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A Proposed Model for Applying the Problem-Based Learning (PBL) Approach in Engineering Schools

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Abstract. In the last decades there have been a great increase in engineering knowledge and a rapid rate of what students should learn. Also, there has been a rising need for gaining different skills. This led education institutions to try some student-centered learning approaches such as problem-based learning (PBL). This approach showed many advantages. Nevertheless, it suffers from some problems and disadvantages. In the present paper, many of the PBL trials have been reviewed thoroughly. A model for applying PBL approach in engineering education has been proposed. The model enables benefiting from the advantages of this approach such as increasing the students' motivation and increasing their skills. Also, the model avoids the disadvantages and cures the problems of the PBL approach.

Keywords: PBL, problem-based learning, engineering education, student-centered learning.

1. Introduction

One glance to the amount of knowledge that engineering students are expected to acquire is enough to show the dilemma that engineering education is facing. Dilemma posed primarily by a dramatic increase in specific knowledge and the rapid obsolescence rate of much amount of what students learn. Also, there has been a rising need in engineering practice for other kinds of knowledge, including skills such as problem-solving, teamwork, resources management, self- and peer evaluation and attitudes such as ethics, motivation, cooperation, self-directed and life-long learning. This led some worldwide engineering institutions to try some student-centered learning approaches such as Problem-Based Learning (PBL), which is considered a very effective approach in medical schools

Boud and Feletti [1] consider the PBL as one of the most influential innovations of the last decades, and define it as a carefully planned curriculum, which is entirely based on practical cases and on solving practical problems. PBL originated at McMaster University Medical School in the late 1960s. Later on, PBL spread to different disciplines, such as law, economy, business administration and engineering [2,3].

1.1 What is a Problem Based Learning Approach?

PBL is an instructional approach that uses problems to initiate, focus and motivate students' acquisition of specific knowledge and development of professional skills and attitudes. PBL offers an environment in which learning is triggered and guided by a problem, which may interdisciplinary drive the curriculum. In PBL students must define the problem, identify and acquire the skills and knowledge needed to solve it, and work through the solution. Students are required to take responsibility for their own learning as well as the groups learning, and hence they are both autonomous and dependent. Learning is self-directed and takes place in the context of a realistic problem. The manner of work is being close to that of engineers in industry [4].

1.2 Scope of the Paper

The literatures in the last decade show that many worldwide engineering institutions tried to introduce the PBL approach in their programs using different methods of application. Some of them applied curriculum-wide PBL. Others applied the PBL on senior students or on certain courses. In this paper most of these trials will be reviewed, and the problems they faced will be investigated. The merits and drawbacks of using the PBL approach will be highlighted. Finally, an application model for using the PBL approach in engineering education will be proposed. This model will avoid the problems inherent in PBL approach and compromises between the merits and drawbacks of applying this approach in engineering education. The different application modes and assessment strategies are beyond the scope of this paper. They are covered extensively in the literature [5-9].

2. Review of Previous Trials in Applying PBL

Many universities and engineering institutions around the world in the last decade tried to apply the PBL approach in different ways, some of them applied PBL as a

curriculum-wide. Others applied it as a part of the curriculum in one year, or at least in one course.

The following trials applied the PBL approach for the entire or part of the curriculum:

i) In Denmark Aalborg University had implemented the PBL approach in all engineering programs. The curriculum consists of 50% project work, 25% course work that support the project work, and the remaining 25% coursework in fundamental studies such as mathematics, physics etc. which is taught primarily in a traditional format. Project-based teaching at Aalborg university is strongly problem- oriented, and the projects are often practical industry problems [10, 11].

ii) In 2001, Manchester University in UK introduced the PBL as the primary teaching method for undergraduate engineering programs. The purpose was to organize the curricular content around problem scenarios rather than subjects or disciplines [12,13].

iii) In 1998, Monash University in Australia had implemented problem based learning in several courses within its civil engineering program [11, 14].

iv) In 1998, Central Queensland University introduced a PBL approach in four of engineering programs; civil, electrical, mechanical and computer systems engineering. All of these programs have adopted a problem-based model in 50% of the student's workload in each semester. The projects gradually increase in length and difficulty throughout the program [11, 15].

