Title: Problem based learning in engineering: methods of evaluation and difficulties in a Brazilian discipline

Anna Paula Galvão Scheidegger
Universidade Federal de Itajubá

Camila Pereira Pinto
Universidade Federal de Itajubá

João Batista Turrioni
Universidade Federal de Itajubá

Juliana Helena Daroz Gaudêncio (juliana_hdg@yahoo.com.br)
Universidade Federal de Itajubá

ABSTRACT
This work discusses the problem-based learning approach adopted in an engineering discipline conducted in partnership between a Brazilian university (UNIFEI) and a multinational company in Brazil. It aims exploring difficulties encountered by students during the development of the project and discussing evaluation methods of the discipline.

Keywords: Problem-based learning, European project semester, Engineering

Introduction:
According to Ribeiro and Mizukami (2005), the world is undergoing a process of rapid change, attributed to the recent technological revolution. Once much of the engineering knowledge covers immediate technological applications, still according to these authors is needless to say that this revolution also affects the Engineering Teaching since it promotes a rapid expansion in the knowledge base and, at the same time, an unpredictable obsolescence of much of what is learned at Universities.

Hence, only the traditional teaching methods do not seem to be able to develop the knowledge base necessary for engineering students and the skills required by the professional market, as for example: independent learning, critical thinking, initiative, creativity, and teamwork, among others (Ribeiro and Mizukami 2005, Noordin et al. 2011). As engineers must present both the technical knowledge and skills required by the market, in recent years, the demand for methods and effective teaching strategies that may improve the quality of university education has grown, as indicated by Lee and Lim (2012).

Thus, Martins (2002) affirms that an educational revolution is taking place: previously, the teacher was the center of the educational system; while now, we are searching for a student-
centered learning, as they learn best when they actively participate in solving a problem. In Engineering Teaching, the Problem-Based Learning (PBL) is a popular approach that is being implemented in universities around the world to form versatile engineers (Noordin et al. 2011). Ribeiro and Mizukami (2005) claim that this methodology has gained acceptance by providing a satisfactory response to this new education challenge.

The PBL is, therefore, a student-centered teaching strategy in which the students learn to face real problems and to work as a team, and become responsible for their own learning, while the teacher becomes a facilitator (Echavarria 2010).

Cockayne; Feland III and Leifer (2003) argue that a large number of engineering students, both undergraduate and graduate, must attend at least on PBL class, in which the main objective is to create a situation where the skills and the knowledge experienced are analogous to that in the real world. The advantage of this environment is that students can rely on additional support, time for reflection, lessons, or feedback that may not be possible in the real world.

On the other hand, Ribeiro and Mizukami (2005) believe that the response to this new education challenge is not simple, because if on the side of the teacher is necessary to reorganize the educational process and rethink the classroom, on the side of the student is necessary to find the best solution to the problem, considering and overcoming the restrictions imposed by the educational context, such as time, resources, etc. Mitchell and Delaney (2004) and Cavalcanti et al. (2008) also emphasize that educators have to deal with the difficulty of defining the best way to assess the students and their individual contribution to the resolution of the problem, their collaborative effort or contribution to the team and their formal learning.

So, considering the importance of the PBL approach to engineering education, it was proposed and created the "Project Semester" discipline in the Production Engineering course from the Federal University of Itajubá (UNIFEI); result of a partnership between the University and a multinational company. However, some difficulties, not only regarding to the conduct of the projects from the students’ point of view, but also to the assessment methods to be adopted by the teacher, were found and overcome during the course. The authors, who participated in the discipline as teacher or tutors, believe to be important to present the project developed, to disseminate the importance of the approach to the Engineering teaching, and to discuss the difficulties in order to provide assistance and details to the interested ones.

Consequently, considering this context, the interest of this article emerged, which aims: to examine, under the perception of the tutors, the difficulties encountered by students during the development of the projects and to discuss the methods of evaluation adopted in the discipline.

