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Promoting Problem-based Learning in Engineering Courses at Universiti Teknologi Malaysia

Khairiyah Mohd Yusof, Zaidatun Tasir, Jamalludin Haron, and Syed Ahmad Helmi Syed Hassan

Universiti Teknologi Malaysia
Johor Bahru, Malaysia

ABSTRACT: In this paper, the authors describe efforts in promoting the implementation of problem-based learning (PBL) in Universiti Teknologi Malaysia (UTM), Johor Bahru, Malaysia, which is essentially the groundwork phase of the university-wide PBL project. The move to train a core-group of lecturers to implement PBL was initiated in 2002. The litmus test on the effectiveness and the possible applicability of PBL in engineering courses at UTM was conducted in the 2003/04-1 semester in *Process Control and Dynamics*, a required subject for fourth year students in the Department of Chemical Engineering, Faculty of Chemical and Natural Resources Engineering. The outcome of the pilot implementation was highly successful, that the department allowed PBL to be implemented in other classes. This also encouraged other faculties to promote PBL implementations. Since then, there have been several implementations in the Faculty of Chemical and Natural Resources Engineering, the Faculty of Mechanical Engineering, the Faculty of Electrical Engineering and the Faculty of Civil Engineering.

INTRODUCTION

Universiti Teknologi Malaysia (UTM) is a technology-based public university that produces the highest number of engineering graduates in Malaysia. The university's mission is to provide quality education for the masses, in line with the vision of the country. UTM is not elitist. Being a public university, the student intake is determined by the government, which provide the major source of funding. There are a variety of students from different academic and social backgrounds who meet the academic requirements pursuing engineering degrees and diplomas. Given a myriad of students entering the university, UTM is committed to provide quality education for all at the future technical manpower and leaders of Malaysia.

To produce quality graduates, UTM had recently come up with attributes to reflect its graduates. UTM graduates shall have sound disciplinary and professional knowledge, high self-esteem and effective skills in communication, team-working, problem solving and lifelong learning. To achieve the desired outcomes of expertise in content knowledge, positive attitude and ability in generic skills, student-centred teaching and learning techniques, especially Problem-based Learning (PBL), are highly encouraged.

PBL originated and gained wide acceptance in medical education. In the last decade, however, there has been a growing movement throughout the world to adopt PBL in other fields, including engineering. Many implementations are reported in North and South America, Europe and Australia.

Initially, there were many lecturers in UTM and faculty administrators who were sceptical that PBL can be effective. One of the major concerns is the high number of students in a class, which will cause difficulties in facilitation and assessment. Whereas most PBL implementations have less than 30 students per class, a typical class in UTM consists of 60 to 70 students, and some common subjects may have up to 120 students. In addition, adopting PBL with just 14 weeks in a semester to cover the required content is challenging, if not impossible. There were also those who were just resistant to any form of change. It was clearly evident that persuading lecturers to adopt PBL was going to be an up-hill battle.

An on-going effort by the Active Learning Task Force. which is funded by the Center for Teaching and Learning (CTL) in UTM, to convince lecturers to adopt PBL in the various engineering curricula, is described in this paper. Successful outcomes of PBL in the subject *Process Control and Dynamics*, which is the most important evidence in gaining the acceptance of lecturers and faculty administrators in UTM, will also be included.

PROBLEM-BASED LEARNING (PBL)

Problem-based Learning (PBL) is a learning strategy based on student-centred learning. The implementation of PBL in higher education has been discussed widely in many disciplines such as medicine, engineering, education, etc. In 1969 McMaster University in Canada introduced Problem-Based Learning (PBL) into its medical school in an effort to provide a multi-discipline approach to medical education and to promote problem solving in its graduates [1].

The PBL approach sought to embed small groups of students in the role of a professional and present them with a messy, unstructured, real-world problem, based within the context of the profession, to solve. Students are then guided by cognitive coaches through the problem solving process and develop high levels of generic skills and attributes, along with the content specific knowledge and skills they require. PBL practitioners often claim that their learners are more motivated and independent in their learning

PBL is based on constructivism learning theory. It is suggested by a number of proponents of PBL, and notably by Savery and Duffy [2] that PBL is consistent with current philosophical views of human learning, particularly constructivism. According to constructivism, learning occurred when learners construct their own knowledge or understanding based on their prior knowledge, environment and previous experiences [2]. Hence an approach such as PBL, which encourages self-directed learning and knowledge construction, the evaluation of personal understandings and interpretations against those of others, and ongoing cognitive restructuring, is perceived as congruent with learning theory. PBL might be considered as a practical actualisation of the constructivist philosophy.

