The Management of Teaching and Assessment: Analysis of a Biomedical Engineering Course using the PBL Methodology

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Abstract

Engineering schools have been going through a global and effective change, with new relationships being established between faculties, students, and the available resources. Engineering students that have just graduated are being questioned whether their degree provided them knowledge and skills necessary to solve routine problems on their chosen profession. These questions could be easily avoided by the implementation of a new methodology in engineering courses.
The aim of this work is to discuss processes of the management of teaching and assessment implemented in the Biomedical Engineering course that runs at PUC-SP.

1. Introduction

The PBL (Problem/Project Based Learning) methodology could provide a solution to demands and problems faced by human resources, especially in the area of Engineering [1].

The PBL methodology involves the development of a set of skills that match the profile of a professional willing to work in an innovative way in companies having specialized and cooperative environments suited with innovation, drawing up and projects to gather funds for research support, development and technological innovation. To overcome these challenges it is necessary to develop a model of management for the teaching staff. This model must be committed with the principles of PBL and the profile of the engineer that the global market needs. This model of management must be efficiently coordinated to plan the activities of the teaching staff in order to determine the time that must be dedicated to administrative tasks [2].

One of the roles of the coordinator is to adopt principles that allow the development of works in meetings and committees that do not take up too much the teachers' time. According to the subjects learned in basic education, professionalizing and specific professional courses, the low previous knowledge in basic sciences and mathematics is one of the biggest challenges for the PBL implementation based on the Curriculum Directives for engineering courses in Brazil [3].

To overcome this and other challenges, instruments of continuous assessment have been used and critically analyzed by the course coordinator and discussed with the teaching staff, so that their interpretations could be used to improve the course and ward off the challenges that are constantly found in this methodology. The challenges faced by the teaching staff and the implementation of different instruments for the assessment of student´s level of learning, show that they are crucial in the development of a course structured according to the PBL methodology. The purpose of these reflections and analysis is to ensure a continuous process of rethinking about all the aspects that the new methodology is based on as well as the possibility of reworking them.

2. A PBL course project

The traditional teaching of engineering does not answer the new demands of professionals' needs in this area in the globalized world. As such, new teaching tools and methodologies have to be proposed and adopted. Within this context, a biomedical engineering course was created at PUC/SP based on the PBL methodology. This course complies with the clause in the report published by the International Commission on Education in the XXI Century, by UNESCO [4],[5], which defined the central pillars for education in the future. These principles are also included in the Institutional Pedagogic Project prepared by PUC/SP.

Although there are more than 1,000 engineering courses currently running in Brazil, the volume of work involving the problem-based learning (PBL) methodology in teaching engineering is practically none at the moment. In addition, the initiatives are extremely recent and restricted to a small number of specific disciplines within a course designed to be taken over a period of at least five years.

The extent of the challenges involved in student learning is vast, as it requires them to develop multidisciplinary skills and knowledge in biology, chemistry, mathematics, physics, information technology, and technological content. Newstetter [1] states that certain engineering courses, such as the one offered at the University of Aalborg in Denmark; and the University of Twente in the Netherlands, have adopted a series of educational practices based on those used in medical schools for more than three decades to draw up strategies to solve interdisciplinary problems and integrate knowledge.

Other methodological variations have been developed within the scope of PBL. Eberlein et al [6] present the characteristics of three methodologies commonly used in the teaching of sciences, comparing and contrasting them to make it possible to choose one; or a combination in any given situation. The three methodologies that the authors present are: Problem-Based Learning – PBL, Process-Oriented Guided Inquiry Learning – POGIL and Peer-Led Team Learning – PLTL, all these methodologies are centered on students and consider active learning.

Several institutions around the world are working with new methodologies for teaching engineering, e.g., Wim and Maria [7], who work at the University of Twente, in the Netherlands, have developed a PLEE (Project-Led Engineering Education) project, focused on group work. Xiangyun and Stojcevski [8] have developed, at the University of Victoria in Australia, an innovational educational approach based on problems, projects and practices for teaching engineering, adopting a technique for subject matter at institutional, community and corporate levels. Lima [9],[10] coordinates a work group with engineering students with strong industrial ties at the University of Minho, in Portugal.

According to Newstetter [1], PBL has been used as a means of integrating a basic graduation in sciences with a graduate degree in engineering. Based on this approach, student learning is non-linear, but allows them to explore the scope of a problem. If different groups of students are confronted with the same problem, they will likely choose different routes to solve it and quite possibly arrive at different solutions. Multiple topics and areas of knowledge are inherent in this process, which helps the students to build a more extensive, integrated and flexible knowledge basis.

