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# Implementation Model of a Problem-Based Laboratory (PBlab) Established for a Bachelor Of Engineering (Electrical) Program at Universiti Teknologi Malaysia

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**Abstract**

Problem-based laboratory has since 2007 replaced the conventional instructional based laboratory as the 4th Year Electrical Engineering Laboratory in the curriculum of the Bachelor of Engineering (Electrical) program offered at Universiti Teknologi Malaysia. The initiative to replace the conventional conduct of the 4th Year Laboratory derived from various issues including the feedback obtained from former students, industry and the Engineering Accreditation Council (EAC) that evaluated the program in 2005. Moreover, if the conventional laboratory conduct were to be maintained, it was discovered that the laboratory contact hours would not be able to meet the EAC requirement of fifty-six hours for a two credit hour course. This paper presents an implementation model of a Problem-based Laboratory (PBLab) that has been established as one of the core courses for the Bachelor of Engineering (Electrical) program and has been running for the past three years. The preparations that have been made as well as the tools developed to support the implementation of the PBLab will be the main points of elaboration in the paper. This is followed by some description on the implementation model of the PBlab in terms of laboratory conduct, facilitation, activities and evaluation criteria. Finally some feedback from the students that underwent the PBLab will be highlighted as an indication on their level of acceptance towards its overall implementation.

**Keywords:** Laboratory, Problem-based learning

## 1. Introduction

The Bachelor of Engineering (Electrical) program offered at Universiti Teknologi Malaysia is a 4 Year program that requires completion of ten credit hours of laboratory work. Prior to 2007, the 4th Year Undergraduate Laboratory has been conducted using traditional methods which provide the students with specific instructions that they follow step by step in order to finish their work in the laboratory. In recent years, engineering education has changed from lecturer-centered to student-centered learning as well as from lecture-based to technology-based learning. Experiments in laboratories for instance have been conducted with additional software based or virtual instruments rather than using purely hardware based instruments. The former are introduced as extra tools for the students to analyze or verify the results they obtained from the experimental work conducted.

Since 2007, the Bachelor of Engineering (Electrical) program has begun to conduct the 4th Year Laboratory as one of its core course, in a non-conventional way with the introduction of a Problem-based laboratory (PBLab). The main factor that contributes to the introduction of the PBLab is to comply to the requirements as set by the Engineering Accreditation Council (EAC), Malaysia. The EAC is a body that has been delegated by the Board of Engineers Malaysia (BEM) to primarily set policy and conduct approval and accreditation evaluations to engineering degree programs offered in Malaysia [1]. The Engineering Program Accreditation Manual 2007 states that " For a 14-week semester (not including examination or mid-term break), one credit hour is defined as: two hours per week of laboratory or workshop".

The 4th Year Laboratory is a two credit hour course that contributes to the curriculum of the Bachelor of Engineering (Electrical) program. To be eligible as a two credit hour course, in accordance to the EAC requirement, if twelve weeks of laboratory is proposed per semester, a total of at most five hours of laboratory per week is required. With the previous laboratory conduct, it is not possible to fulfill this laboratory hours requirement. This is due to the laboratory structure that requires the students to conduct different experiments offered by various laboratories with time allocation of only three hours per week, in a maximum of twelve weeks per semester.

In the previous laboratory conduct, students have also been assigned to work in a group. However the extent of team working skills that have been acquired by the students is equivocal as most of the time students in a group will divide the work related

to the experiments conducted among themselves. For instance, although a group report is required for each experiment conducted, feedback from the students have indicated that the report will be prepared by only one of the group member in rotational basis each week rather than based on group consensus. Review on the reports submitted have shown that they are of the same format as directed in the laboratory sheets without any essence of creativity and innovation from the part of the students.

Another motivating factor that promotes PBLab as one of the courses offered by the program is the fact that the students are already in their final year and will soon be entering the job market in the field of electrical engineering Through research and reference to several laboratory models applied in engineering degree programs [2,3,4,5], it is found that the Problem-based Learning (PBL) approach in conducting the 4th Year laboratory may not only fulfill the requirements of the EAC but may also benefit the students greatly in terms of enhancing their learning. PBL approach has been acknowledged as a teaching and learning (T&L) method that can further develop the students' interpersonal, problem solving, critical thinking and communication skills. This is also in line with the demand from the industries for graduates who know how to learn, to tackle and solve problems in the real-world as well as posses transferable skills in terms of communication and group working.