The definition of learning by constructivists is related with the principles of PBL that have elements in common with those of adult learning and life-long learning. In PBL, students use their existing knowledge in order to learn rather than being treated as a *blank slate*; the process of enquiry fosters self-directed learning; and students *learn how to learn* so that they are better able to apply problem-solving to new situations in the workplace and in the community [3].

Many researches have shown the effectiveness of PBL in enhancing students' performance in learning. The results of 43 empirical studies on problem based learning in tertiary education suggest that students in PBL are better in applying their knowledge as they suggest a robust positive effect from PBL on the skills of students [4]. In engineering, PBL was recommended and implemented particularly because it promotes deep learning and problem-solving skills [5,6]. Other engineering implementations also noted enhanced generic skills and promotion of positive attitude among students who had gone through PBL [7,8].

LAYING THE GROUNDWORK

A gradual, non-drastic approach is taken to raise awareness and educate lecturers and students on the techniques during the groundwork period, which took about two years. A group of student-centred lecturers were chosen to form a central committee, called the Active Learning taskforce, to facilitate the promotion of PBL to all levels of the academic community in UTM. This is a difficult and uncertain period where the taskforce and core-group were moving against the tide to plant the initial seeds of change – the major tasks was to introduce, convince and train. The natural progression is essential in winning the hearts and minds, and thus the support of the academic community.

Four initial series of workshops held on PBL had been sufficient for the central and faculty core-groups to implement PBL. Meetings are held to update and share information and ideas as pioneers in the university. However, even after the workshops, most of the lecturers who went through the training were apprehensive and reluctant to make the drastic change from lectures to PBL.

PILOT IMPLEMENTATION IN UTM: PROCESS CONTROL AND DYNAMICS

Process Control and Dynamics is a required course for fourth year undergraduate chemical engineering students. It is a three credit-hour course, which means that there are three hours of classes per week, for 14 weeks. The course is notorious for the high number of failures (around 30%), low passing grades (mostly in 40-50%) and considered by many to be difficult. The course deals with mathematical modelling of process dynamics, and control systems design and analysis of chemical processes. Students need to understand and visualize a process in operation, and relate mathematical theories to the physical reality. They also need a strong background in mathematics and other chemical engineering concepts, learned earlier, to fully appreciate the class material.

In the first trial, PBL was implemented over a period of four weeks in two of the five sections offered in the 03/ 04-1 semester. Sections 2, 3 and 4, used lectures. Sections 1 and 5 were taught using cooperative learning and PBL. The lecturers teaching the two sections had undergone PBL workshops, and decided to try and cover some particularly difficult topics in the syllabus with PBL. Section 5 consists of weak students, who usually have low motivation. All sections sit for the same tests and final examination, which were taken individually. All the answer scripts in the tests and examination were graded by the lecturer who set the respective questions to ensure consistency. Details of this first PBL implementation can be seen in Khairiyah et al [8].

Figure 1 shows the marks distribution for question 2, which was on the topics covered using PBL, of students from all five sections. S1, S2, S3, S4 and S5 refer to sections 1, 2, 3, 4 and 5 respectively. The average for sections 1, 2, 3, 4 and 5 were 20.25, 10.85, 9.3, 5.15 and 13.76 respectively. The total marks for the question was 33. Students in section 1 performed the best among all sections (the lecturer for section 1 did *not* set the question nor marked the answer scripts). More than 60% of the students in section 1 scored above 20 for the question. The class average, 20.25, is about twice of the highest average for lecture-based classes. The performance of the students in section 5 was a pleasant surprise. Although most of their marks were clustered around 5 to 15, more than 40% of the students in section 5 scored higher than 15, and only about 5% scored less than 4. With an average of 13.76, the students' performance was better than the lecture-based sections.

