PROBLEM-BASED LEARNING
A Graph Theory Experience

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Keywords: Problem-based learning, Graph theory, Engineering education.

Abstract: Problem-based learning is a widely used technique in supporting different educational efforts, in which the core idea is to understand a real problem and, starting from this point, to seek the elements that are necessary to solve it. This work presents an experience that shows the results of applying this technique in a typical computer science topic in a classical engineering curriculum. Preliminary results obtained by using this technique are discussed, and some directions for future work are proposed.

1 INTRODUCTION

Problem-Based Learning (PBL) can be defined as an inquiry process that resolves questions, curiosities, doubts, and uncertainties about complex phenomena in life. A problem is any doubt, difficulty, or uncertainty that invites or needs some kind of resolution. According to (Barell, 2007), student inquiry is very much an integral part of PBL and problem resolution. In other words, PBL requires to establish a classroom environment that welcomes questioning and different points of view, and that thrives on collaboration among all participants.

PBL was first applied in the 60s, to health sciences teaching; in the Faculty of Health Sciences of McMaster University, Canada (Walsh, 2005), and in the School of Medicine of Case Western Reserve University, USA, trying to reach two fundamental goals: to develop problem solving skills in students and to place learning closer to real problems. This successful experience was rapidly spread from medical and professional schools to different disciplines.

Currently, this strategy is implemented as a learning environment in which the problem drives the learning, i.e., a problem is presented to the students before they rally acquire any knowledge. The idea is that the students have to discover that they need to learn some new knowledge, before they can solve the problem. If a problem is presented to a student before learning, for them it becomes a more motivating activity. This happens because in the seek of new knowledge, students really know why they are learning. Additionally, learning triggered by the need to solve a problem, allows to store that knowledge in the form of patterns that later, when necessary, can be easily retrieved.

Table 1 shows different learning structures in PBL and traditional learning methodologies (Garcia-Famoso, 2005):

One important point to remark is that PBL is not problem solving. Problem solving is the process used to solve a problem, so the students involved in a PBL process should be skilled in solving problems or, at least, in critical thinking. The case-based approach strategy, on the other hand, usually integrates existing knowledge; and therefore is not, according to the previous assessment, problem-based learning.

Keeping in mind the idea of a new learning paradigm, it is important to be aware that students should be guided towards solutions, and not be driven towards them. This means that tutors must let each group make a reasonable attempt at the set problems before intervening. This can lead to the fact that the same explanation should be given to different groups at different times.

Angélica Pinninghoff J. M., Contreras A. R. and Salcedo L. P. (2010).
PROBLEM-BASED LEARNING - A Graph Theory Experience.
In *Proceedings of the 2nd International Conference on Computer Supported Education*, pages 79-83
DOI: 10.5220/0002768700790083

Table 1: PBL and traditional learning structures.

Traditional Methodologies	Problem-Based Learning
Teacher centered	Student centered
Linear and rational	Coherent and relevant
Teacher as transmitter	Instructor as facilitator or collaborator
Students as passive receivers	Students as constructors. Active
Structured environment	Flexible environment
Individual and competitive	Co-operative
Assessment is a teacher responsibility	Assessment is a shared responsibility

The aim of this work is to show the results of introducing PBL in an engineering course. The inclusion of PBL in the course *Graphs and Algorithms* was accomplished having in mind that the key objective is to familiarize students with this model. Furthermore, the core idea is to show that this strategy can help in keeping students' interest when exposed to particular subjects. As expected, this approach presents some pros and cons, that are mentioned in the conclusions.

This article is structured as follows; the first section is made up of the present introduction; the second section describes some previous experiences in computer science related to the specific topic to be dealt with; the third section is devoted to our particular experience, while the fourth section shows the preliminary results we obtained with our approach, and the final section shows the conclusions of the work.

2 PBL IN COMPUTER SCIENCE

The traditional approach, for teaching specific topics in computer science, has been carried out in a sequence that considers the introduction of conceptual material in lectures. This material is complemented with a set of examples and a set of exercises. Sometimes, these activities are supported with practical work in laboratory sessions.

While pioneer work in PBL is associated to medical learning; computer science, as a discipline, is playing an important role in the application of this paradigm. We can mention the work in the School of Computer Science and Information Technology in Melbourne, Australia, which describes the experience of dealing with a specific topic: computing theory. We share with the authors the perception that by using PBL, students are more involved in the teaching learning process (Hamilton et al., 2003).

Positive results in computer science are also reported in (Chinn and Martin, 2005), where authors describe the experience carried out in the Institute of Technology, University of Washington, Tacoma. They combine the use of PBL with collaborative learning, and describe the design and implementation of such learning environment for courses in the beginning sequence of a computer science program. In computer science, the top-down approach of introducing different topics in lectures, reinforcing it with examples, and applying it as a kind of magic recipe, frequently leads to a lack of motivation, due in part to the nature of the topics, and in part (and most important) because its applications are not clear in advance (Hamilton et al., 2003).