This paper presents the implementation model of a PBLab that has been established as one of the core courses for the Bachelor of Engineering (Electrical) program and has been running for the past 3 years. The preparations that have been made as well as the tools developed to support the implementation of the PBLab will be further elaborated in the sections that follows. This is followed by some description on the implementation model of the PBlab in terms of laboratory conduct, facilitation, activities and evaluation criteria. Finally some feedback from the students that underwent the PBLab will be highlighted as an indication on their level of acceptance towards its overall implementation.

## 2. PBLab chronology

The PBLab history goes back to 2003 when the 4th Year Laboratory Coordinators have been directed to propose a laboratory structure for the new 4 Year Program that is supposed to commence in the 2004/2005 academic year. The PBLab structure has been presented and later approved for implementation by the Faculty's Academics as well as Administrative Committees at the end of 2003. Following that, a task force consisting of mainly senior lecturers has been set up to provide feedbacks and suggestions on the PBLab structure as proposed by the Laboratory Coordinators. After a series of meetings among the task force members, the PBLab structure is finally conceptually ready by the end of 2005.

To support the then future implementation of the PBLab, a series of programs have been arranged for the staff consisting of academia and laboratory technicians throughout 2006 and 2007 as shown in Table 1. The programs are necessary as not all staff are familiar or even aware of what PBL is all about. In fact, only a few of the staff have had some background on PBL based on the trainings conducted by the university's Centre for Teaching and Learning which are mainly on voluntary basis.

Table 1. List of staff support programs

| Date | Program |
|---|---|
| **19th April 2006** | PBL Talk (delivered by a PBL trainer and practitioner) |
| **29th June 2006** | 4th Year Laboratory Problem Design Workshop |
| **July 2006** | Website development - downloadable templates and relevant documents |
| **March 2007** | Review on the designed problems from each laboratory |
| | Complete Laboratory Evaluation System (LES) development |
| **April 2007** | Workshop for laboratory technicians |
| **May 2007** | Briefing for facilitators |
| **July 2007** | Briefing for students |

Although the PBLab has been running for three consecutive years since 2007,briefings would still be conducted not only for the students but also for the laboratory technicians and facilitators who are responsible for the running of the laboratories.

A Laboratory Evaluation System (LES) has also been developed to support the management of the PBLab, particularly in determining the final grade of each student. The system is web-based, thus allowing proper monitoring of the PBLab evaluation process which involves both the Laboratory Technicians and students. Further details on LES are as elaborated in [6]. Fig. 1 shows the LES main web page.

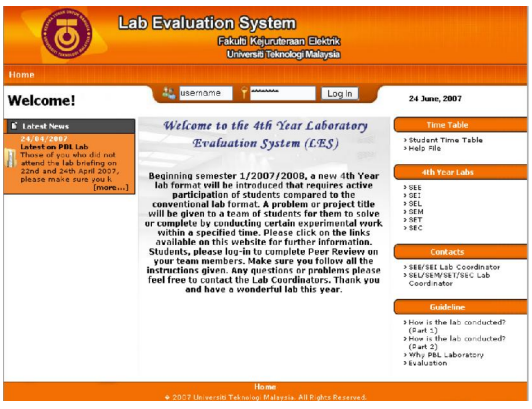


Fig. 1. The main web page for LES

## 2. PBLab structure

The PBLab is typically conducted on the first semester of the final year based on the 4 Year program curriculum. Although PBLab actually refers to problems that need to be solved involving experimental work, due to certain constraints in designing real-world problems, in this early stage of implementation, projects are also offered by the laboratories. The laboratories assigned to offer problems or projects for the 4th Year Laboratory under the Bachelor of Engineering (Electrical) program are the Advanced Power, Power Electronics and High Voltage laboratories.