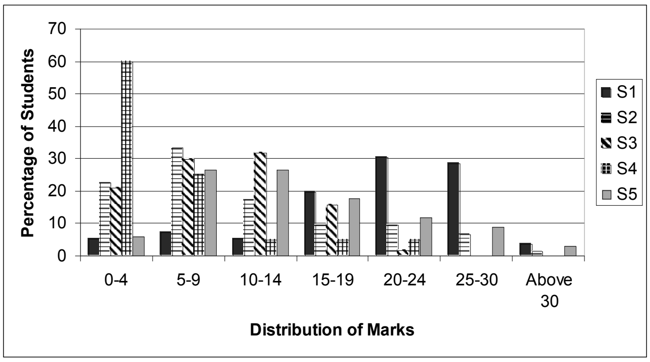

Figure 1. Distribution of marks on question 2.

A questionnaire was given to students on whether PBL helped increase the four generic skills listed in Table 1. The skills are listed in the first column, and the percentage of students giving positive and negative response for sections 1 and 5 (ie. S1 and S5) are tabulated in the respective columns. Most students felt that PBL increased their problem-solving abilities, self-learning and motivation for learning, interaction and teamwork skills, and self-confidence. Some students, who tended to be reserved, claimed that they had become vocal and defended their opinion in group discussions. They were not afraid to offer their view even if their idea might be wrong. Consequently, they did not feel shy to speak-up in class anymore. Students also noted that they were able to learn how to tolerate and accept differences, communicate with different people, and had made good new friends, even among different races. Many reported that they felt motivated to learn because they felt responsible towards their group to help solve the problem and contribute in discussions. 70% and 84% from sections 1 and 5 respectively responded that PBL increased their confidence. They felt more confident to present, and face the examinations.

Table 1. Results of questionnaire

Generic Skills	Increased		The Same		Undecided	
	S1	S5	S5	S5	S1	S5
Problem-solving ability	76	96	15	4	9	0
Self- directed learning and motivation	87	96	7	4	6	0
Interaction and team-work skills	89	100	7	0	4	0
Self-confidence	70	84	18	8	12	8

As a consequence of the first successful implementation, the department allowed PBL to be implemented to all classes of Process Control and Dynamics. To date, up to 70% of the syllabus are covered using PBL, while the rest are covered using cooperative learning (CL) and mini lectures. Figure 2 shows the grade distribution of the subject for 4 semesters taught by the same lecturer using different techniques.

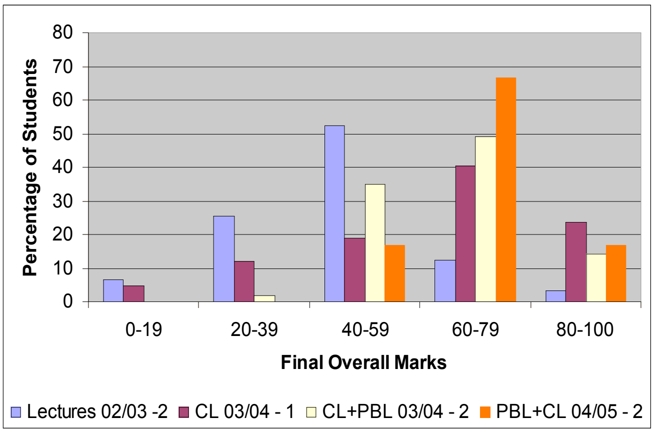

Figure 2. Grade distribution using different techniques.

There were also numerous feedback obtained from students. Students who had experienced PBL after one semester appreciated PBL more once they realised the skills and positive attitude gained. One student in the first PBL implementation wrote:

> *"PBL opens my eyes on how university life should be. I was able to view the word "study" from a helicopter view. From what I see among my coursemates, PBL did change some of them from exam orientated to a learning style that is not only restricted to the syllabus. I'm able to think outside the box and think further, even though the changes are not drastic, it is a good thing for me."*

Another wrote:

> *"PBL improved my generic skills. Now I feel more comfortable to work in a group and have confidence to solve problems. At least I won't feel scared when facing a problem that I have never seen before."*

From the response obtained, PBL helped students to mature as learners, although they may initially resist ("*Now I feel like a student in university, and not in school*"). They actually appreciate that they are given the chance to think and explore on their own, and not being spoon fed ("*PBL really works! No spoon-feeding 'coz we're grown-ups. This is the best and most enjoyable class!*"). There were, of course, negative responses especially in the initial phases, though in the end there were much fewer. Among them:

> *"I hate PBL! I'm here to learn Process Control and not anything else!"*

CURRENT STATUS

In UTM, PBL has been implemented across all disciplines. After initial implementations in Chemical Engineering courses, PBL implementations spread out to other engineering fields such as Mechanical Engineering, Civil Engineering and Electrical Engineering. PBL also has been introduced to other disciplines in UTM such as Education and Human Resource Management.