In the project related with PUC/SP course, the curricular organization is no longer based on subjects, as the priority has shifted to a multidisciplinary course framework in inter and trans-disciplinary modules. The module is a planned unit and designed to be linked with or adjusted to other analogue units in various different ways, forming a functional whole. However, a module is a complete unit designed for learning in a full-time course environment and focused on a central theme that includes contents from different subjects. The course is structured to include five different thematic areas, which are dealt with progressively, as well as complement and integrate ways of learning over the period of the course (five years). The thematic areas are [11]:

1) Medical Images: the area of biomedical engineering that studies the principles, forms and mechanisms used to create images of the human body.
2) Medical Electronics: the area of biomedical engineering that studies the application of electricity in medicine and health, projects and the development of diagnostic equipment, therapies, control and data collection systems, as well as the analysis of biomedical signals and sensors.
3) Medical Informatics: the area that integrates computer sciences with biomedical information, the development of systems, management of information, simulations and data processing.
4) Biomechanics and Rehabilitation Engineering: the area that studies the mechanics of living beings, analyzing their movements and structures from a mechanical viewpoint, studies and develops prostheses and orthosis and mechanical efforts, as well as the study and development of materials and their properties.
5) Clinical Engineering and Health Management: a specialized area responsible for the application and management of biomedical technology to optimize health, manage hospitals, clinics, companies and people, as well as the physical and financial resources to ensure the quality of the health systems adopted.

Each area is treated specifically in each year of the course, with different concepts and levels of depth. An introduction is taught in the first year, together with the basic applications of the technology associated with the area of health. The second year includes analysis and discussion about the current and more specific applications of technology in the area of health. The third year includes presentations and discussions related to the applications, focused on the development of technologies specifically designed for the area of health. The fourth year includes discussion and analysis of the state-of-the-art of technology related to the area of health. The fifth year includes presentations and discussions of technological research in the health area and their practical applications in the day-to-day running of a clinic.

The thematic areas are structured into central and associated modules. The former are determined by the theoretical content and practices in each academic year related to each thematic area. The latter complement the existing content in the central modules and include the presentation of communication skills and expression, administration, legislation, entrepreneurial skills, bioethics, social inclusion and sustainability.

Each module consists of a set of problems and their related themes. The themes allow the horizontal integration (correlation of the same topic with various subject matters) and vertical integration (correlation within and between the basic and professionalizing subject matter during the various stages of the course).

The problems included in each module prioritize the technical, ethical and humanist aspects, the most important situations, the most likely to occur and those with the highest potential in terms of successful intervention.

The content is presented in different problems produced to make them accessible to students in self-directed study. The various contents are distributed throughout the five-year course, and taught based on their importance on the problem solving.

3. Challenges

The pedagogic project established tutors as the backbone of the course. To be a tutor one has to acquire an entirely new set of skills compared with those of a teacher giving courses structured into different subjects. Rather than giving the student the information and all the data, in classes and notes, they now have to adapt to facilitating learning and, indirectly, guide the student’s learning process. They should allow students to determine, by themselves, what they need to learn and, at the same time, know the resources they will need, particularly in terms of the university's human resources pool. Rather than telling the student exactly what they should learn and the sequence this should done in, the tutor should help students determine this independently. The role of a tutor should be to ensure the learning process is a process centered on the student and not the teaching staff. This represents facilitating learning rather than offering ready-made knowledge. The tutor should constantly provide the student the opportunity to learn how to learn.

There are a series of challenges related to these new roles for tutors in terms of implementing the course. First, the teachers giving the biomedical engineering course graduated in traditional BA/BSC degree courses, such as engineering, mathematics, physics and medicine. Thus their degrees, as for most university professors, did not involve questions of a didactic and pedagogic nature. As such, the professors interested in using this methodology tend to be those with some successful experience in the classroom, and not necessarily solely theoretical thoughts about the steps that should be taken in an environment of tutorials/seminars. The work involved in updating previously-qualified tutors will be essential in raising their awareness of and rethinking the skills necessary to be successful teaching with this methodology. However, the need was identified for some form of continuous and permanent activity in terms of both study methods and thought about the approach taken in tutorials.

To adequately perform the role of a supervisor and answer the questions about new theories that the students encounter during their research to resolve the problem set, it is absolutely vital that tutors constantly update their own knowledge and broaden their range of experience. "In problem-based learning, you never know what the students will ask, but they all expect their teacher to know what is going on." [12](p.19).

