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DESIGN AND INNOVATION WITH PROBLEM BASED LEARNING METHODS: AN ENGINEERING PERSPECTIVE

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ABSTRACT

Of the many diverse and fascinating challenges we face today, the most intense and important is how to understand and shape the new technology revolution. One would assume that the educational systems in particular for undergraduate engineering students would follow the same trend and that educating engineers should be affected by this paradigm change. Recently, there has been a political wind that is blowing in the direction of problem based and in particular, research based learning methods. Problem based learning and problem based project are teaching methods in which the students initially are presented with a problem to be solved, prior to any form of lectures. The learning shall take place as the students try to solve the problem. They will have to find the information they need, structure the information and evaluate if it is sufficient to solve the problem. The tasks given to a graduated engineer will often be problem solving or to create new products or services. There are challenges to integrate these learning methods with other criteria that involves innovation and creativity. In our department, we have experience with problem based learning in single courses and we will share our learning points. In this paper, we are presenting a combinational problem based learning as it is comprehended from an engineer perspective, and specifically sketch how we could activate different cognitive levels in a learning model that uses problem based learning.

Keywords: Engineering education, Problem based learning, Project based learning

1 INTRODUCTION

Technology is getting exponentially faster, more immersive and intuitive. We are at the beginning of a revolution that is fundamentally changing the way we live, work, and relate to one another. As the technology changes, so does the way we live and the way we learn and comprehend the world.

Although there has been a lot of technological advances and more to be in the future, there is still the question of the most effective way to teach and learn. The Greek philosopher Aristotle was absolutely certain that the golden grail of learning, was in the practical way of teaching when quoting: “For the things we have to learn before we can do, we learn by doing” [1].

The education model for engineers has mostly been based on “Chalk and Talk” with large classes/auditoriums and single discipline in particular at early years of study [2]. Today, we are still struggling with overcrowded auditoriums where students are bystanders for a lecture that varies between one or two academic hours. We still expect that our students learn by attending these lectures in addition to reading a book with the same thickness as their own head. In addition, we expect that they do not only understand everything, but also become creative and innovative and use that knowledge in their future carrier.

Although there are numerous ways of testing the teaching effects, there is still the question of how much the students have learned in general, and how well they can apply it in an engineering concept.

Developments in student active learning such as problem based and project based learning have had relatively little impact on mainstream engineering education. This paper is challenging how a problem based learning is comprehended from an engineer perspective. In addition, we are sketching up our model on how we activate different cognitive levels in a learning model that uses problem based

learning based on our experiences at the faculty of Technology, Art and Design at Oslo and Akershus university college, Oslo, Norway.

2 STATUS OF ENGINEERING EDUCATION

To meet the challenges with the fast changes of technology, there has been conducted several studies to determine the requirement for an engineer of today's industry [3,4,5]. In a European context, expectations of new engineering skills have been put on the agenda of the current practice, for instance, clearly stated in the accreditation of European engineering Programs and Graduates (Eur-ACE). Responding to such a demand, most of the engineering institutions in Norway are in an ongoing process of transforming from traditional paradigm, which is defined as discipline-oriented, lecture centered, and based on basic and applied technical knowledge, into new paradigm consisting of interdisciplinary, contextualized, student centered, and based on complex understanding of technical knowledge [5]. So far, most approaches used by institutions is the implementation of problem based oriented and project based learning methods. This is due to the fact, that the shift from teaching to learning is considered the most important innovative aspect of educating engineers, which consequently alters the transfer of knowledge in facilitating the learning process of the students [6].

Historically, problem based learning (PBL) as a concept originated in Canada (McMaster University) in the 60s, and was initially developed as a model for use in medical schools. The concept was eventually formed as an educational program, and at the end of the 80s, the Harvard University used a similar method in its programs, which became known as Problem-based Learning [7].

