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The Effects of Problem Based Learning on Mathematics Performance and Affective Attributes in Learning Statistics at Form Four Secondary Level

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Abstract

The challenge of globalisation today requires students to acquire problem solving and communication skills besides good procedural and conceptual knowledge of mathematics. This study was conducted to explore the effects of Problem Based Learning (PBL) as an alternative instructional strategy in the teaching and learning of mathematics effectively in Malaysian secondary schools. Previous research had discovered that that PBL enhances students' team work, problem solving skills and communication skills. In addition, interest in the subject significantly improved. A quasi experimental study with non-equivalent control group posttest only design was conducted to investigate the effects of PBL on form four Malaysian students' mathematics performance, instructional efficiency and affective attributes. The experiment was carried out for six weeks involving 53 Form Four students randomly selected from the district of Port Dickson. The experimental (PBL) group (n=29) were exposed to the PBL instruction whereas the control (CT) group (n=24) were taught conventionally. There were five instruments used in this study namely, mathematical learning worksheets, a posttest, Paas Mental Effort Rating Scale, a questionnaire on perception towards group work, interest in mathematics and perception towards mathematics learning experience and a rubric evaluating students' effective use of Polya's problem solving procedures, mathematical communication and teamwork. The data were analysed using analysis of covariance (ANCOVA) and independent t-test. Students' response to the questionnaire and researcher's observations based on the rubric were described using means, standard deviations and percentages. The findings of the study indicated that PBL is just as efficient as the conventional teaching strategy in enhancing Form Four students' mathematics performance. Even though both groups of students showed positive perception towards group work, interest in mathematics and perception towards the learning experience they went through, the PBL group used the Polya's problem solving procedures more effectively, displayed better mathematical communication skills and showed stronger teamwork compared to the CT group.

Keywords**:** Problem based learning; Mathematics performance; Instructional efficiency; Affective attributes

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1. Introduction

Since Independence, the Mathematics Education curriculum has undergone major reforms. A review of the education system in Malaysia had been planned to meet the demands and challenges of globalisation and the k-economy. A product approach was proposed in the teaching and learning process in all classrooms. A total review in the mathematics curriculum emphasises on several important aspects in mathematics education which includes communication and problem solving in mathematics (Sharifah, 2003).

In Malaysian schools, high performance in the examinations especially in the public examinations means everything. As this is the priority of parents and schools alike, teachers are very concerned with finishing the syllabus and drilling students the exam answers and questions. They are reluctant therefore to involve other approaches to the teaching and learning of mathematics as it would take up too much time and are irrelevant to passing examinations. The chalk and talk method are dominant in explaining rules, definitions and solving problems (T. Subahan, 2007).

This study was conducted to explore the effects of Problem Based Learning (PBL) as an alternative instructional strategy which could be introduced to Malaysian classrooms in the teaching and learning of mathematics. Students taught in traditional mathematics education environments are preoccupied by exercises, rules, and equations that need to be learned, but are of limited use in unfamiliar situations such as solving real-life mathematics projects. In contrast to conventional mathematics classroom environments, a PBL environment provides students with opportunities to develop their abilities to adapt and change methods to fit new situations. Further, students participating in PBL environments have greater opportunity to learn mathematical processes associated with communication, representation, modeling, and reasoning (Smith, 1998; Erickson, 1999; Lubienski, 1999).

The specific objectives of this study were:

1. To compare the overall mathematics performance between the PBL group and the CT group.
2. To compare instructional efficiency based on a Paas Mental Effort Rating Scale between the PBL group and the CT group.
3. To investigate perception of group work, interest in mathematics and the mathematics learning experience between the PBL group and the CT group.
4. To investigate effective use of Polya's problem solving heuristics, mathematical communication and teamwork between the PBL group and the CT group.

2. Methodology

In this study, a quasi-experimental *post-test only control group* design was employed. Two Form Four science elective classes were selected as intact groups in this study. The PBL group involved 29 students whereas the CT group consisted of 24 students. A total of eight 70 minute lessons and four 35 minute lessons of mathematics were conducted by the researcher herself throughout the study. During the acquisition phase of each lesson a worksheet was given to assess students' mental effort (load) expended to answer the given question. Throughout the experiment, students' effective use of Polya's problem solving heuristic, mathematical communication and teamwork were evaluated using a rubric by the researcher through observation. All the learning sessions in both PBL and CT groups were recorded on tape to avoid experimenter bias. At the end of the treatment a posttest and questionnaire were administered to both groups.

Five instruments were used in this study. The instruments applied were the learning assessments on mathematical concepts and skills learnt in the topic Statistics, the posttest, the Paas Mental Effort Rating Scale (PMERS), a questionnaire on perception of group work, interest in mathematics and perception of mathematics learning experience and a rubric on the use of Polya's problem solving heuristic, mathematical communication and teamwork.

The learning assessments and the posttest were validated by experienced mathematics educators and teachers. The questionnaire and the rubric were adopted and adapted from existing researches. The PMERS is a standard scale developed by Pass (1992). Reliability for the posttest, PMERS and the questionnaire were determined by the Cronbach Alpha reliability and were found to be minimally acceptable or better (Fraenkel & Wallen, 1990).

