

The effect of the blended Problem-Based Learning method on the acquisition of content-specific knowledge in mechanical engineering

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ABSTRACT: Problem-Based Learning (PBL) on its own has not been very successful in ensuring the learning of content-specific knowledge in engineering. The purpose of this study was to determine the effect of blending PBL and conventional teaching methods on students' achievements in mechanical engineering. The quasi-experimental design method was used with two classes of first year mechanical engineering students who registered for the *Fluid Mechanics I* course at Tun Hussein Onn University of Malaysia in Johor Darul Takzim, Malaysia. The experimental group (n=28) was prescribed the blended PBL method while the control group (n=52) used the conventional method for completing group tasks. A pre-test and two post-tests on selected topics in *Fluid Mechanics I* were administered to both groups before the study in weeks 4 and 11, respectively. The results showed that the mean scores on the achievement tests of the blended PBL group was statistically significantly higher than the conventional group in both instances (weeks 4 and 11) with the effect sizes ranging from 0.56 to 1.1. It was concluded that blended PBL is better at developing content-specific knowledge compared to the conventional method.

INTRODUCTION

It is well accepted that engineers of the future need to develop additional skills to be able to cope with the continuously changing, technologically advanced, socially and politically complex working environments. Thus, besides having a good grasp of basic engineering principles, engineers also need to have additional attributes to be:

- Good communicators;
- Innovative;
- Creative;
- Able to manage people as well as systems;
- Life-long learners;
- Adaptable [1].

Therefore, there is an urgent need for teaching and learning innovations in engineering education to achieve the goals of future engineering education that support not only the need to acquire content-specific knowledge, but also the development of the broad knowledge and skills that are demanded of future engineers. As such the emphasis on Subject-Based Learning (SBL), with the teacher being the centre of learning process, is being replaced or complemented with a more appropriate learning approach.

PROBLEM-BASED LEARNING

Problem-Based Learning (PBL), where the problem is an important element in the learning process, has been attracting much interest from engineering educators' recently due to its potential in promoting the development of wholesome engineers of the future. The PBL method is based on constructivism, which proposes that learning is a process wherein the learner actively constructs knowledge. Learning results from a learner's actions; instruction plays a role only to the extent that it enables and fosters constructive activities [2].

According to constructivist theory, learning occurs as a result of a process where students actively construct their own knowledge from their experiences. Learning occurs when students are able to make connections of new information with knowledge and experiences that they have already assimilated. Learning becomes an act of discovery as students examine the problem, research its background, analyse possible solutions, develop a proposal, and produce a final result.

Knowing about knowing or metacognition, which refers to the ability of knowing how one knows or learns, affects learning. Good students can detect when they understand – or do not understand – new information, and know when to use different strategies to make sense of new knowledge and experiences. They are able to judge the difficulty of problems and assess their own progress in resolving them.

Social and cultural factors affect learning and, therefore, the emphasis is on learning within a context to ensure greater understanding by making connections between learning materials and real-life applications. In PBL, students are dealing with problems that are designed to be as close to real-life situations as possible. The social interaction imposed through PBL (working in groups) is not only instrumental in ensuring that learning occurs, but probably helps in the longer retention of knowledge. In one such study on medical students, the author found that PBL improved learning with effect sizes as high as 0.5; not only that, he also found that medical students who used PBL still retained their knowledge even as long as two years after it was learned [3]. In general, the characteristics of the PBL method appear to provide the right learning experiences that have the potential to develop excellent analytical skills and the ability to deal with complex engineering problems.

In PBL, students learn about contents through challenges in the form of problems relevant to their future practice [4]. This is the opposite of the conventional teaching method that teaches content to help students solve problems. PBL uses the problem to challenge, motivate, focus and initiate learning [5]. In the PBL method, real-life problems that are not defined in engineering terms are posed to students. Therefore, problem analysis, definition and formulation in engineering terms are the critical prerequisites of the problem-solving process [6].

According to Woods, the fundamental difference between PBL and content-based learning or Subject-Based Learning (SBL) is in the starting point of the learning cycle [7]. In PBL, the learning process starts when students are given a problem following which they identify what they need to know in order to solve the problem. In SBL, students are given what they need to know to solve a problem following which they are given the problem.

PROBLEM STATEMENT

Although much support has been found for the efficacy of PBL in developing generic skills, its effect on the learning of content-specific knowledge is not as positive [8]. PBL has caused some students to feel ... *unsure how much self directed study to do and what information is relevant and useful* [9]. Learning the course content was found to be the main challenge and students perceived that they learnt less content in PBL compared to learning in a traditional course [10].