The case study method, the project based learning, and PBL are all student active methods and build on the known pedagogical concept of learning-by-doing and learning-by-discovery. Although, these concepts have much in common, it is important to be aware that they also have their typical characteristics. For instance, the Case Method / case teaching [8] is primarily based on situations that occur in a real professional practice, and can be included as a key element in a typically traditional teaching. Case study describes, for example, which actors are involved, and it is customary to add up the work with case studies in three phases, which is preparation, group and plenary discussion [9]. The project based teaching [10] is characterized by the fact that it often stretches over several weeks, and it is required that students use methods such as interviews, questionnaires and observation. In PBL [9] the focus is, however, more on "the development of knowledge and understanding, than on concrete problem solving" (ibid: 164). However, the focus is not on correct answers, but the tasks as a primarily process to motivate and obtain knowledge.

One would assume that PBL represents an educational concept for developing learning environments that promote and support depth learning. PBL is based on the humanistic view of man who claims that every human being must be seen as active, creative, able and willing to acquire knowledge and expertise. In addition, PBL touches the cognitive pedagogy, as described by Piaget, Dewey, Bruner, Rogers, Freire and others [11].

2.1 Definition of Problem Based Learning

PBL is generally characterized in terms of six typical principles:

1. The teaching is based on practice-oriented, authentic descriptions of situations, cases and case sticks.
2. Students receive close monitoring, support and assistance
3. Learning activities in groups following a progression and structure
4. Students are responsible for managing their own learning
5. Teaching, curricula and study course organized into interdisciplinary teaching blocks
6. Students will gain early contact with authentic tasks.

The main motto representing PBL is "always the problem first!" This is normally a radical change from the students' prior schooling. They are traditionally used to initially being introduced to theory rather than practice. In other words, a quantitative and reproducing concept of learning and knowledge. Although the problem based learning and project based learning have a common goal, which is offering students an active learning alternative, they may differ in structure. Pettersen [12] defines PBL in seven different stages 1. PROBLEM AWARENESS: Prepare basics and recognizing that a problem situation represents a challenge 2. PROBLEM DEFINITION: Narrow and define the problematic situation. What is the problem? What does it include? What relationship is included in it?

Are there one or several problems? 3. **PROBLEM ANALYSIS:** Finding possible ways to understand and explain the defined problem - meaning, causes and / or consequences. 4. **IMPACT:** Systematic analysis, evaluation and critical editing of what appears in Step 3. What do we need to learn to get a better grip and understanding of the defined problem? 5. **PLANNING AND SELECTION:** Formulating learning needs and learning objectives, and choose how to acquire and acquire the necessary knowledge and resources to understand, cope with or solve the problem. 6. **IMPLEMENTATION:** Implement learning or attempts to solve the problem. 7. **SUMMARY AND EVALUATION:** What the new knowledge or technology the group and group members have gained in dealing with the problem - and an assessment of the group's new understanding of the problem. These methods also claim to offer a deeper understanding of the theory and the ability to apply the theory to new problems or in new projects.

2.1 Comprehension of PBL amongst teachers and administrative leaders

Since PBL is an important tool applied in engineering education, how is it integrated as a part of the educational program at our Mechanical, Electrical and Chemical engineering institute (HiOA) in particular the program for electrical engineering? First, there was a need to understand how the concept is comprehended and introduced at administrative and teacher level. Consequently, we have made a small survey only to a selected number of teachers and the administrative leader. Although the number of answers are limited and the statistical significance can be questioned, we still believe that the results are good indications of how PBL has been practiced and comprehended in our department. We asked three main questions and the answers were as follows:

Question one: *What do you think characterizes PLB in engineering education?*

-The administrative leader replied: PBL is a teaching method that aims at practical understanding and motivation to practical knowledge. This kind of learning form can provide a fragmented knowledge as the students engage in a specific problem, but the students may not understand the whole curriculum.

-The teachers in general replied: PBL can be described as a form of learning which is aimed at a problem. If properly used, it will motivate students. It will also give students a better foundation and greater appreciation for being able to apply theoretical material. There is also a risk that this type of learning becomes inaccurate and superficial.

Question 2: *What is your goal with your PBL teaching?*

-The teachers responded in general: PBL by definition is not used at our program for educating electrical engineering students, and therefore one cannot say exactly what the objectives of PBL teaching is. However, if you look at the various student projects as a form of PBL the goal is to provide students with practical understanding and motivation for learning.

