TEACHING ELECTRICAL ENGINEERING USING THE PROBLEM BASED LEARNING APPROACH

Suhana Mohd Said, Faisal Rafiq Mahamd Adikan, Saad Mekhilef, Nasrudin Abd Rahim
University of Malaya

Introduction

The Problem Based Learning (PBL) method is an innovative teaching approach which places an emphasis on problems as a starting point for the acquisition of knowledge. Its aims are twofold: it encourages students to think for themselves, and it helps the students acquire the necessary technical knowledge and transferable skills required in a certain course of study [1]-[3].

The PBL method was originally implemented in the training of medical students, and subsequently been adapted to other academic disciplines, including engineering. The PBL method contains many parallels to the problem solving scenarios faced by practicing engineers [4]-[6]. Realising this, the Department of Electrical Engineering and Telecommunication has started to incorporate elements of PBL into its teaching methodology, with the intention of improving the quality of teaching, and its subsequent quality of graduates.

The Department of Electrical Engineering & Telecommunication, University Of Malaya

The Department of Electrical Engineering, University of Malaya was established in 1959. Its mission is to educate and mould world-class undergraduates and postgraduate students that would become nation builders, knowledge seekers and innovators [7]. Amongst the objectives of the Department are:

- To produce world-class graduates/engineers capable of identifying and formulating a solution to an engineering problem innovatively
- To produce graduates with broad engineering skills and awareness
- To develop strong relationships with industry
- To develop new knowledge and cutting edge technologies in improving the quality of life

Central to the underlying themes of the objectives are the ability of the Department's graduates to think critically, and propose pro-active solutions in their careers. They must also be able to communicate their solutions and ideas in an articulate manner, and see through the implementation of their projects efficiently and within the time constraints set [8]-[9]. Given such lofty expectations, it is appropriate that the Department take the necessary steps in order to hone the relevant transferable skills expected of such a graduate. In the following section, the relevance of PBL in teaching engineering as perceived by the Department of Electrical Engineering, will be discussed.

Elements of PBL in Teaching Engineering

PBL methodology, and its role in developing transferable skills for an engineer

The PBL method is a departure from the conventional teaching method at the tertiary level, where a course typically consists of a series of lectures. In such lectures, the interaction is mainly one-sided: the lecturer speaks for most of the duration of the lecture, followed by a brief question and answer session. Conversely, the PBL session begins with a problem proposed by the lecturer, and the student is expected to devise a solution (or solutions) to the problem based on one's own initiative, be it from the existing body of knowledge, or through further reading. These solutions from the different students will then be presented and discussed within small discussion groups, with the lecturer now acting as a facilitator for the discussion. These discussion sessions encourage two-way discussion between the lecturer/facilitator and the students, and serve as a platform for the germination of other possible solutions and ideas which may not have been thought of by the individual members of the group.

Table 1 shows the similarities between the stages in the PBL learning process, compared to a typical project cycle encountered by a practicing engineer, and the corresponding transferable skills involved during each stage. An example of a PBL project is the design and implementation of a solar car. Such a design project could exist in industry, for engineers to design a solar car for mass production, for example. Therefore, we start to see the parallels between PBL and a real project cycle; i.e. that the PBL scenario as far as possible tries to present the learning process that emulates a realistic situation that could occur in daily life. The intent is to challenge a learner with problems found in practice both as stimulus for learning and a focus for organizing what has been learned for later recall and application to future work.

The first step is to first identify the main problem. In some cases, the problem is explicitly stated, either in the question stated by the facilitator in the example of PBL, or a project brief as presented by the customer in an engineering project cycle. However, in many real-life situations, the context in which the question is posed is vague. There may be a large amount of accompanying data, for example statistical or financial data regarding the feasibility of marketing a solar car on the open market, which the engineer has to sift through to identify the relevant details. There will also be situations where the data presented is incomplete. These situations require analytical skills, for example the technical knowledge to read and understand the data sheets given, or the accounting background to make sense of the marketing figures presented. Therefore, in a PBL exercise, a facilitator should be perceptive enough to include such 'hurdles' when setting a problem for the students.

Once the main problem has been identified, efforts should be made to solve the problem. A problem such as the solar car requires knowledge of the various engineering disciplines (the ones in bracket) – structural design (engineering design and manufacturing), power electronics (electrical), suspension and propulsion (mechanical), ergonomics and safety (civil and biomedical), energy cells (chemical) and environmental issues (environment). In a PBL exercise, different students will be assigned different aspects of the design process, and are expected to think through the possible solutions through research, followed up by a brainstorming session. The relevant skills include critical and lateral thinking skills to offer creative solutions to the problem at hand, and they must be guided by the facilitator through thought-provoking questions. In a working environment, such skills are invaluable, with the difference being that a facilitator is no longer available to guide through one's thought process, so an engineer must be able to think independently as a result of training at university.