### *2.1. Laboratory conduct*

Since 2007, the number of students assigned in a group for the laboratory has dropped from 4 to 5 to 3 to 4. Each group is required to complete 3 problems or projects by conducting experiments with each of it designed to be completed in 4 weeks. Thus, in one semester the students are expected to spend 12 weeks to complete all the problems or projects. The experiments conducted can be software-based, hardware based or both depending on the laboratory requirements. Students basically spend 3 hours per week in the respective laboratories with facilitation, which is known as the in-lab sessions (total of 36 hours). In addition they also need to meet at least 2 hours per week outside of the laboratory to further discuss the problem or project assigned with the group members which is known as the out-lab sessions (total of 24 hours).

### *2.2. Facilitation and laboratory activities*

If in the previous laboratory conduct, the lecturers are given the role as supervisors, in the PBLab, they are assigned to become facilitators . The role of the PBLab facilitators are as follows:

- To facilitate each group in a laboratory session in solving a problem or conducting a project
- To evaluate the students laboratory performance based on the outlined evaluation criteria
- To make sure that the evaluation process is completed according to schedule for each assigned problem/project

In the first week of entering a laboratory it is assigned to, each group will be given a problem or project. Each problem or project comes with a *Student Pack* that consists of relevant materials that can assist a group when solving problems or conducting projects. The activities that are typically being carried out in the first week is as given in Table 2. Based on the given problem or project, students are required to brainstorm and discuss the possible solutions. After discussing with the facilitator in charge, then only the students are allowed to download the *Student Pack* from the laboratory website. Each designed problem or project should also be accompanied by a *Facilitator Pack* for the facilitator in charge to refer to. *Facilitator packs* consist of relevant materials that can assist a facilitator when facilitating a group in solving problems or projects. Since the *Facilitator packs* are considered as highly classified materials, only the hard copies are provided at the laboratory and can be requested from the laboratory technicians by the facilitator in charge only.

Tables 3 to 5 shows the PBLab activities for weeks two, three and four respectively.

Table 2. First week of laboratory activities

| | **In-lab session** ***3 hours*** | **Out-lab session** ***2 hours*** |
|---|---|---|
| Week 1 (Each group assigned a problem) | 1. Understanding the problem with guide from facilitator<br>2. Brainstorming, giving ideas to solve problem<br>3. Identifying available resources and tools<br>4. Identifying what you know and what you need to know in solving the problem<br>5. Facilitator marks individual in-lab activities | 1. Get more resources to help understand the problem<br>2. Divide work among group members<br>3. Report findings to group<br>4. Agree on a solution |

Table 3. Second week of laboratory activities

| | **In-lab session** ***3 hours*** | **Out-lab session** ***2 hours*** |
|---|---|---|
| Week 2 | 1. Present solution to facilitator<br>2. Facilitator comments on solution, making sure the group is on the right track<br>3. Group begins to design the experiment<br>4. Group confirms the experiment layout<br>5. Facilitator monitors and marks individual in-lab activities and group log book | 1. Group conducts some simulation work to reconfirm design<br>2. Group verifies availability of equipment and tools to conduct experiment<br>3. Group prepares schematic or connection diagrams for experiment |

Table 4. Third week of laboratory activities

| | **In-lab session** ***3 hours*** | **Out-lab session** ***2 hours*** |
|---|---|---|
| Week 3 | 1. Group begins to conduct experiment<br>2. Facilitator monitors and marks individual in-lab activities and group log book<br>3. Group get results from experimental work | 1. Group prepares slides for presentation of completed work<br>2. Group starts preparing report |

Table 5. Fourth week of laboratory activities

| | **In-lab session** *3 hours* | **Out-lab session** *2 hours* |
|---|---|---|
| Week 4 | 1. Group presentation and demo<br>2. Report writing<br>(Facilitator monitors and marks individual in-lab activities and group log book. Facilitators also evaluate all group presentations) | 1. Continuation of report writing and submission exactly one week later to the Lab Technician to be recorded and given to the facilitators |

*2.2. Evaluation criteria*

One of the decisions that has been made by the Task Force members mentioned earlier relates to the evaluation criteria of the PBlab. This issue has to be discussed thoroughly among the members to ensure that the evaluation criteria chosen are in line with the objective of the faculty to produce graduates with not only sound electrical engineering knowledge but also with personal attributes that are favorable to the industry. Five main criteria has been decided for the PBlab with percentage distribution towards the final marks as given in Table 6.