This article is organized into five sections. In this first section, it was contextualized the issue and presented the rationale for conducting this work, in Section 2 it will be presented the PBL theoretical background, followed by the research method in Section 3. Section 4 describes the development of the research, while Section 5 presents the conclusions.

Theoretical background:

Problem-Based Learning (PBL):
PBL is a teaching methodology that was formalized in the 50s and 60s, for medical educators to meet the knowledge expansion in medicine. By presenting complex cases of real patients as an excuse for learning, PBL demanded that students resort to a base of multidisciplinary and integrated knowledge (Allen et al. 2011).
Also according to Allen et al. (2011), in the learning cycle idealized by PBL, students work in teams and learn by solving real problems of medicine through the scope definition and understanding the limits of the problem. The teams perform questions based on gaps identified by them and use them to guide research outside the classroom, which is divided among the team members. When the team meets up, each member presents his discovery and discussions are generated by integrating their new knowledge and skills in the context of the problem. As the team is moved through stages of a complex problem, new areas of learning need are still being defined during the search of the solution. Finally, the solution will be an accurate diagnosis and successful treatment recommendations to the patient.

As PBL explicitly addresses some of the shortcomings of science education, this approach migrated and has been used as a way to integrate basic training in science and engineering education in different countries of the world such as Australia, Canada, Denmark, Mexico, United States, Argentina, Peru, Colombia and Brazil (Echavarria 2010).

According Echavarria (2010), a significant number of universities, schools and institutions have been implementing certain changes in the philosophy and engineering methodologies learning and teaching process to find the main purpose of engineering education, which is the application of theory in order to solve real world problems.

Despite the importance of PBL in engineering education, when considering the amount of engineering courses in Brazil, it appears that the number of studies involving this methodology is virtually meaningless, because these initiatives are very recent and limited to specific disciplines within the engineering course lasting at least five years (Campos et al. 2011).

**European Project Semester (EPS):**

In European countries, the practice of PBL is more widespread among engineering courses through the EPS approach. The EPS was created by Arvid Andersen in 1995, at the University of Copenhagen, Denmark and it is a program in which engineering undergraduate students from various countries work for a semester in interdisciplinary projects addressing real business needs (Andersen 2004).

According to Andersen (2004), the EPS raised in 1987 and came in the context of complying with the European international development through funding programs that aim to provide international exchanges for European students. Since then, an increasing number of students, also from universities outside Europe, have applied annually EPS for the improvement and harmonization of the European / global higher engineering education.

In each semester, a maximum of 50 international students from approximately 12 different countries and from different areas are approved to participate in the EPS. According to Andersen (2004), the students learn during the semester how to manage engineering projects. Each team is involved in the definition, organization, planning and navigation of his own project. An academic supervisor and a company advisor are allocated to each team and there are mandatory weekly meetings where the project development, the teamwork problems and so on are discussed. From these weekly meetings, the students learn good meeting techniques and, in addition, skills such as self-confidence, responsibility and English communication are improved. The capacities to listen, discuss and negotiate solutions are also developed.

Finally, Andersen (2004) concludes that the main idea of EPS is the active participation of students and thus, featuring a collective workgroup with international members towards a social project. As work is performed by an international team, the participants learn how to
engage, understand the meaning of the word “synergy”, and also learn to appreciate diversity and differences.

**The role of tutors in Problem-Based Learning:**

According to Campos et al. (2011), the tutor who will accompany the group during the execution of a PBL project must acquire new skills when compared to a teacher who works in structured disciplines. The tutor must learn to facilitate and guide student learning rather than giving all the necessary data and information and should also allow students to determine for themselves what they need to learn and what resources need to be used, for instance, human resources and university structures. The tutor will make the learning process always being centered on the student and not on the teacher, i.e., the teacher is supposed to facilitate the student learning rather than giving him the answer / end solution. The role of the tutor will be offer the opportunity for students to learn to learn.