The next step is to evaluate the possible solutions, and propose the optimum solution, be it in a PBL situation, or an engineering project. In such cases, impeccable communication skills, both written and oral, are essential, in order communicate the proposal effectively, especially in a working environment when an engineer has to 'sell' the idea to the client, and impressions play an important role.

Once a proposal has been approved, implementation of the project requires the relevant technical skills and ability to work in a team. Time management skills are of the essence, as the project has a deadline. It is hoped that by incorporating PBL during the course of study for the undergraduate programme in the Department, these skills will be gradually acquired by the students. In the following section, we will propose the format through which the PBL method should be incorporated into the overall structure of the undergraduate course at the Department.

Table 1: PBL Process

	PBL Process	**Project cycle**	**Skills acquired**
A	Identification of the main problem	Project brief	Analytical skills
B	Research for solutions, resulting in a number of different possible solutions	Brainstorming and Research	Critical and lateral thinking skills
D	Evaluation of possible solutions, and proposal of the optimum solution.	Project proposal – presented either orally or in the form of a report	Communication and written skills
E	Implementation of solution	Implementation of project	Technical skills, teamwork
F	Solution delivered by deadline set by facilitator	Project delivered by deadline set by the customer.	Time management skills

Incorporation of PBL in the coursework structure for the Department

In order to devise a more cohesive approach to the implementation of PBL into the structure of the undergraduate course, it is suggested that the PBL content be gradually introduced through the academic years, as shown in Figure 1. The PBL method is based on the fact that in order to solve problems, the student must be able to utilize his or her existing body of knowledge. The PBL content in a first year course will be minimal, because a first year undergraduate at the department will only have STPM- or matriculation-level knowledge of Mathematics and Physics, and therefore the types of PBL problems are limited to simple problems that can be solved using this level of Mathematics and Physics. Other fundamental subjects in Electrical Engineering and Telecommunication taught in the first year, such as Engineering Mathematics, Circuit Theory, and Electromagnetic Theory should still be taught in a classical framework, in order to establish solid grounding of theoretical knowledge in these subjects.

In the second year, the implementation of PBL may begin in earnest. A course on thinking and communication skills will be taught to all second year undergraduates in University Malaya, commencing in the 2003/2004 session. This course is based the premise that thinking and communication skills can be enhanced if taught in an organized approach, and it is hoped that these skills will be utilised in tackling PBL-based courses within the Department. By the second year, the undergraduates' knowledge base in electrical engineering will have increased, and therefore the number of courses to be taught using the PBL approach may be increased. By the same token, the number of courses taught by PBL may be increased even more in the third year.

By the time an undergraduate reaches the fourth (and final) year, he or she will have amassed enough engineering knowledge for most of the fourth year courses to be implemented through PBL. The final year thesis project may be translated into an interdisciplinary PBL problem, by assigning a group of students from various engineering programmes to a single, comprehensive project that carries a common theme. For example, the faculty could choose renewable energy or the transportation system of the future as a theme. The latter would involve, among other things, the design and implementation of a solar car, as described in Section 3.1.

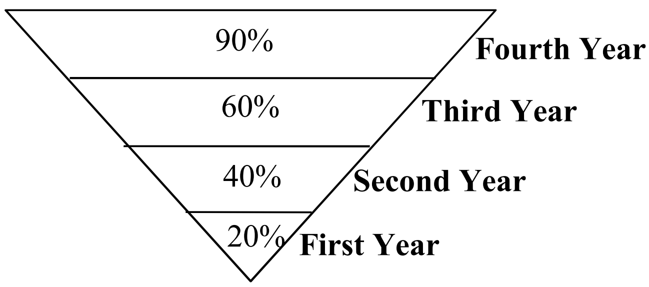

Figure 1: Proposed percentage of courses with PBL content in the undergraduate Electrical Engineering and Telecommunication course, according to year.

It is evident that the form of the PBL questions posed will increase in complexity as the students progress through the course. The forms that these questions may take will be further elaborated in the following section.

The form of PBL problems

Some lecturers are taking a pro-active approach in blending between the traditional teaching approach and PBL. A format which blends both teaching approaches is by formulating quasi-PBL questions, which are useful in allowing first and second year students to familiarise themselves with the PBL concept. A quasi-PBL question is a problem which is subject-centric, rather than interdisciplinary investigation, which should be easier for the students at this level to tackle. An example of a quasi-PBL assignment question taken from a course in Computer Organization and Architecture is shown below:

You are the lead systems analyst on a new software project for your company. You have been given the responsibility to choose the hardware platform for the project. Your supervisor, a business major, has come to you with some suggestions. She states, "I think this new 750 MhZ CPU in those XYZ brand computers is probably best. We don't really want to use those older 500 MhZ ABC brand machines when we can get one so much faster now." What is your response?

