

Seminar Pasca Ijazah dalam Pendidikan 2011

**THE EFFECT OF PROBLEM BASED LEARNING ON
STUDENTS' KNOWLEDGE ACQUISITION, CRITICAL
THINKING ABILITY, AND INTRINSIC MOTIVATION IN THE
POLYTECHNIC'S ELECTRICAL ENGINEERING COURSE**

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Abstract

The purpose of this paper is to propose Problem Based Learning (PBL) instructional procedures and to examine its effect on students' knowledge acquisitions, critical thinking ability, and intrinsic motivation. This study was conducted using an experimental research, pre-test and post-test with control group design. Samples involved two groups of students that attended the Electrical Technology Module during their first semester in the polytechnic's Diploma Electrical Engineering course. The treatment used a special design of PBL procedures in the experimental group and the traditional learning approaches was exclusively for the control group. The data collection used three instruments namely Multiple Choice Question (MCQ) for achievement test, The Cornell Critical Thinking Test Specimen (CCTTS) set, and Intrinsic Motivation Questionnaire (IMQ). Currently, the pre-data collection phase has just been completed. The treatment has been ongoing. However, the two weeks of preliminary implementation indicated positive results in some aspects of students' learning domain.

INTRODUCTION

In regards to the recent polytechnic campaign to improve their teaching and learning system, a Student-Centered Learning approach using PBL is one of the proposed methods (DPE, 2010). However, there have been many challenges in implementing PBL into polytechnic engineering courses. One of these implementation challenges is that polytechnic lecturers were not adequately exposed to PBL, due to a lack of relevant resources and training. Most of the PBL implementation was performed without specific guidance, especially the aspect of procedural design and implementation, and the facilitation of PBL tutorial classes. Consequently, any PBL intervention may result in student frustration and an inability to reach an effective learning stage (Hmelo-Silver, 2004; Artino, 2008). In the first attempts to implement self-designed PBL procedures, it has been difficult to stimulate students' intrinsic motivation in learning, and thus have an impact on other learning domains including students' knowledge acquisition and critical thinking ability.

Knowledge acquisition is amongst the common variable of interest in evaluating PBL effectiveness. It can be measured in a specific manner. According to Sugrue (1995), assessing knowledge can be specific according to concepts, principles, and procedures. In this context, previous studies indicated that PBL was effective in constructing students' knowledge acquisition, in the aspect of concepts and principles (Capon and Kuhn, 2004; Bilgin et al. 2009). On the other hand, evidence also indicated that PBL was equally effective as traditional learning approach on students' concepts and principles knowledge acquisition (Dehkordi and Heydarnejad, 2008; Sendaq and Odabas, 2009).

In relation, in a wider context of educations, the number of evidences that reported PBL to be less effective (Matthews, 2004; Anderson, 2007) were quite balanced with the studies that reported more effective in constructing students' knowledge of procedures or applications (Capon and Kuhn, 2004; Dehkordi and Heydarnejad, 2008). When compared to Bloom's taxonomy of cognitive domain, PBL appeared to be effective in promoting students' learning at higher cognitive level at application and evaluation, but not in understanding level (Alcazar and Fitzgerald, 2005). A systematic review in medical field supported that students in PBL approach gained slightly less factual knowledge of concepts and principles (Dochy et al. 2003). There was no convincing evidence to support PBL instructional approach improved students' knowledge and clinical performance (Colliver, 2000). Given the knowledge as a whole structure of concepts, principles, and procedures; the systematic evidence on the effectiveness of PBL appeared to be equivocal according to these structures (Gijbel et al. 2005).

In relating PBL to critical thinking, several studies resulted with positive findings (Tiwari et al. 2006). However, several studies also resulted with negative findings or no significant difference of two groups' comparison on the effects of PBL on critical

thinking (Polanco et al. 2004; Choi, 2004). In addition, the studies on critical thinking were mostly done in mathematical field (Leikin, 2009). There has been a scarcity of studies that scrutinized the link between PBL and critical thinking, particularly in across disciplines and populations (Tan et al. 2009).