According to Dr. Walsh (2005), it is necessary for tutors to find the right balance between mastering the learning and "retreating" from the student learning. This requires a considerable judgment by the tutor and a willingness to reflect on the learning process and to perform feedbacks with students. New students probably will benefit from more structured curricula. The tutor should be able to adjust the level required of each student group.

Figure 1 shows the relationship between teacher (tutor) - student and their tasks / skills in PBL.

![Figure 1 – Problem-Based Learning model](source: Campos (2012))

**Methods of evaluation:**

According to Campos et al. (2011), the formative evaluation is used to monitor the process of teaching and learning from students and teachers (tutors). Regarding the students, it enables to identify the difficulties encountered by them during the execution of the project and also redirect them to other paths. For teachers (tutors), the assessment allows to rethink the role in driving the project and the directives given to the group.
In formative assessment, focusing on the learning process in a perspective of interaction and dialogue also puts on the student, not just on the teacher, the responsibility for his progress and his needs. But for this to occur, it is necessary the student to know the goals that must be achieved, as well as the criteria that will be used to verify and analyze his learning progress. Thus, formative assessment provides to the students greater responsibility about their own learning process and autonomy (Fernandes 2006).

**PBL project documentation:**
According to Campos *et al.* (2011), students must learn to keep precise records of team decisions and tasks developed along the stages of the project in order to assist them in the management and monitoring of project progress.

University of Aalborg, Denmark, wrote a sort of guide that describes the principles of PBL and how projects developed by this approach, within the university, should be developed by the people involved. Barge (2010) reported that the institution systematically gathers its data to document the PBL model for internal and external purposes, to develop an internal system of teaching model improvement, to document current and emergent local practices, to relate contextualized educational practice and theory, and finally, to relate the data and research findings of other international studies.

**Research method:**

**Methodological framework:**
The interest of this paper came with the consolidation of the partnership between a Brazilian University and a multinational company, which enabled the creation of a discipline called "Project Semester", following the PBL approach. The design of this course was the result of the identification of the importance of PBL for engineering education, after years of an author’s teaching practice, and after performing a horizontal scan of the literature. This initial search of work enabled the authors to identify the difficulties and challenges in conducting PBL courses.

During the semester, the authors actively participated as tutors or teacher conducting the course, observing the student performance and hence the evaluating them. During this participation, and after a deep scan of the literature, the objectives for this study were defined; the theoretical framework was constructed and it was discussed the research method that best fitted to this work.

According to Silva and Menezes (2005), surveys can be classified according to the nature, purpose, approach and method. Regarding its nature, the research can be classified as applied that, according to Marconi and Lakatos (2010), studies a problem related to the applicability of scientific knowledge.

Referring to the purpose, the research can be classified as descriptive as it describes the characteristics of a given population, and observes, records, analyzes and correlates facts without manipulating them (Cooper and Schindler, 2011).

Since the research focuses on the processes of the object of study rather than its structure, it was decided to use the qualitative approach, in which the subjective reality of individuals involved is considered relevant to the research development (Martins, 2012).

Finally, regarding the method it was adopted the action research that, according to Mello *et al.* (2012) is an approach in which the researcher and the client collaborate in developing a
diagnosis and also in solving a problem by implementing an action. The methodological framework of the research is summarized in Table 1.

**Table 1 - Methodological framework**

<table>
<thead>
<tr>
<th>Methodological framework</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Nature</td>
<td>Applied</td>
</tr>
<tr>
<td>Purpose</td>
<td>Descriptive</td>
</tr>
<tr>
<td>Approach</td>
<td>Qualitative</td>
</tr>
<tr>
<td>Method</td>
<td>Action research</td>
</tr>
</tbody>
</table>

**Methodological procedures:**
To conduct the research, it was adopted the structure proposed by Coughlan and Coghlan (2002). In each partial delivery of activities by students, i.e., approximately in every two weeks a new cycle of research was initiated.