Table 6. PBlab evaluation criteria

| No. | Criteria | Percentage |
|---|---|---|
| 1. | Individual in-lab activities | 20 |
| 2. | Peer and self evaluation | 10 |
| 3. | Group log book | 30 |
| 4. | Group presentation | 20 |
| 5. | Group report | 20 |
| | Total | 100 |

For criteria 1, 3, 4 and 5, evaluation rubrics have been developed that allow the Laboratory Facilitators to rate the students performance, whether as an individual or as a group. Ratings are set to be in the range of 1 to 4 with 1 rated as poor followed by fair, good and excellent for each of the components under each criteria. As the group of students will be assigned to a particular laboratory for four weeks, criteria 1 for example has to be evaluated by the facilitators every week. Similarly, criteria 3 is evaluated every week after the first week while criteria 4 and 5 are evaluated once at the end of the four weeks.

Criteria 2 requires the students to submit Peer and Self evaluation forms that allow them to rate their group members as well as themselves in terms of contribution towards solving the given problem. Only one Peer and Self evaluation form needs to be submitted by each student at the end of the four weeks laboratory sessions. This evaluation process is repeated when the group of students move to other laboratories in the fifth and ninth week. The marks obtained from each problem solved at the respective laboratory is then averaged to obtain the final grade for each student.

## 3. Student Feedback

The latest Peer and Self Evaluation forms have been designed to include written feedback from students based on three aspects; namely comments on group members, problem or project given and laboratory conditions. The feedback is important as it allows the Laboratory Coordinators to identify any arising issues related to the three aspects so that proper actions can be taken to improve the PBLab operation in the following year. Table 7 gives excerpts taken from the Peer and Self Evaluation forms as submitted by the students during the 2008/2009/1 semester.

Table 7. Excerpts taken from the Peer and Self Evaluation forms

| No. | Group members | Problem/project given | Laboratory |
|---|---|---|---|
| 1. | Each member give full cooperation and supporting each other in order to make the experiment is a success. | The project given is related to the real application and the theory taught in class, thus increase the undertaking of student to the subject. | The lab had given enough facilities in order to conduct the experiment and all staff Inca love (technician and supervisor) gives full support to the student. |
| 2. | - All of Them very cooperative, | -Nice and interesting<br>- Quiet challenging | - Supervisor always ready give advices and helps |
| 3. | Have a good team work and work together | Nice and Interesting | Still ok, but it will be nice if make some improvement on it's looks & facilities. |
| 4. | All group members are cooperate very well | The project is quit easy for us after all. | The lab is good and facilitate us to do our work |
| 5. | Good corporations given | Quite Challenging | All equipment needed for this project are well provided |
| 6. | All hardworking | | Computer in the lab should be replaced with good ones. |

Table 7 in general is able to give some indication on how the students respond to the PBLab . On the aspect of group members, there are no major issues

although the students have been grouped together in a random manner. Each group member seems to know his or her responsibility in solving the given problem or project as a team. In fact, the marks obtained by the students as assessed by the Laboratory Facilitator based on the developed rubrics for individual in-lab activities and log book seem to support the students' comments or opinions. On the aspect of the problem or project given, the students seem to agree that it is an interesting one that relates to real world application and rather challenging. The laboratory condition is generally acceptable to the students although there is still room for improvement.

## 4. Conclusion

This paper has presented the implementation model of a PBLab that has been established as one of the core courses for the Bachelor of Engineering (Electrical) program. Overview on the PBLab model implemented over the past three years has been given in terms of laboratory conduct, facilitation, activities and evaluation criteria. Both positive and negative feedbacks from the students on the aspects of group members, problem or project given and laboratory conditions have given some indication on their level of acceptance towards the overall implementation of the PBLab.

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