Previous research has also revealed a gap in determining the effects of PBL on students' intrinsic motivation. The plethora of research resulted in equivocal findings, when PBL was inserted into an existing curriculum, outside of medical education (Polanco et al., 2004; Anderson, 2007; Artino, 2008). This may be because several PBL procedures were not properly designed and were always inserted as single interventions amongst an entire curriculum (Artino, 2008). As a result, students became uncomfortable (Hmelo-Silver, 2004) and therefore, the effects of PBL on students' intrinsic motivation were difficult to determine (Artino, 2008).

The effects of PBL on students' intrinsic motivation are not consistent across multiple academic domains. In the medical field, students enjoyed and were intrinsically motivated by PBL, compared to students using conventional methods (Hmelo-Silver and Evensen, 2000; Artino, 2008). In other disciplines, students' intrinsic motivation levels always resulted in equivocal findings. For example, in the engineering field, as part of Polanco et al., (2004) study, general motivation levels for students in Mexican universities were not significantly different, before and after PBL treatment. In agricultural science, Anderson (2007) studied motivational profiles from students in a Chicago High School. His data indicated that students' intrinsic motivation was at a moderate level after undergoing PBL. One study concluded that the insertion of PBL does not always to lead students having a higher intrinsic motivation (Wijnia et al., 2011). Wijnia et al. compared two learning environments for undergraduate students in educational psychology, involving PBL and a lecture-based environment. Their study suggests that there must be a balance between controlling elements and the students' autonomy, in designing the right amount of structure in learning environments.

In this paper, the main purpose is to investigate the effects of PBL on students' learning domains according to PBL philosophy. These include knowledge acquisition, critical thinking ability, and intrinsic motivation (Hmelo-Silver, 2004; Wee, 2004; Belland, French and Etmer, 2009). Within this, a special design of PBL procedures was developed, which combined several key approaches from existing PBL models (Masek and Yamin, 2010). The design was then tested in the polytechnic, which was within controlled and experimental condition and used actual measures (Tan et al. 2009). Preliminary findings revealed that PBL afforded a small contribution to some aspect of students' learning domains. The PBL designs used, left many variables open for future research.

METHODOLOGY

This study employed an experimental, pre-test and post-test with control group design (Campbell and Stanley, 1963). Two instructional methods were used; PBL was exclusively for the experimental group and traditional learning approach for the control group. The pre-test and post-test took place at the beginning and at the end of the 10 weeks of treatment. The 10 weeks of experiment duration was aligned with Burris (2005), in order to detect any differences caused by the treatment on variables such as critical thinking ability.

POPULATION AND SAMPLE

A total of 70 first year Diploma Electrical Engineering students from two isolated polytechnics (Merlimau Polytechnic (PMM) and Kota Melaka Polytechnic (PKM)) were involved in the study. These polytechnics were chosen amongst 22 polytechnics in which the ET101 module is offered. Then, a class in each of these polytechnics was randomly selected and assigned to either the experimental (PMM) or the control group (PKM).

The PMM and PKM were chosen in the basis of control factors, especially to avoid treatment diffusion. It was therefore, both classes must be homogeneous, which was confirmed by the pre-test result. Moreover, samples homogeneity was justified based on; first, students' entry requirements and intake for polytechnics were standardized and centralized (DPE, 2009). Second, students' placement in the polytechnic was centralized according to the courses applied. Third, students were randomly placed in a particular class due to the higher number of students' intake instead of students' particular characteristics.

TREATMENT PROCEDURE

The unit of instructions used for this study, involving of two selected units of the Electrical Technology (ET101) module syllabus (Unit 3 and 4).

- i) *An Introduction to Electric Circuit*
- ii) *DC Equivalent Circuit and Network Theorems*

These two major units accommodate the timeframes of 14 hours of lecture and 20 hours of practical, within eight to ten weeks period. In this study, the timeframe for these units of instruction were prefixed into ten weeks durations in both groups.