The need to resolve the aforementioned problem and the identification of certain other deficiencies mean that the student will have contact with other ideas and even people. Creative and innovative solutions may result from this type of interaction, and that do not just simply reproduce pre-defined models. This means that the tutor should bear in mind that it is their responsibility to develop the students' competence and more autonomy in terms of the learning process. According to Rué [13], in the efficient management of information and time available; as far as the work, study and research, both individual and in groups are concerned; it is attitudes such as flexibility, imagination, open mindedness to new information and methodologies; and self-regulation of any work done that are the fundamental conditions for the development of autonomy in learning.

These challenges discovered in the implementation of the course presuppose a tutor is also committed to teaching, research, development and innovation. These tutors should have an academic trajectory that has or will provide them with the requisite experience in defining problems, analysis, theories, experiments, syntheses, possible and acceptable solutions, as well as conclusions, evaluations and possible consequences.

4. The evaluation process

According to the content offered in basic education, professionalizing and specific professional courses conforming to the Curriculum Directives for engineering courses of Brazil, is the biggest challenge for PBL. To overcome this and other challenges, instruments of continuous evaluation were used and critically analyzed. The coordinators and the collegiate of the course discuss the matter, so that their interpretations could be used to ward off the challenges that are constantly interposed in this methodology.

The system of evaluating PBL methodology offers some extremely important insights in terms of improving the course and ensuring its continuation. According to Enermark and Kjaersdam [12], the students need to develop the necessary skills to solve unknown problems in their future profession and the capacity to learn how to learn, cooperate in and run projects. It is important too refine their communication with tradesmen, businessmen and industrial workers to solve problems that they encounter during their projects and straiten the interaction between teaching and research to stimulate the most innovative solutions. As such, the evaluations proposed for the course need to include questions about the students, the teachers, the coordination and the actual curriculum, as these all represent the elements essential to making any improvements to the course, and thus have to be included in the analysis and discussion.

The instruments for the evaluation proposed include new ways of evaluation involving not only the student, but also the teaching staff and the course itself. Forms were prepared for the evaluation, along with portfolios and exams, as well as meetings with both students and teachers. The purpose of these evaluations and their analysis is to allow for a continuous process of considering all the aspects that the new curriculum was based on, as well as their frequent rethinking. Another important aspect of the diverse evaluation instruments used is to contemplate the formative and summative characteristics of the evaluation processes, which are outlined below.

The formative evaluation should be used to monitor the teaching-learning process providing continuous feedback, both for student and teacher. As far as the students are concerned, this reinforces successful learning and helps identify the difficulties, thus providing a way to correct the course. For the teachers, the formative evaluation allows, by means of the constant feedback provided by the students, their roles to be rethought. Neither concepts nor grades will be attributed to these instruments.

The instruments used in formative evaluation at different pedagogic moments are: structured models, portfolios and progressive tests.

The structured models include pre-defined topics to evaluate the quality of student participation, teachers and the problems used, specifically in the tutorial sessions. The evaluation of problems involves filling out forms, such as a self-evaluation by students, student evaluation and of the group by the tutor, and evaluation of the problem by the group. The evaluation modules also include forms for self-evaluation by the tutor, for an evaluation of the tutor by the student, as well as of the group by the group.

The portfolio is the work produced by the student that can be presented for an evaluation of the various different activities undertaken during the week. The portfolio was considered as a means for the student to learn during the constructive process. The portfolio should simultaneously be a strategy that facilitates learning and one that can be evaluated. Portfolios were collected from support laboratories; the theoretical support given and from tutorials.

The students create their files by gathering the information they present collectively, illustrating the strong points and weaknesses of their development during the course. These files contain the results of the various laboratory work experience, their research of books and magazines, the problems solved during the modules, as well as the exercises and theoretical references studied. In this way, “the file is used to encourage them to reflect on the objectives associated with their learning and experiences during their graduate course, and to evaluate their own performance.”[14] (p. 90).

The progressive tests are multiple choice papers designed to evaluate cognitive skills, and are given once a year. These tests have not been given yet, as the first year of the course still has to be completed.

The summative evaluations are designed to analyze whether and how the student is progressing over the years. They also classify them at the end of a given period of learning (year, semester, month, module), according to whether or not they are used to. The instruments used for general evaluations at different pedagogic moments are written exams, triple jump assessment and final reports.

The written exams were considered cognitive evaluation instruments and include discursive, interpretative and multiple-choice questions. The aim of these exams is to evaluate the students' individual capacity to analyze and summarize answers to questions based on the subjects in the units studied.

In the so-called triple jump, at its first stage (the first hurdle), the students individually and in writing evaluate a problem situation in the same way as during a tutorial. At the second stage (second hurdle) the students find and select learning material about a given situation. At the third stage (third hurdle) the students should answer the questions posed about the subject matter involved in the problem.