Educating administrators, lecturers and students on CL and PBL was a major focus. Road shows on CL and PBL were held at all faculties to create awareness on the need for change in the teaching and learning techniques, and what is active learning, CL and PBL. Evidence of implementations and outcomes in the form of students' performance and response were also shared during the road shows. Experience obtained from giving presentations in different faculties have also given exposure and enriched the knowledge of the taskforce members to the different perspectives and problems faced by lecturers. Other than road shows, technical papers and articles are written to disseminate information on the techniques and implementations.

Taking a gradual approach, lecturers who were apprehensive of the rather drastic change to PBL are encouraged to implement cooperative learning first. This enabled them to experience facilitating group dynamics and active learning. Then, PBL was implemented at a micro level, ie over a segment of two to four weeks, before moving on to possibly whole-class implementation. After implementing PBL in their respective classes, the lecturers become the faculty champion and resource person, by sharing their experiences. Based on the authors' experiences, this approach, coupled with organising awareness talks to each faculty, has attracted other lecturers to try to implement PBL in their classes and won over faculty administrators.

In promoting CL and PBL at the grassroots level (mainly by word of mouth) by the core-group, most found it easier to convince younger lecturers. Nevertheless, there had been senior lecturers who were initially sceptical, but somehow turned around and at least agreed with the idea of the need for active learning in the classrooms. Mentoring lecturers in PBL are also taking place in some faculties.

The administrators in UTM have decided to go for PBL in stages, through the bottom-up, top-down approach. Lecturers are not forced, but volunteer to use PBL as one of their teaching approaches. The aim is to have a macro implementation of PBL, where at least 10% of the total contact hours in all undergraduate programmes. Each programme will have to determine the strategic placement of PBL in the curriculum that will yield the greatest impact of its benefits to students. To ensure that the plan is implemented, the university administrators are applying subtle pressures on the faculties to report all PBL applications. The Faculty administrators, in turn, are expected to keep track and ensure that lecturers who had received training applies PBL in their classes.

To support the lecturers who want to implement PBL in his/her class, the PBL resource staff conducts regular meetings with members of the Active Learning Task Force. A portal is currently being planned to provide ready references, forms, and an electronic forum for lecturers interested to discuss PBL. Training on CL and PBL are conducted on a regular basis at the university and faculty level. Co-teaching and/or mentoring with experienced lecturers are encouraged. A crucial support from the faculty is to allow lecturers implementing CL and PBL to choose the suitable subject, time slot and classroom. To ease the burden of lecturers in terms of the increased workload, especially in the initial stages of implementation, student tutors or teaching assistants should be assigned to them.

To find out the potential of e-learning in helping the implementation process of PBL, a study was carried out to find out students' perceptions toward PBL through e-learning. E-PBL is the implementation of PBL through any Learning Management Systems (LMS). In UTM, Moodle, an open-source LMS, is used. Through e-learning, learning can take place anywhere and anytime through the communication tools that it has. The study was conducted in the Faculty of Education [9]. Findings showed that students often feel that the use of PBL through e-learning is relevant in their studies and future work. Students also feel that some e-learning tools such as electronic forum, chatting and electronic journal help the process of implementing PBL. E-learning is needed to help the implementation of PBL among university students especially in the discussion session which can be continued outside the class. Through e-learning, PBL problem can be posted earlier before the lecture session starts.

CONCLUSION

On the whole, the move towards encouraging lecturers to adopt PBL seemed rather sluggish, especially in the initial stage. This is because time is needed for those initiating the change to be trained, implement and gain experience in the techniques. Time is also needed for others to be convinced and prescribe to the change.

The Active Learning taskforce and core groups are well aware of the effort, patience, determination and resilience required to successfully promote university-wide implementation of PBL. Nevertheless, with clear intention, goals and plan of action, coupled with support from the highest level of university key personnel, the taskforce and core-groups are optimistic that a well-coordinated university-wide implementation of PBL will materialise in the near future.

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