v) In 2001, the Dokuz Eylul University in Turkey has adopted the problem based active learning system in electrical and electronics, geological and geophysics engineering and mining engineering departments. The system is based on real engineering problems which values teamwork and the integration of information from different disciplines and it places the student at the center of the learning process [16].

vi) in 2003, the Turku Polytechnic University of Applied Sciences introduced the PBL approach in the program of Information Technology [17].

vii) In 2001, the Lahti University of Applied Sciences in Finland used a PBL approach as curriculum strategy in the mechatronics program [18].

viii) At Republic Polytechnic in Singapore a different approach has been developed. This approach is termed "one-day one-problem approach", where students spend one whole day working on a single problem [7].

In addition, many of engineering institutions or universities tried to apply the PBL approach in a single course such as: communication systems course in University College in London [19], administration theory course for the electrical engineering students at a public university in Brazil [20], digital electronics course at Chitkara Institute of Engineering and Technology In India [21], mathematics at college of Maryland in Cumberland, USA [22], mathematics in the Republic Polytechnic in Singapore [23], statistics course for engineering students at Slovenian University in Slovenia [24], and control theory course at Linkping University in Sweden [25].

3. Evaluation of The Previous Trials of Applying PBL

A deep study have been applied on all studies illustrated in the previous section to determine the merits and drawbacks of applying the PBL approach in engineering education, and to highlight the problems they faced. During this study, the following questions had to be answered:

How did they deal with these problems?, Are these problems inherent in the PBL approach or as an implementation problems?, What is the response of students and professors about using PBL in engineering education?, Is PBL suitable for application on all types of courses.

In this study, all these questions and more will be addressed. Then, depending on the findings a model will be proposed for applying the PBL in engineering education. This model will determine the conditions of using the PBL in engineering education and will formulate the specifications of courses that are suitable for applying PBL.

3.1 The Merits of Using the PBL Approach in Engineering Education.

Many advantages of using PBL have been reported by the previous studies as follows:

i) Improving the soft skills of students such as: problem solving, time and task managements, reporting, negotiating and communication skills [11, 13, 19, 26].

ii) PBL is more effective in motivating students and improving their study habits. It encourages life-long and self-directed learning [11, 13, 19, 26, 27, 28].

iii) PBL transfers the responsibility of learning to student side [13, 19, 26]

iv) PBL engages the students in a deep and effective learning experience and encourages their participation and commitment [8, 13, 26, 29]

v) PBL improves the skills of team working and team managements [11, 19, 26]

vi) PBL approach is favorable by students and they enjoy it [11, 13, 27, 30, 31].

3.2 The Drawbacks of Using the PBL Approach in Engineering Education.

i) The acquisition of knowledge using PBL approach does not follow a certain order. The student may acquire certain knowledge before acquiring its basic concepts, or may go deep through unneeded knowledge while skip a necessary knowledge. This is due the hierarchical structure of most of engineering courses where many topics must be learned in certain order. If the student missed the earlier topic, it will be very hard to continue in the next topic. This problem of the particular hierarchical structure of engineering courses is the most obstacle which faces applying the PBL approach in engineering education [7, 11, 19, 24]. This is the cause behind the success of applying PBL approach in medical learning as Perrenet et al describe the medical courses as “encyclopedic knowledge structure”, (i.e. any topic will not be affected by missing the earlier topic) [32].

ii) PBL approach doesn’t give the students sufficient theoretical background for the problem under study. This led to lack in basic knowledge and concepts. This issue is stated extensively by students [13], and it is clear from the low quality of the

theoretical parts in the student's reports [11, 13, 19]. The students in medical schools which apply the PBL suffer from the lack in the basic theoretical information while these students are excellent in application side [27].

iii) The PBL approach increases the time or the workload of students, because they have to seek knowledge. Also, they have to process this knowledge and apply it to solve problems. Team work is time consuming as well. Tasks such scheduling extra meetings, collecting work done by team members and building consensus do need more time. So, The PBL approach consumes more time than traditional teaching methods. This time may reach up to 300% both in class and out of class work [8, 11, 13, 19, 21, 26]

iv) It is difficult to use PBL approach in teaching the mathematics or analytical courses such as static, dynamics, analysis of electric circuits. The analytical and mathematical skills should be owned by each individual and the PBL approach doesn't give the student the chance to do more practice which is essential skill for learning mathematics or any analytical course [18, 23, 25, 33].