Control group: In brief, the procedures in the control group were retained as according to the existing setting. In this setting, the lecture took place for two hours meeting session with additional two hours for laboratory session within a week. The instruction was going on for 10 weeks parallel with the experimental group.

For the Unit 3 and 4 of the syllabus, the lecture mostly took place in the class sessions. The lecturer was typically active in delivering information and facts, explaining the terms, symbols, concepts, and procedures. Students in this case acted as a passive learner. In certain learning topics, for example the “Kirchhoff’s Law”, the lecturer had used to introduce the theorem before showed some examples of application and calculation. Students then applied their knowledge in the practical session in the laboratory.

The pedagogical approach was typically according to lecturer’s creativity that based on the semester’s teaching plan. Due to the nature of this module contents with large amount of concepts and principles, the teaching approach using lecturing has always been the primary method of instruction. However, this study was not prefixing any methods of instruction in the control group.

Experimental group: Several established PBL models, taken from wider education contexts and disciplines, were referenced to design PBL according to appropriate techniques and procedures. In this context, the researcher identified several critical components that became key success factors in implementing PBL (Masek and Yamin, 2010). In order to adapt to local educational requirements, several recently successful pilot projects in Malaysia’s higher educational scene (especially in electrical engineering fields), were also reviewed. This combination produced an exemplary instructional PBL model that could be tested specifically in an existing polytechnic curriculum setting.

For the overall structure of treatment, PBL was implemented over a period of ten weeks for students to solve five PBL problems that cover two of the sub-topics in the ET101 module. Within these, students were scheduled to have two weeks period to complete one cycle of PBL problem. The first week’s sessions were generally devoted to groups receiving their problem scenario. The second week was devoted to assessment activities. The subject-centric problem was used as a trigger (Kolmos, 1996) and a mini lecture was used to fill the gaps within the subject-centric problem (Yusof et al., 2005). Mini lectures were incorporated into tutorial sessions and lasted for a maximum of 10 minutes.

In one block of PBL cycle, the PBL groups were scheduled to attend four meeting sessions within two weeks. In each week, the PBL groups were scheduled to have a two blocks of two hours of meeting sessions. The first meeting session in the first week was compulsory, while the second meeting was optional session. In the second week, the first meeting session was optional, while the second meeting session was compulsory for presentation session.

The pre-test instruments were administered a week before the experiment had begun. Students were then divided into eight groups, consisting of four to five members each (Kolmos et al., 2007), according to previous test results. A leader was then appointed and rotated for each PBL problem. All groups received the PBL problem in the form of written scenarios. Each group was given several documents, including a problem analysis table, humanistic skills rubric, process skills rubric, and grading forms. A facilitator then conducted a mini lecture to introduce the problem, explain several important concepts, and to explain the students' role. Then, the PBL groups immediately began work to understand the problem.

During the tutorial session, the facilitator guided students through the problem solving process. The floating facilitator concept was applied (Yusof et al., 2005), where the facilitator moved from one group to another. The facilitator assisted students through the process of understanding the problem according to "what they know," "what they do not know," and "what they need to know" (Wee, 2004). This information was inserted into the problem analysis table. The facilitator also probed students with questions, but did not directly give any answers (O'Grady and Alwis, 2002). The tutorial session continued in the second meeting in the first week; and the third meeting in the second week, which was optional for groups requiring further assistance.

In between meeting sessions, students were encouraged to conduct an independent self-study (Schmidt, 1993; Wee, 2004), in order to seek relevant information for the problem. Students were free to conduct additional independent group discussion sessions, outside of the tutorial sessions. Students were also free to collaborate with relevant experts (Kolmos et al., 2007) pertaining to the problem at hand. Within this process, students prepared a proposed solution and readied themselves to share their information during a short presentation session (McDonald and Savin-Baden, 2004).

