculty members or the other way around.
e) It brings flexibility to rearrange groups of students involved in the projects.

f) There is a possibility of maintaining students in projects even after the end of the courses in which the projects were initially addressed.
g) Motivating the engagement of students in the Baja Team or in other existing teams or even the formation of new automotive or robotics competition teams.
h) Motivating the engagement of post-graduate students as TA's in the courses involved in this proposal by offering training in the methodologies of PBL which can be useful in their academic life.

B. Challenges

Not as disadvantages, but as challenges to be faced, we can highlight:
a) Bring in the institution a debate on a curriculum reform and also experimentation of new pedagogical proposals.
b) Overcoming the resistance of faculty members to abandon the position of repassing of knowledge and adopt the attitude of co-participants in the search for knowledge to solve real problems of engineering and their socio-economic and environmental consequences.
c) Introducing the regular workshop with specialists in the field of education.

6. Conclusions

In this paper an approach of integrating engineering courses is used to implement a PBL methodology. To achieve this goal a laboratory course offered to different engineering areas was proposed.
The laboratory course is sought such that activities of different engineering courses and different specialties are used in solving previously established problems arising from real needs and with the short and medium-term solutions applicability. As discussed above, the problems are raised from Baja-SAE race car developed by the EESC USP Baja Team, organized as a small business, which acts as an aggregating element. The students' response has been very positive since they are highly motivated to work on real world problems.

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