The question above allows the students to discuss the consideration that should be taken before making the final decision on which brand of computer the company will purchase. Here, there will be a discussion on how to measure the performance of a computer system, whether it is based on the processor speed, data bus width, MIPS, memory size and access time, software availability, cost or brand. The advice of the supervisor and her background in the subject matter will also be considered.

A fully fledged PBL approach could be implemented in teaching third year and final year undergraduates, when a students' knowledge of the fundamental engineering subjects has been consolidated. An example of a full PBL assignment is given below:

Faraday's law characterises the voltage drop across an inductor as $V_L = L\ (dI/dt)$ where V_L = voltage drop (Volt), L = inductance (henrys; 1 H = 1 V. s/A), I = current (Amperes), and t = time (seconds). Determine the voltage drop as a function of time from the following data for an inductance of 4H.

t (seconds)	*0.00*	*0.10*	*0.20*	*0.30*	*0.50*	*0.70*
I (Ampere)	*0.00*	*0.15*	*0.30*	*0.55*	*0.80*	*1.90*

The question above requires students to choose a numerical method in order to solve it. It assumes that the students have a good grasp of how inductors behave under forced conditions – the forcing condition being the application of voltage. In making the decision on which method/approach to use, consideration regarding the inductor's transient behaviour should also be made. This again implies that students already know the fact that the charging an inductor involves two phases – the transient and steady states. Students would also have to discuss or justify the method chosen based on the efficiency and accuracy of the method in attaining the final solution.

In order to ensure that the PBL approach is conducted smoothly, it is essential to train lecturers to become PBL facilitators. The characteristics of a PBL facilitator will be discussed in the following section.

The characteristics of PBL facilitators

Currently, implementation of PBL within the Department is in its infant stage where lecturers are currently being trained to become PBL facilitators. The Faculty has employed a top-down approach whereby a central committee headed by a senior member of the teaching staff is responsible in identifying and recruiting lecturers from every department as part of the PBL team. The team would then follow a series of training programmes and a more or less subject-centred PBL approach is gradually being introduced. The project is proposed to expedite this process by taking the 'learning by doing' approach. This approach is analogous to the idea that the lecturer learns more about the subject that he is teaching when he has to prepare the lecture for that particular subject.

The first step that a PBL facilitator has to take is to recognize that there has been a shift in the role of himself as the educator – from the sole source of knowledge in a lecture-based environment, to the facilitator who aids the acquisition of knowledge in a PBL-based environment. This requires a shift in mindset, which may be challenging for the lecturer himself, if he has spent his whole academic life in the role of the former. The following traits should prove valuable in a PBL facilitator:

- The facilitator should have a thorough and integrated understanding of the subject as a whole. This is essential, in order to allow the students a better perspective of the subject, so that they are able to relate to the different aspects of the subject, and how it is applied to real life situations.
- The facilitator must be able to pose problems in such a manner that encourages inquisitiveness on the part of the students. The questions may be deliberately vague, as explained in Section 3.1, because real-life problems are not usually clear-cut.
- The facilitator should be able to, in a discussion session, be able to probe the student's understanding through provocative questions that are able to break down fallacies and mistaken assumptions by the students.
- The facilitator should be able to encourage open discussion, so that the students are able to express their ideas in a concise and articulate manner. Typically, in the early stages of establishing PBL, the facilitator will encounter resistance from the students, as this method entails more work on the part of the student, as they have to use their own resources to acquire knowledge, and then present them in front of an audience. Therefore, the facilitator also needs to be prepared for this eventuality.

Conclusions

In this paper, the implementation of the PBL approach in the Department is presented. The PBL methodology contains many similarities to the project cycle encountered by practicing engineers. Therefore, it is useful in developing the relevant transferable skills expected of an engineer, for example critical thinking skills, communication skills and analytical skills.

The implementation of PBL at the Department is still in its early stages, and in order to implement it successfully, it would be useful for the Department to collaborate with educationists and industry. Ongoing collaboration with educationists is of the essence, in order to continuously introduce improvements to the teaching methodology. A method of evaluation of the effectiveness of these methods should also be formulated.

It is also important to establish links with industry, for example allocating work placements for undergraduates during their long semester break. This is to allow them to practice the skills acquired through PBL, and to give them an insight to working life as an engineer. In some cases, it also presents the possibility of networking and an opportunity to work with the same company after graduation.

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