Question 3: *Do you think PBL have any contributions in learning?*

-Most of the teachers in the group agreed that good projects might have motivational effects. In addition, the students learn the methods that are required to implement specific projects.

3 INTRODUCING PBL IN OUR EDUCATIONAL PROGRAM

Based upon the European educational demands for engineering education, and the replies from the administrative and academic colleagues, we decided to test this concept in practice. The Medical technology program at Oslo and Akershus University College started in 2008. The program is a subprogram of Electronic engineering. The students can choose Medical technology or Automation after completing the first year as their specialty, and they graduate as Bachelor in Engineering. Most of the topics in engineering is given as traditional courses with lectures, problem solving and laboratory courses and in some cases additional project work. The lectures give the students the theory they need for solving the problems and the problem solving works as a rehearsal of the theory. The problem solving also prepare the students for the final exam when the exam consist of similar problems to be solved. As an argument of choosing such a pedagogical approach, one would argue that engineering education has a main goal of teaching the students necessary tools, methods and algorithms in order to obtain their goals. As an example, a set of mathematical tools as frequency and network analysis are needed in order to work as an electrical engineer, but how well can the student find the best tool for solving a real life problem?

We decided in 2010 to try to transform a part of the study in Medical Technology into more student active learning methods. Two courses in the fourth semester were chosen for this experiment. The first course was Signal processing and linear systems (10 ETCs). This course included five ETCs of

mathematics. The course can be described as applied mathematics where the aim is to learn mathematical tools like the Fourier transform and the Laplace transform in order for the students to be able to design signal processing networks. The other course in the experiment was Medical instrumentation (15 ETCs). This course included five ETCs of electronic circuit design. This course included description of different equipment used in medicine and was more knowledge based. The electronic circuit design part is often perceived as a topic that is easier to learn by doing than reading. For the PBL project, we chose an ECG instrument. The overall goal for the students was to build the necessary equipment for measuring the ECG signal on themselves. Figure 1 shows an overview of the PBL model used in Medical technology. The problems given to the students are in the left column and the learning objectives are in the right column. The first problem is to find out how ECG is measured.

Design an ECG instrument

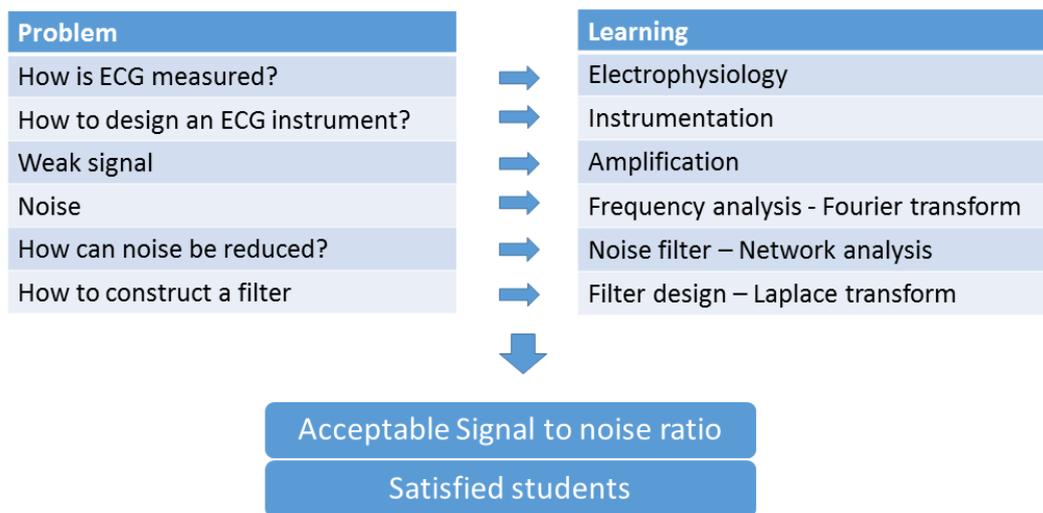


Figure 1: An overview of the problems and the learnings of the student active project.