The pre-phase of context and objectives definition was presented previously in Section 1 and Section 3.1. So the next step was to define the techniques of data collection. According to Cooper and Schindler (2011), when considering the scope of qualitative research, several approaches are available, including: exploratory interviews, observation, questionnaires and document analysis. These were the means used to collect data in this study.

Later, data were returned to the involved ones and the tutors, teacher and students talked about the results of last activity delivered and planned actions for the next activity. Over one to three weeks, the whole group implemented the planned actions, i.e., the students implemented the actions under their responsibility, such as update the schedule, visit the company, design the RACI matrix; the tutors performed individual and collaborative assessments, and supported the development of activities, and the teacher planned theoretical topics to be discussed, based on the needs of each project, followed the reviews and made the necessary adjustments. Finally, a review of the planned activities was hold and a new cycle of research was initiated.

The cycles were conducted over an entire semester. During the period there was a fixed two-hour meeting among all stakeholders of the project on Fridays and another fixed weekly meeting between members of the group and its tutors. Moreover, scheduled visits to the company were also undertaken by all involved and weekly meetings with company tutors were hold by phone.

**Project development:**
The “Project Semester” discipline has begun with a partnership between a multinational company and a Brazilian university, through a contract signed between the parties, where the responsibilities of both were set so that the project could elapse in the best possible way for students, company and the University.

The course officially began in the second semester of 2013, but the negotiations to consolidate the partnership began in 2012, when the company contacted the University to invite it to participate in a company project called "Ambassadors" which aimed to bring together students from target-universities in business environment through visits and lectures and stimulate the professional interest of the students. In this same period, the University, in administrative restructuring process, was looking for a company that agreed to participate in an
experimental deployment of student-centered discipline, according to PBL approach. Then with these objectives the partnership has emerged, giving students the opportunity to be the pioneers in this type of learning in the Production Engineering in Brazil, along with the university and the industry.

Signed this union, the problems proposed by the company were presented to the students: real problems which the company tutors, called ambassadors, must deal daily in the exercise of their functions. Topics from different areas were established so as not to favor any team.

At random and given a size of not very big team, but that could at the same time develops quality solutions, the students were divided into four groups of approximately eight members each, totaling thirty-two students in the discipline. So there were four projects involving the areas of Lean Tools, Analysis of Cost Control, Inventory Management and Cost Reduction.

After the definition of the teams and their project scope, the students started to work. For this, as the first activity the students started the organization and division of labor that was done by establishing the responsibilities of each member using diagrams as RACI Matrix and SIPOC and setting the schedule of activities to be delivered. Finally, through visits, meetings, studies and research, the students began to develop the best solution for the proposed problem, considering the restrictions imposed by the discipline, such as time and software availability at company. Students then had to seek viable and acceptable solutions through consultation and literature research, tutors’ guidelines and brainstorming with teachers, mentors and ambassadors, but so that no external experience influence or interfere the action or tool chosen for solving the problem. However, as mentioned earlier in this paper, despite the importance of the PBL approach, implementing it is still a challenge. Thus, throughout the development of the course and the projects it was possible to survey the main difficulties that the students found.

Among the main difficulties encountered, it is important to highlight those identified as most critical and common to all four groups. There are:

- Duration of the discipline and extension of the project;
- Scope and language alignment;
- Schedules and priorities reconciliation;
- Leadership (group hierarchy);
- Distance between the university and the company.

The duration of the project refers to the short time that students had to develop their ideas. A semester is a relatively appropriate period since whole dedicated to the development of the project. However, this was not possible due to the second difficulty found, the scope and language alignment, once the teams demanded a long time to understand in detail what was expected by the company and to make clear the business dynamics and the corporate language. This time required for aligning the scope and understanding the internal language of the company generated some delay in the development of solutions and therefore restricted time dedication of students to solve problems.