The student-centred nature of the PBL method has also caused frustrations among some students, who have strongly believed that the only way to learn is by … *attending lectures and by listening to faculty* [10]. This study also found that students who were new to PBL required longer periods of orientation to solve problems compared to those students using the conventional method and who received more inputs from their lecturers. Most students tended to have the opinion that the lecturer is the source of knowledge, thus the change from teacher-dependent to self-directed learning requires a change of paradigm which is not something that is easily acquired.

On top of the demand for increased students' efforts to acquire new knowledge and skills, students also need to develop self-assessment skills to monitor their own progress. The inadequacy of PBL in promoting content knowledge developments has been further supported by Kirschner, Sweller and Clark, who provided the theoretical foundations on why minimal guidance as provided in PBL is not effective in learning content-specific knowledge or problem solving [11].

Therefore, according to Savin-Baden, a blended PBL method, where some components of the conventional method are retained, would be more appropriate, especially with learners who are new to PBL where the goal of teaching and learning is to develop competent applications of knowledge in problem solving [12][13]. One such model has been proposed by Fink where conventional components (lectures, tutorials and experiments (laboratory assignments)), are blended with the following PBL components, namely:

- Problem analysis;
- Literature reviews;
- Field studies;
- Group work;
- Problem-solving;
- Reporting [6].

The purpose of this study is to determine the effectiveness of Fink's PBL model on the achievements among mechanical engineering students. The null hypothesis given below was formulated to guide the study:

- Ho: There was no statistically significant difference in the means of test scores between the PBL and the control group.

The independent variable is the teaching method (PBL or conventional teaching method) and the dependent variable is the learning gain operationalised as the score on the achievement test in the *Fluid Mechanics I* course offered at Tun Hussein Onn University of Malaysia in Johor Darul Takzim, Malaysia. The conceptual framework for the study is shown in Figure 1.

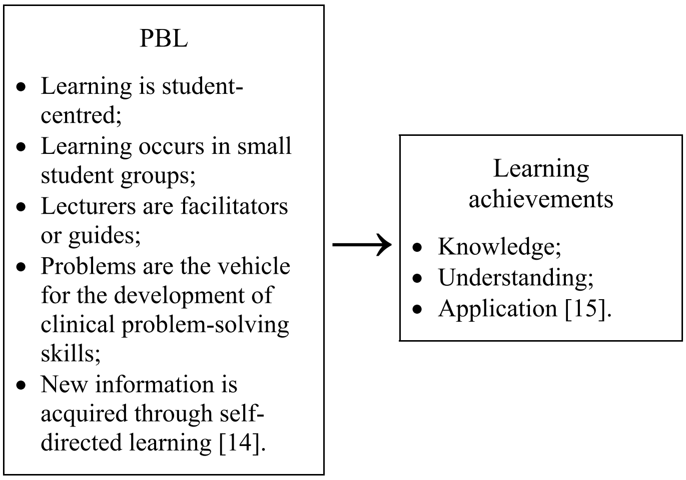

Figure 1: The conceptual framework.

METHODOLOGY

Research Design

The quasi-experimental design method was used with two classes of first year students from the Mechanical Engineering programme at Tun Hussein Onn University of Malaysia who registered for the *Fluid Mechanics I* course as the samples. One group was asked to use a prescribed PBL method (n=28) to complete their group assignments while the other group used the conventional group method (n=52). The two classes were taught by experienced but different lecturers.

Instruments

Three achievement tests, namely pre-test, Test 1 and Test 2, were used to gather data on students' content-specific knowledge of *Fluid Mechanics I*. The items in these tests were designed at the knowledge, understanding and application levels based on Bloom's taxonomy of learning in the cognitive domain [14].

The pre-test consisted of 13 items on the topics of fluids in equilibrium, Test 1 had six items on the same topic and Test 2 consisted of three items on basic equations in fluid mechanics, which is the last topic in the *Fluid Mechanics I* syllabus. These achievement tests were developed by two subject matter experts. A table of specifications was constructed as a planning tool to ensure content validity and standardised marking schemes were developed in order to ensure intra-scorer and inter-scorer reliability.

Procedure

The study was carried out over 11 weeks in duration. Both groups were pre-tested before the intervention to determine their baseline knowledge and skills. Both groups were asked to complete three group tasks: Task 1, Task 2 and Task 3. The pre-test was administered before Task 1. Test 1 was conducted after Task 1 (at four weeks into the semester) and Test 2 after Task 3 (at 11 weeks into the semester).

For the PBL group, the tasks were completed using the following steps:

- Respond to the problems (triggers) – FILA table;
- Generate hypothesis;
- Research – KND chart;
- Problem solving;
- Presentation;
- Documentation;
- Assessment.