Mathematics performance was measured by the overall mathematics performance scores, the conceptual knowledge scores, the procedural knowledge scores and the number of errors committed per problem. Mental effort (load) was measured by the PMERS when answering the learning assessments and during the posttest. Instructional efficiency was calculated based on mental effort during the acquisition phase and the posttest and also the overall performance scores. The use of Polya's problem solving procedure, mathematical communication and teamwork were evaluated by using the rubric.

3. Findings

This research finding reports in detail the results of the analysis of both quantitative and qualitative data acquired during the experiment. All the data that were gathered were analysed using Statistics Package for Social Science (SPSS) and the results are presented as follows:

3.1 Hypothesis 1

There is significant difference in the overall mathematics performance between the PBL group and the CT group

Table 1: ANCOVA on overall mathematics performance between PBL and CT group

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	4880.388[b]	2	2440.19	8.71	0.001	0.26
Intercept	6022.55	1	6022.55	21.49	0.000	0.30
Pre PMR Scores	4273.88	1	4273.88	15.25	0.000	0.23
Group	409.76	1	409.76	1.46	0.23	0.03
Error	14012.78	50	280.26			
Total	238034.00	53				
Corrected Total	18893.17	52				

The ANCOVA showed that while the PBL group (M=67.38, SD=19.75) seemed to perform better in the overall mathematics performance than the CT group (M=60.58, SD=17.90) the difference was not significant ($F = 1.46$, $p > .05$)

Looking closely at the overall performance scores of both groups, the PBL group appeared to obtain a higher mean score as compared to the CT group. However the difference was not significant. Albanese and Mitchell (1993) and Vernon and Blake (1993) reported that performance in conventional tests of knowledge was the same for both PBL and traditional trained students. Similar studies were also done by Blake, Hosokawa and Riley (2000); Albano (1996) and Farquhar, Haf, and Kotabe (1986). Jones (1996) stressed the importance of appropriate assessment of student performance as the PBL strategy differs significantly from conventional teaching. Major (1999) agreed that a conventional pedagogy requires conventional methods of assessment but for an alternative instructional strategy like PBL an alternative assessment measure would surely be reasonable.

3.2 Hypothesis 2

There is significant difference in the mean relative condition efficiency index between the CT group and the PBL group.

Table 2: Independent sample t-test on mean relative condition efficiency index between the PBL and the CT group

Group	n	Mean	SD	t	df	Sig (2 tailed)
PBL Group	29	- 0.26	1.26	-1.70	51	0.095
CT Group	24	0.32	1.22			

From the results of independent t-test analysis there was no significant difference ($t(51) = -1.70$, $p < .05$) for mean relative condition efficiency index between the PBL group and the CT group. It is concluded that the PBL instructional strategy was just as efficient as the CT instructional strategy.

In terms of mental effort (load) the CT group seemed to expend less mental effort while solving their worksheets in the acquisition phase and answering the posttest in the test phase. However, both instructional strategies seemed to be equally efficient in this experiment. It is possible that a higher mean in the achievement test for the PBL showed increased germane cognitive load. This could be positive if the total cognitive load of the posttest is lower than the total available mental resources in working memory. Schmidt, Loyens, van Gog and Paas (2006) recommended that to show the positive effects of PBL, alternative form of assessments is most appropriate.

3.3 What are the perception of group work, interest in mathematics and the mathematics learning experience between the PBL group and the CT group.

Raw data for this analysis was obtained through a questionnaire administered to the students after the post test at the end of the experiment. The results of this analysis were described in terms of percentages, means and standard deviations. Each answer for the statement in the questionnaire was measured using the Likert scales. These statements reflected favorable and unfavorable preferences. Subjects responded on a five-point scale: "most favorable', "favorable", "less favorable", "not favorable" and "most unfavorable". Values from 1 to 5 were assigned on the scales. A score of 5 on the Likert scale was treated as the most favorable of the response. A mean score of greater than or equal to 3.0 was considered a positive perspective or attitude whereas a mean score less than 3.0 is associated with a negative perception or attitude (Kubiszyn & Borich, 1996).

It was found that both PBL and CT group showed positive perception towards group work and endorsed the importance of helping and working with their classmates. However, many find it hard to explain themselves while working in a group. On the aspect of interest in mathematics, although overall both groups showed positive interest in the subject, students in the CT group showed a higher interest for mathematics. On students' perception towards the learning experience they went through, the experimental group agreed that the PBL instructional strategy was a more effective approach in explaining difficult mathematical concepts and led them to understand the content better. This group also recommended the PBL approach for the next lessons and the teaching of other subjects.

In supporting studies, Albanese and Mitchell (1993) stated that PBL students find learning more significant, applicable and relevant. Challenging and engaging problems leads to better understanding and skill development as compared to traditional instruction. PBL students also found their lesson more interesting, stimulating and useful (de Vries, Schmidt, & de Graaff, 1989; Schmidt, Dauphinee, & Patel, 1987). Other studies on school children also reported that students were also clearly gaining other skills such as information mining, working in teams, being more involved in the learning process (Gabric & Ludovice , 2001).