The schedules and priorities reconciliation was a problem on both sides. Students allege that project performance could have been better if they have had not the concerns of the end of the course, such as internship interviews, tests from other disciplines and the final works. It also was not easy for them to reconcile a time to meet the staff and ambassadors of the company to discuss the progress of the project.

As for the difficulty of leadership, in some teams, once they were classmates there were difficulties to respect the established hierarchy in the team, i.e., the positions and responsibilities of each member. This difficulty precluded, for example, that the project manager had levied
actions to correct possible delays and consequently ended up overloading some members, more responsible and committed to the discipline than others.

The distance between the company and the university was pointed out by the students by limiting access and the amount of visits to the environment, thereby restricting the collection of more precise information and details, checking available resources and delaying or even preventing the development of some actions.

Finally, the final phase of this project was on November 29, 2013, where students officially presented to the ambassadors and Directors of the company, as well as for teachers and administrators of the University, their main results and the best solution found to the problem. The company judged the performance of the team and all the solutions proposed were approved to be deployed in the company. The results were so good that the directors of the company approved at the same day the execution of the discipline on the next year. In the university, the teacher and tutors made a final assessment, supplemented by peer reviews, establishing the student's grade in the course.

In this article it was also proposed to discuss the method of evaluation in the discipline, since this challenge is widely discussed among specialists.

After consulting other published works and discussing the topic with other experts, it was defined the 360-degree assessment for the project, where students are evaluated by peers, clients and managers, i.e., by all parties. In this particular case, the evaluation took place in four stages:

Student-Student: a peer review in which each member evaluates classmates, according to some criteria such as contribution to the team’s results, giving grades 1-10 without repetition. That is, each member should order from best to worst colleagues in each criterion.

Tutor-Student: through continuous assessments, the tutor followed the progress of the project and the performance of individual students.

Teacher-student: periodic assessments, where the teacher punctuated the project deliverables according to previously established goals.

Company-Team: the ambassadors of the company evaluated the teams according to the development and results obtained, in previously scheduled visits.

Characterizing, thus, a formative assessment, as described in Section 2.4 of this paper, which also gives to the students a responsible role in analyzing their progress in the project and also their classmates progress and not just focusing on the teacher as responsible for evaluating the process learning.

Conclusions:
Despite the difficulties encountered, it can be concluded that the Problem Based Learning enabled students to develop skills not normally stimulated by the traditional teaching method, such as communication, teamwork and focus on problem solving. Another benefit observed was the students’ familiarization with the business environment before the actual insertion in the professional market. This was a point considered as very positive by the students who were looking for internship opportunities, since they have learned how to behave in dynamic and internship interviews and allowed them to see better know the areas of interest to work for. Finally, the experience provided them a real sense of professional environment, such as deadlines, responsibilities, follow up, etc.

Regarding the method of evaluation applied, tutors, teachers, students and partners of the company considered suitable as it allowed for a comprehensive analysis of the performance of all team members, with no benefits, e.g. in terms of friendship. It is worth mentioning that the
method without scores repetition, at first, led one of the teams to match score for all members to stay with the same mean, thus preventing individuals with very low grades. However, as a result of the evaluation itself, this "problem" was easily identified by tutors and criticized by the students themselves, as some were not satisfied with the results, since members who worked more received the same score as others that did not work.

Finally, the authors of this article believe that most of the difficulties encountered, is justified because it is the first initiative of PBL at the University and that these will be minimized in future executions. Furthermore, it is noteworthy that results expected by teachers, students and business partners for this first implementation were largely met, as well as the goals set for this paper.

It is hoped that this work stimulate interest and adoption of more teachers for the approach in question, as well as assist them in future planning and implementation of PBL courses.

References:


DR. Walsh, A. 2005. The tutor in Problem Based Learning: A novice’s guide. Hamilton, Faculty of Health Sciences, Mc Master University.