Based on the partial reports made up the analysis of students' portfolios, the teacher prepares a final report at the end of the module or course/subject during which this instrument is used. The evaluation made comprises all the instruments that indicate, as well as whether the student can continue the course, a means of redirection in terms of course development.

The purpose of this system of evaluation is to develop the students' individual competence and autonomy in the cognitive environment as well as awareness of their responsibilities. For Rué [13](p.162), what makes a student more autonomous is:

- have a clear understanding of their style of learning and their overall strategies;
- adopt a communicative approach to the tasks undertaken;
- be willing to take risks and make mistakes;
- to do the lessons and individual tasks, independent to being evaluated or not;
- give importance to the formal concepts and their assimilation.

Furthermore, Rué [13] distinguishes three possibilities in terms of the concept of autonomy: one that emphasizes the technical nature of student autonomy; other that strengthens their cognitive dimension and another that highlights the capacity to be an agent in their own learning process, emphasizing a political dimension.

On implementing the course, it can be seen that not all the learning situations favor the development of student autonomy, although this is the intention of those responsible for the course. Another question refers to the students' interest and motivation to actually be more autonomous in their learning process given the favorable conditions for this type of development. Finally, it should be emphasized that even in determined contexts potentially favorable to the development of student autonomy, they do not have the same effect on all students.

As such, an efficient management process of the evaluation by the course coordinators is required; of the time available for learning and development of problems by the students; of the purposes of the study and research, as well as the individual and group work, by the teaching staff; and the preparation of instruments for the self-regulation of their own work undertaken by all are highlighted in this analysis as a fundamental characteristic for implementing the course.

5. Final Considerations

To overcome the challenges presented, it is essential to develop a management model for the teaching staff. This model should be committed to the principles of PBL and the profile of an engineer who wants to graduate to work in as innovative a manner as possible in the market.
This management model presupposes efficient coordination in planning the activities of the teaching staff and determining the time dedicated to administrative tasks. It is also the role of this coordination to adopt the principles that will allow the development of work in meetings and committees in a way that does not take up too much of the teachers' time. According to Branda [15](p. 221), these principles are:

> 1) ensure that everyone has the opportunity to be heard; 2) respect all the participants and their legitimate interests; 3) adopt a corresponding system of interdependent thought; 4)

speak concisely, without any ambiguities and without repeating what has already been said; 5) show a commitment to expressing possible disagreements; 6) know how to differentiate brainstorming sessions from meetings designed to take decisions; 7) facilitate decision making based on consensus, ensuring that this corresponds with the group's requirements.

Several levels of evaluation are necessary to measure the results of this management. The first, which already exists for the various graduate courses on offer, involves student evaluations of subject matter, format and the how well the course is organized. The PBL methodology adopted demanded the adoption of new instruments of assessment in order to contemplate the content, the competences and the skills acquired by the students. The difficulty is how to consolidate all the outcomes obtained by the instruments along the modules. The second level, which is on the agendas of institutions of higher learning, includes an evaluation of the implementation of the pedagogic project and teachers. This level of assessment is nowadays running and shows the needs of continuing learning to teachers that are working and an initial formation to those that are starting in the team using the PBL methodology. The last level, which is still not included in the results metrics of teaching management and the faculty staff, refers to the evaluation of the course coordination, and which deserves special attention from the committee for didactic courses and university management.

The challenges faced by the teaching staff of the course and the implementation of the evaluation instruments presented, show that evaluation and its analysis are crucial in the development of a course structured according to PBL. The purpose of these evaluations and analyses is to ensure a continuous process of rethinking all the aspects that the new curriculum is based on as well as the possibility of reworking them.

The changes proposed in the evaluation methods often tend to be forgotten, altered or omitted. "In many cases, maintaining the 'old' methods of evaluation by teaching staff allows them to pretend that the new model works, when they are actually following the evaluation criteria of the old system. This situation is counterproductive and should be frowned upon, mainly to ensure the evaluation method adjusts to the new philosophy of teaching and learning." [16](p. 55).

In the first evaluation of the process are highlighted both positive and negative points. Some of the positive points are: coverage of the issues evaluated in a more agreeable and relaxed fashion; more interaction between the student work groups; more student involvement in dealing with complex problems and developing an interest in research by seeking to acquire the skills to provide workable solutions to the problems set.

Of particular note among the points that need to rethought to generate the necessary changes in the organization of the course, and to better suit the main objectives in graduating from a course based on this methodology, are: a diagnostic of the previous knowledge of the students in areas such as basic sciences and mathematics; interaction between the teachers and the work groups; student preparation to understand the new methodology; planning of classes, exercises and laboratory work, as well as the evaluation process of the results obtained.

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