v) The assessment system used in PBL approach, which originally depend on teamwork activates, may give a chance to the ineffective student to pass the course depending on the teamwork only (i.e. lets him pass without learning the contents) [13].

vi) PBL approach, originally, is unguided learning process. Some studies emphases that the unguided or minimal guided PBL is significantly less effective than guided process that is specifically designed to support the cognitive processing necessary for learning [21, 34, 35]. Also, the unguided PBL may have negative results when students acquire misconception or incomplete knowledge [34, 35]

3.3 Recommendations for Resolving the Drawbacks of PBL

i) The problem of particular hierarchical structure of engineering courses, and the problem of lack of theoretical information and basic knowledge and concepts associated with PBL may be resolved by mixing the PBL approach with some lectures in a traditional way. This insures that the student has acquired all necessary information and basic concepts in its correct order.

ii) The long time needed for doing the PBL activities and the extra loading of students are inherent problems of PBL. These problems are obvious in case of curriculum-wide application of PBL, or when the student has many PBL courses in the same semester. In curriculum-wide mode, the engineering program should be five years or more if all or most courses should be taught using PBL, otherwise some courses should be omitted to limit the program by four years as most of engineering programs in the world. So, the curriculum-wide mode is not recommended for this cause. The problem may be resolved if PBL courses was limited by one or two courses in each semester. The rest of courses in the program may be taught in traditional way. This partial application of PBL is enough to satisfy all the merits of using PBL approach and gives a reasonable student loading in each semester without increasing program period.

iii) For reinforcing the individual analytical skills of students, the analytical courses and mathematics and similar courses should be excluded from teaching using PBL. The application courses which are rich in real world problem are the best candidates for applying the PBL approach. For example, in electrical engineering program courses such as electronics, electrical machines, high voltage engineering, industrial power system design and digital design are recommended

iv) The problem of assessment system, which may give a chance to an ineffective student to pass depending on the teamwork only, may be resolved by designing an assessment system where the mark of all team activities is less than the grade required for passing the course. Thus, a part of passing mark should be collected from individual work only.

v) The problem of the low effect of unguided PBL, where the students may acquire misconception or incomplete knowledge may be resolved by adopting the guided PBL approach, where the objectives and steps of problem should be clear to the students. As Paul A. Kirschner [35] showed in his study that the guided students can achieve more than double the knowledge that the unguided students can achieve in half of the time needed

4. The Proposed Model for Applying PBL

From the analysis and recommendations in previous section we can determine the main specifications and conditions of applying the PBL approach in engineering education as follows:

i) The program should be a mixture of PBL courses and traditional courses where the percentage of PBL courses does not exceed 25% of the total courses in the program, and at the same time does not exceed two courses in each semester.

ii) PBL approach is applied in teaching the application courses, while the mathematics and analytical courses are taught using traditional methods.

iii) The PBL courses should be inoculated with some necessary and key theoretical lectures.

iv) The PBL activates should be guided (i.e. the objectives and instructions are given and should be clear).

v) The assessment system should be well designed to prevent the ineffective students from passing depending on team work only.

5. Conclusion

Several engineering institutions in the world have incorporated the PBL approach in their engineering curricula in last decade for resolving some of critical issues of engineering education. In this study, a review of several trials of incorporating the PBL approach in engineering education has been done to recognize the problems of implementation and to extract the merits and drawbacks of applying PBL in engineering education. The reviewed studies showed the effectiveness of PBL approach in enhancing the soft skills of students such as problem solving, communication skills, teamwork, lifelong learning, etc. However, some of key drawbacks were reported, such as the weakness of theoretical knowledge and basic

concepts for students, extra time loading, inadequacy of teaching mathematics and analytical course, and the gaps in assessment system. In this study, a group of solutions and precautions have been recommended to achieve the merits and avoid the drawbacks of applying the PBL approach in engineering education. Finally, a model for applying the PBL approach partially in engineering education has been suggested. This model can satisfy all the advantages of PBL, while avoids the drawbacks at the same time.

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نموذج مقترح لتطبيق طريقة التعلم المعتمد على حل المشكلات في كليات الهندسة

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