The time given for students to complete their tasks was one week for each task. An orientation session was provided to help students familiarise themselves with the PBL method. Students worked in groups of four or five with members of their choice.

The same tasks were also given to the conventional group that worked in groups of four or five members of their choice. The favoured working strategy for the conventional group was to divide a given task among group members and combine their efforts later before submission.

RESULTS

Group Equivalence

The Welch *t*-test was used to compare the means on the pre-test because the samples had an unequal variance as shown by the Levene's test results in Table 3. The pre-test scores of the PBL group ($\bar{x}$=8.77, s=5.92) and the conventional group ($\bar{x}$=8.73, s=3.34) were very similar and not statistically significant at the 0.05 level (p>0.975) as shown in Table 1. Therefore, it can be concluded that at the start of the study, the two groups were equivalent with respect to their cognitive skills.

Table 1: Results of the Welch *t*-test on the pre-test means.

Levene's test		*Welch t*-test		
F	*p*	*t*	*df*	*p*
5.805	0.018	0.032	39.88	0.975

The Effect of PBL on Cognitive Skills

The results of the independent *t*-test on the difference between the mean scores in Test 1 are shown in Table 2. The obtained *p*-value was smaller than 0.05; therefore, the null hypothesis of no difference was rejected. This means there was a statistically significant difference between the mean scores, with the PBL group scoring higher than the control group on Test 1.

An effect size of d=1.113 was obtained using the Cohen method [15]. It was found that 86% of the students in the control group obtained scores below the mean of the PBL group.

Table 2: Results of the t-test based on Test 1.

Group	$\bar{x}$	s	*t*	*df*	*p*
PBL	18.7 (62.3%)	4.80	4.68	78	0.000
Control	13.6 (45.2%)	4.60			

The results of the independent *t*-test on the difference between the mean scores in Test 2 are shown in Table 3. The obtained *p*-value was smaller than 0.05; therefore, the null hypothesis of no difference was again rejected. This means that there is a statistically significant difference between the mean scores, with the PBL group scoring higher than the control group for Test 2.

Table 3: Results of the t-test on long-term learning.

Group	$\bar{x}$	S	*t*	*df*	*p*
PBL	11.2 (56.1%)	5.10	2.29	78	0.025
Control	8.7 (43.4%)	4.50			

The effect size was 0.56 for Test 2. Although smaller in size compared to the effect size in Test 1, according to ref. [16], a size of above 0.50 is considered to be moderately significant. The effect size value of 0.56 shows that the mean of the PBL group is at the 71st percentile of the control group.

DISCUSSION

The consistently higher achievements obtained by the PBL group on cognitive skills is in contrast with Glew and Wood [8][9]. The differing results may be explained in terms of the specific PBL model used in the current study. In the current study, the PBL method was not used to replace the existing method, but rather to complement it. The existing conventional teaching and learning method, namely lectures, laboratory assignments, etc, were still used hand-in-hand with the PBL method.

Such an introduction to the PBL method probably reduces the *cultural shock* that students have often faced when using the PBL method for the first time. Furthermore, the current PBL model may provide greater opportunities to meet students' varied learning preferences. This could be the reason why the students in the PBL group obtained better results on the achievement tests as compared to the conventional group. The meeting of learning style needs is still a hypothesis that remains to be tested in the future.

The effect of novelty is a common problem in teaching and learning studies. Nevertheless, such an effect in some aspects is good, as stated by Hawthorn (in Cohen and Manion): *Put people in a novel situation and observe them and they will work harder (for a time)* [16]. This means any *new item* in teaching and learning will attract attention and become a catalyst for a better result even though only for a short period. However, if the increased achievements in the PBL group were the result of novelty, then the level would have declined steeply after the initial excitement was over, which is not so in this case. The PBL group was still better at week 11, while the conventional group remained at the previous level. This could mean that the PBL method is indeed more effective than the conventional method.

Another major finding from this study is that the learning obtained is not only statistically significant, but also academically significant as the effect size was consistently large (0.56 and 1.11). The large effect size (*d*>1.0) is not only an indication of the effectiveness of the PBL method, but also indirectly a reflection of how poorly the outcome of the conventional method is because if the conventional group had done better, the observed effect size (*d*=1.113) would not have been possible. In medical education, for example, where students' performance is generally very good, the effect size obtained rarely reaches above 0.8 [3].

CONCLUSION

In this research, the authors set out to determine if learning effectiveness in engineering can be enhanced by complementing the conventional teaching method with PBL. The data generated supported the conclusion that the learning effectiveness of engineering subject matter content can be enhanced when PBL is used to complement the current teaching method. The findings were not only statistically significant, but also academically significant meaning that the results obtained were worth the effort.

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