During the last meeting session of the second week, the major activities involved information sharing, assessment, and feedback process (McDonald and Savin-Baden, 2004). The PBL groups took turns to present their solution proposal. These short presentations were conducted in a group-based format, with all group members presenting their part (Kolmos et al., 2007). While this going on, other groups performed peer-assessments to evaluate the other groups' performances. At the end of the presentation session, students were asked to rate their team members' performance, according to the rubric rating scale (Foldevi et al., 1994). The facilitator immediately provided feedback to each group (Woods, 2000), based on the rubric rating scale. The facilitator and the students then generalized the learning experience, relevant to the learning outcomes. Post-test instruments were then administered at the end of the session.

INSTRUMENTS

Multiple Choice Questions (MCQ) Achievement Test: A set of 36 items of MCQ tests was developed according to three level of knowledge structure, namely concepts, principles (declarative knowledge), and procedural knowledge (Sugrue, 1995). All concepts, principles, and procedural knowledge of ET101 (Unit 3 and 4) were first be listed out according to the syllabus content and the module intended learning outcomes, as well as according to lecturers' advice. Then, example of relevant questions from several books and internet sources were modified and adapted, in order to construct a good set of items. In this case, concepts, principles, and procedural knowledge were assessed using key words from the Bloom's taxonomy (Bloom, 1956), according to specification provided by McMillan (1997). In addition, the Test Specification Table (TST) was used to equally distribute items and increase the validity of the test (Notar et al. 2004).

The Cornell Critical Thinking Test Specimen (CCTTS): The CCTTS measures critical thinking based on principles of thinking such as inference, which is based on induction, deduction, credibility, observation, meaning, assumption, and disposition (Ennis et al., 2005). The CCTTS comprised of 52 MCQ tests item (translated into Bahasa Melayu) that can be completed within 55 minutes. Choosing CCTTS was in the basis of several reasons; firstly, according to Ennis et al. (2005), the CCTTS is the most common instrument being used in measuring critical thinking abilities and is intended for various levels of audience including college students, which is comparable to students in polytechnic. Secondly, the CCTTS is fair for students in term of political, economic and social value, since items not involve any value judgements. Thirdly, the CCTTS is appropriate for an experimental study, in order to see improvement on critical thinking.

Intrinsic Motivation Questionnaire (IMQ): The IMQ was developed consisting of 22 items adapted based on Intrinsic Motivation Inventory (Ryan, 1982). Items were modified based on six subscales of intrinsic motivation (interest/enjoyment, option/choices, perceived competence, efforts/importance, pressure/tension, and value/usefulness), as well as according to the ET101 learning context. Students responded to items according to their agreement based on five points Likert Scale.

DATA ANALYSIS

The data analysis was first comparing the pre-test and post-test data, in order to determine the precondition of variables and homogeneity of samples. Further, the data analysis then compared the gain score for both control and experimental groups. Univariate Analysis of Covariance (ANCOVA) will be used to test the hypotheses as follows.

- (i) Null Hypothesis: There is no significant difference in mean knowledge acquisition between the control and experimental groups.
- (ii) Null Hypothesis: There is no significant difference in mean critical thinking ability between the control and experimental groups.
- (iii) Null Hypothesis: There is no significant difference in mean intrinsic motivation between the control and experimental groups.

RESULT AND DISCUSSION

The PBL preliminary implementation was successfully implemented in April 2011. The preliminary implementation was lasting for two weeks; students solved one PBL problem and complete all process in the PBL. All instruments were run tested at the end of the two week of PBL cycle. The result however, the intrinsic motivation findings can only be reported in this paper.

The pre-test questionnaire was completed by 22 students. However, four students did not attend the class when the post-test was administered. Therefore, only 18 complete pairs of data were analyzed. Within these, 13 respondents were male and five were female. Gender was equally distributed in each group.

Since the sample observation was small, the pre-test and post-test data was tested for normality. A Kolmogorov-Smirnov test indicated that both sets of pre-test and post-test data were not significantly different from a normal distribution ($p > 0.2$ both pre-test and post-test). Furthermore, the data was analyzed using a paired t-test; the results of that analysis are illustrated in **Table 1**.