A recent work (dos Santos et al., 2009) propose an innovative pedagogical methodology based on PBL to improve the learning effectiveness in software engineering, through the implementation of software factories, where students can work together to solve real problems.

PBL has been applied in graduate programs, as reported in (Linge and Parsons, 2006), that addresses the challenge of developing techniques for the effective teaching of computer network design, within the context of a master's program module and using a two-threaded approach, that comprised a problem-based learning thread and a conventional lecture thread.

3 TEACHING GRAPH THEORY WITH PBL

We have selected a specific course in computer science: Graphs and Algorithms. It is necessary to notice that the first step was to switch from the classic concept of chapter to the concept of unit. Units help ensure that all the various activities add up to meaningful learnings. Chapters, on the other hand, don't help to students' inquiry, because of the long period devoted to a chapter coverage, compared to the limited, and typically short time associated to a specific unit.

PBL can be carried out in a collaborative learning environment, which is the case under discussion, or it can be carried out as an individual project; in the latter it doesn't require cooperation among students. We have chosen the collaborative environment as opposed to a competitive one, where students are in a race against each other in order to get best marks, because this is the model they will find in a real working place.

3.1 Basic Considerations

We have selected Graph Theory based on the premise that this subject is widely considered conceptually difficult, but accepting that it's strongly connected to interesting and real problems. The traditional approach to this subject finishes a specific topic by showing a well known problem that students understand but that simply *appears*. We think that, from this perspective, students need to start a backtracking process to grasp how different concepts, previously seen, are assembled to obtain a solution. The PBL approach, on the other hand, encourages a search process having in mind the problem to be solved.

As a first step in the introduction of PBL, we decided to address the effort devoted to introduce the new paradigm in a specific unit: spanning trees. In simple words, a spanning tree is a set of nodes (e.g., points representing locations) having one condition; all of them are connected, i.e., given two arbitrary chosen nodes, there is a path between them. If we add the condition that the cost of connecting all the nodes is as low as possible, we are dealing with a minimum spanning tree. In doing so, we decided to implement a two thread view for the specific unit (spanning trees). It means that the PBL strategy was adopted when working with the specific problem concerning minimum spanning trees, as described in the next subsection, and as a second thread we supported students with conventional lectures, aimed to solve doubts and to provide key concepts.

3.2 The Particular Assignment

The specifications of the first assignment used in 2009 is shown below.

Main objective from the teacher perspective: To develop a graph-based model to describe an optimization problem, finding a spanning tree that solves the problem.

Learning objectives from the teachers perspective: i) to understand the benefits of modeling problems by using graphs; students have to construct a graph with labeled arcs that represent an instance of cost; ii) to know how specific algorithms (i.e., Prim and Kruskal) help to get spanning trees; iii) to develop the capability of modeling problems using graphs; iv) to implement a mechanism that allows to solve the posed problem.

The problem presented to the students is the following: This class is going to develop a physical connection using optic fiber, in order to have all the students connected to the university network. Due to economic constraints, students divided into groups, each of which is independent in terms of connectivity. Students belonging to a particular group can be connected among themselves and, at least one member of each group is connected to the university network, trying to find a minimum cost solution. It is necessary to determine how much optic fiber is necessary to implement the solution.

Students had to submit two written reports, a software operating on real data and a final presentation. Students were classified in groups of 3 or 4 members, randomly chosen. For the first report delivery, each one of these groups modeled the problem concerning only students involved in the group. This helped to understand the problem and to take into account the criteria of the group in order to decide the selection of a particular model. For the second report delivery, each group shares the collected data with all the other groups. In doing so, each group is able to implement a particular solution, based on their own models, by considering the complete population to be connected. The implemented solution is a software product which is described in the second report. Finally, each one of the groups developed a presentation for analyzing the experience from their own points of view.

4 PRELIMINARY RESULTS

In this first experience with PBL, the results have been interesting. Students showed a high level of interaction, and class attendance (that is not mandatory) presented very good ratings, compared to the traditional scheme. In the different steps during this experience, students became actively involved, giving opinions and asking for different concepts related to the topic.

It is a policy in the University, to ask the students for an anonymous evaluation about teaching. This is accomplished via web, so students do not need to be physically at the university; in fact, most of them answer the questions during vacations. Among the different aspects considered in this anonymous requirement, the ability to teach is evaluated. The main point here is that the lecturer for this class is the same one they've had for a long period, starting in 2000. The best previous mark the lecturer was given was 5.48 (in a 1 to 7 interval), whereas in 2009, with students emphasizing the PBL experience, this mark raised up to 5.8. This is illustrated in Figure 1.