This will require knowledge of how and why the heart creates an electrical signal. The next step is to design an ECG instrument. The students will then try to find out how the existing ECG instruments work. The first problem of the practical part is that the signal available on the skin is very weak (a few mV). The students must design and build an amplifier suitable for the purpose. This requires insight in types of amplifiers and electronic circuit design. The next practical problem is the noise that always comes together with weak signals. The intention is that the students will understand the need for understanding the nature of noise. This will require frequency analysis and the mathematical tool for this is to apply the Fourier transform. The next step is to find out how to reduce the noise. This can be done by filtering of the signal. The students must then understand how filters can reduce the noise and what kind of filters that are available, and what kind of filters that are suitable for reducing the noise in an ECG instrument. This requires insight in network analysis. The final step is to design and build a filter. The students will need to learn how to design a filter and the mathematical tool for this purpose is the Laplace transform.

The final goal for the students is to be able to measure the ECG signal with an acceptable signal to noise ratio. This may not be achieved in the first round and in this case, some of the steps must be revisited. In particular, the filter design is a step that will require a revisit. The noise in an ECG signal is complex and more than one kind of filter is needed, in order to achieve an acceptable signal to noise ratio.

The Fourier transform and the Laplace transform was lectured in a traditional way in Signal processing and linear systems in parallel with the PBL project. We thought that we could not expect the students to understand the need for these mathematical tools in order to complete the project. Although, we were hoping that the students would be motivated to learn these mathematical tools by understanding the need for them in the PBL project.

4 DISCUSSION

When discussing the student active learning used in our Medical technology program for engineering students, we may need to distinguish between PBL (Problem Based Learning) and project based learning. As indicated by the results of our small survey, there is a confusion regarding these terms at the administrative and teacher levels. However, more important than the distinction between these methods is the question: do they motivate and teach students what is required for a job in electrical engineering?

By definition, the PBL method focuses on the learning and the product may not be as important, while the project based is mainly focusing on the product. In a problem based method, the problems presented to the students can be purely theoretical and the result can be a report or a presentation documenting the learning outcomes. In a PBL model, the order in which the topics are learned is partly defined by the students and hence some topics may be overlooked. In an engineering education, there is a need for hierarchical knowledge structure. Many topics must be learned in a certain order, because missing essential parts will result in failure to learn and combine later concepts. Project based learning have a product as outcome with the learning as a side effect.

The 'Design of an ECG-instrument' as described in Figure 1 is used in this paper as an example of how to address a hierarchical learning structure. The problems in the left column are steps in the overall project that need to be answered in order to build the product. This is therefore a project based learning assignment used in the topic Medical instrumentation. This part of the project worked well. The students were committed to the tasks and actively searched for the information they needed and learned about electronic circuit design, production and trouble-shooting. However, the students were also supposed to learn some theory, like frequency and network analysis, and hopefully understand the need for the Fourier and the Laplace transforms. This combination did not work together. The students did not understand the link between the theory taught in the signal processing course and the given project. The theoretical topics were too far away from the practical part of the project. Retrospectively, we should have included some pure PBL tasks in the project work but with a certain order, which the teacher introduces during the course. As an example, giving a task to design filters to understand the nature of noise by frequency analysis and thereby enforce a study of the theory before they embarked on the search of a filter design. If the relationship between product and process is to be properly addressed, then it is important to consider what is expected of students and what assumptions are made concerning how they will do it [12].

In an engineering perspective, a PBL-like learning method would be more prevalent than PBL in the classical described method, as one chooses to relate to goals rather than being a "true believer" in the model itself. The problem encounters will offer the opportunity for the application of skills and knowledge requiring decision-making, the devising of solutions, creativity and problem solving [12]. When one moves from the educational-theoretical to the practical, based on empirical findings, it is understood that specific models are considered less important than having different working methods, which may activate the various cognitive targets. Taking this as a starting point, it is then possible to see a project as a "language and practice"[3].

Given the objectives of the PBL model, we believe that this kind of learning can be useful and motivating. Although one does not choose to introduce PBL as general practice, by having entire studies organized in line with PBL, we still believe that there may be much to gain from making use of various forms of PBL in engineering education. The classic seven-stage PBL requires training of both students and teachers and thus should be used as a general instruction with possible variations specifically designed for the objective of the course.

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