These findings are also supported by Finucane, Johnson, and Prideaux (1998), Jones, (1996) and Smith (1995). They posited that students in PBL seemed to record an increase in student interest and enjoyment to the subject and develop their professional development.

3.4 To investigate effective use of Polya's problem solving heuristics, mathematical communication and teamwork between the PBL group and the CT group

Raw data for this analysis was obtained from a rubric which was evaluated by the teacher throughout the experiment. A rubric is an instrument for organizing and interpreting descriptive data gathered from observations of student performance. Scores on a scale of 1 to 4 attached to each level of a rubric were given through group work and presentation. Due to time constraints, the overall scores given to the group will reflect the individuals in the group as well. In this study, scores on a scale of 1 to 4 attached to each level of a rubric provided an objective basis for assigning grades. The score 4 would indicate the most outstanding characteristic or trait that was observed. The researcher gave scores on each student's use of Polya's problem solving heuristic, mathematical communication and teamwork based on group work during learning sessions and also during presentation. Table 3 below shows the means and standard deviations on mathematical communication and teamwork for the PBL and the CT group.

Table 3: Means and standard deviations on mathematical communication and teamwork based on rubric

Mathematical Communication	**Means**		**Standard Deviations**	
	PBL	**CT**	**PBL**	**CT**
1 Mathematical language	2.90	2.58	0.41	0.83
2 Representation (tables and graphs)	2.62	2.46	0.56	0.83
3 Explanation	2.48	2.17	0.57	0.76
Total	8.00	7.21	1.55	2.42
Teamwork				
1 Working with others	2.66	2.50	0.55	0.83
2 Attitude in group	2.62	2.50	0.56	0.83
3 Focus on the task	2.62	2.50	0.56	0.83
4 Quality of work	2.59	2.67	0.73	1.01
5 Pride in work	2.76	2.29	0.91	1.00
Total	13.24	12.46	3.32	4.51

Total mean score for mathematical communication for the PBL group (8.00) seemed higher than the CT group (7.21). The PBL group also scored higher mean scores for mathematical language, representation and explanation as compared to the CT group. The PBL group also displayed a higher total mean score for teamwork (13.24) as compared to the CT group (12.46). They were also awarded higher scores for working with others, attitude in group, and focus on the task and taking pride in their work. However, for quality of work, the CT group's mean score was higher (2.67) compared to the PBL group (2.59).

The rubric indicated that the PBL group was better at using the Polya's problem solving heuristics as compared to the control group. They also seemed to display better mathematical communication skills and showed stronger teamwork as compared to the control group.

One reason why PBL students were more efficient in using the Polya's problem solving heuristic more effectively in this study was the introduction of a 'trigger' or a problem in the beginning of the lesson. They were motivated to explore the aspects of the problem that they did not understand. When investigating the problem, the students used their previous experiences and prior knowledge when gathering facts, strategising and planning their solutions. Problems form the organising focus and stimulus for learning (McCombs, 2000). Problems trigger learning as students have to define the problem, analyse it, generate ideas and hypotheses and identify learning issues (Oon, 2003).

This findings of this study was also consistent with studies by Duch, Groh and Allen (2001) reporting that skills such as working as a team and demonstrating effective communication skills are learnt in order to solve a problem. Other studies also showed that PBL students work well in teams and small groups (Gallagher, Rosenthal & Stephien, 1992), gained other skills such as working in teams and being more involved in the learning process (Gabric & Ludovice , 2001) and that a PBL classroom provided students with high level of interaction for peer learning, peer teaching and group presentation (Finucane, Johnson & Prideaux 1998; Jones, 1996; Smith,1995).

The reason why PBL students in this study showed stronger teamwork as compared to the CT group was because they had to work in groups from the beginning of the lesson. They had to learn to be active problem solvers, contributors and participants in group discussions. Through collaborative work with their peers, they assumed responsibilities and self-definition associated with learning interdependently. They also had to learn to rely on their group members, mathematical resources, notes and materials provided as more important sources of authority and knowledge as the teacher's role was only as a facilitator and gave minimal guidance on how to solve the problem. These reasons are consistent with previous studies reported by Oon (2003), Greenwald (2000) and Barrows (1997).

4. Conclusion

This study strived to ascertain the effects of PBL on mathematics performance and instructional efficiency. It also compared the affective products of learning between PBL and the conventional teaching strategy. Research in PBL is not new. Although it started in medical schools it has been studied and researched in other fields including education. The findings of this study are consistent with findings from other literature. The numerous positive effects of PBL such as becoming better problem solvers, demonstrating effective verbal and written communication skills and being able to work collaboratively were also shown in this study.

From this study, it can be contended that the PBL group used the Polya's problem solving heuristic more effectively, displayed better mathematical communication skills and showed stronger teamwork compared to the CT group. However, minimal differential effect on mathematics performance and instructional efficiency was obtained between the PBL and CT group. Hence, this indicated that the efficacy of PBL has yet to be explored in enhancing these aspects in the teaching and learning of mathematics.

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