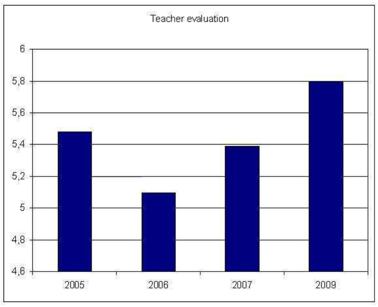

Figure 1: Teacher evaluation evolution.

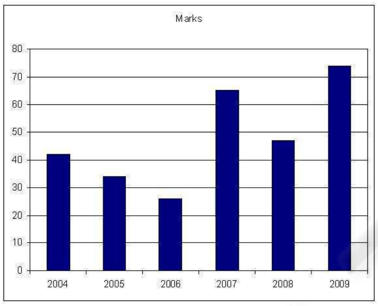

Figure 2: Evolution of marks in Graphs and Algorithms.

In respect to marks obtained by the students, a statistic for *Graphs and Algorithms* shows how marks fit in the different considered ranges. To simplify this, Figure 2 shows marks corresponding to the upper range (that goes from 4.6 to 7) starting with data from 2004. In other words, for the first time in six years, more than 70% of the students got marks in the upper range of the evaluation interval, whereas the previous top value recorded was 65% of the students.

Even though it is very early in the process to infer that PBL improves understanding, interest and, as a consequence, better marks, there is a strong evidence, based on the students' opinions, that it can be a helpful tool in the teaching process.

These increased marks, and a better perception about the teacher's capability for teaching may be a singular point. The novelty of this approach may lead to students to accept changes in the teaching-learning process more easily, and time will let us judge more accurately this particular issue. But we firmly believe that the positive outcomes PBL offers to the teaching-learning process should not be ignored. And this is the reason why we are encouraging this teaching strategy.

5 CONCLUSIONS

The idea of introducing a new teaching paradigm that challenges traditional teaching has been positively considered by the actors involved in the process. Students became gradually interested in the process, and from a passive attitude the level of interaction evolved to a very participative process.

Students have found that PBL approach is more stimulating than standard lectures. The need to deal with a problem that can be easily understood, although solving the problem may be a hard work, it motivates students to work in a collaborative perspective. To place the problem as a central issue that needs to be solved in teamwork, is a new approach for most of the students, where they understand and experience the effects of working in a non competitive approach.

The positive students' evaluation highlights the fact that they had the opportunity of working in different scenarios that had a very important practical dimension and realism.

It is important to notice that students were really involved in this process, we can illustrate this through a simple fact: in order to have a closer contact with the problem, they used Google Earth to obtain precise distances to work with. The importance of having an almost real problem acts as a motivating element. In future planning this fact needs to be taken into account. An important difference deals with evaluation. In this experience, the evaluation process considers a project in which students are actively involved, instead of passive assessments, as it is usually done in classic teaching.

The teacher's opinion is that the additional effort, devoted to material preparation and time for answering questions about the problem is highly rewarding, as students get, in their own style and time, a way to solve a particular situation.

No doubt, this experience needs to be spread out by including more topics and more courses, and there is still a lot of work to be done. Nevertheless, it seems to be a good starting point.

Future directions to be implemented in 2010, consider to increase the number of topics in *Graph and Algorithms*, in order to have a PBL strategy for a complete course. These topics should include graph coloring and planar graphs, among others. Besides that, it is time to include the PBL strategy in another course, and *Software Engineering* looks like a good choice.

ACKNOWLEDGEMENTS

This work has been partially supported by grant DIRDOC 07-014, University of Concepción, Chile.

REFERENCES

Barell, J. (2007). *Problem-Based Learning. An Inquiry Approach*. Corwin Press, 2nd edition.

Chinn, D. and Martin, K. (2005). Collaborative, problem-based learning in computer science. In *Journal of Computing Sciences in Colleges, Volume 21, Issue 1*. Consortium for Computing Sciences in Colleges.

dos Santos et al., S. (2009). Applying PBL in software engineering education. In *22nd Conference on Software Engineering Education and Training*. IEEE Computer Society.

Garcia-Famoso, M. (2005). Problem-based learning: a case study in computer science. In *III International Conference on Multimedia and Information and Communication Technologies in Education*. Formatex Research Center.

Hamilton, M., Harland, J., and Padgham, L. (2003). Experiences in teaching computing theory via aspects of problem-based learning. In *Proceedings of the Fifth Australasian Computing Education Conference (ACE'03), Adelaide*. Australian Computer Society, Inc.

Linge, N. and Parsons, D. (2006). Problem-based learning as an effective tool for teaching computer network design. In *IEEE Transactions on Education, Vol. 49, No. 1*. IEEE Digital Library.

Walsh, A. (2005). *The Tutor in Problem-Based Learning, a Novice's Guide*. McMaster University, Faculty of Health Science, 2nd edition.