Table 1: Paired t-test of students' intrinsic motivation mean scores

Scores	N	Mean	S	df	t	p
Pre-test	18	4.0123	.33418	17	1.121	.278
Post-test	18	4.1173	.49301			

* $p < 0.05$

As can be seen from Table 1, the mean score for students' intrinsic motivation was 4.0123 before PBL treatment and increased to 4.1173 after PBL treatment. This finding indicates that PBL increased students' intrinsic motivation. However, the paired t-test results of students' intrinsic motivation did not have a statistically significant difference between students' pre-test and post-test mean scores [$t(17) = 1.121, p > .278$].

In the current study, results were not significantly different; however, students' intrinsic motivation levels experienced a minimal increase. This result supports

Anderson's (2007) findings, in which the effects of PBL on students' intrinsic motivation were slightly increased. Within the six subscales, enjoyment represents the main subscale of intrinsic motivation (Ryan, 1982; McAuley et al., 1989). Further analysis of the post-test intrinsic motivation subscale was performed. Students indicated their enjoyment of PBL activities, by rating themselves with a high level of mean score, of 4.0. The item contributed to the enjoyment subscale; for example, "I feel happy with the learning activities in these topics," with a mean score of 3.78, and "I enjoy working with an assignment relating to these topics," with a mean score of 3.83.

For the other supportive subscales, the results agreed with the elements that support students' intrinsic motivation, such as choices, challenges, and autonomy (Pederson, 2003). Within these, the competence subscale, i.e., items that resulted in the highest mean score, were "I want to understand each topic's content" (4.0) and "I want to master each topic" (4.05). Other subscale mean scores are shown in **Table 2**:

Table 2: Mean scores for the intrinsic motivation sub-scale post-test

Subscales	Post-test mean score
Choices	4.26
Challenge	4.08
Relatedness	4.09
Competence	4.04
Autonomy	3.77

Based on these study findings, PBL afforded a small contribution to students' intrinsic motivation after three weeks of PBL treatment. Some components of the PBL design may explain these results, such as the problem design and the facilitation process. In PBL, the problem plays an important role to avoid student frustration. According to Hung (2009), the PBL problem should include adequate hints or clues, as a guideline for the students' learning direction. More hints will help the problem to be solved easier. For students at this level, the problem was designed with more hints or clues to help them solve the problem.

In certain cases, students may be unable to recognize the hints within the problem scenario. Therefore, the facilitator must play a major role in helping students to extract this hidden information, and thus present that information in an understandable form (Hmelo-Silver, 2004; Wee, 2004). Students must relate, "What they need to know" to their specific learning outcomes in the problem analysis table.

In this study, the first time implementation facilitator should provide aggressive guidance from table to tables; provide more specific trigger questions; and more time in the tutorial class. There must be an adequate amount of structure in the learning environments, between the controlling elements and the students' autonomy (Wijnia et al., 2011), in order to sustain students' intrinsic motivation in a PBL environment.

CONCLUSION

In this study, PBL was designed and implemented into the ET101 module, as one of the modules in the polytechnic's Electrical Engineering course. The design used key PBL elements that were customized from existing pioneer PBL models. Within this, the preliminary result indicated that students underwent PBL procedures were intrinsically motivated and enjoyed the PBL activities. Their intrinsic motivation was indicated by freedom of choice, autonomy, and challenges, in making a decision. In the context of process and student learning, elements such as problem design and the facilitator's role, played a critical part in ensuring student intrinsic motivation. Many aspects had been under authors' consideration on the possible threats of the true experiment. In real life situation, it almost impossible to fully control the dynamic of human being, but with some serious concern and initiative, the authors hope to increase the validity of study findings and produced robust evidence on the effect of PBL on learning domains.

ACKNOWLEDGMENT

The author/authors would like to thank Universiti Tun Hussein Onn Malaysia for supporting this research under the Postgraduate Incentive Research Grant.

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