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Hybrid Problem Based Learning Games for Effective Mathematics Learning

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Abstract: Poor mathematics achievement is a critical issue that has been discussed lately. The combination of Problem Based Learning (PBL) method and game in mathematic environment can be synchronized to help students mastering mathematic knowledge heuristically. The objective of the study is to explore the effectiveness of using PBL and educational games in enhancing Mathematics learning. The experiment was carried out for three weeks involving 50 randomly selected Year 2 Engineering students who enrolled into Engineering Mathematics 2 course. The experimental group (EG) was exposed to PBL and Educational Game instruction whereas the control group (CG) was taught conventionally. There are three set of instruments used in this study namely PBLMathGame courseware, pre-test and post-test questions, and rubric sheets. The data were analyzed using independent t-test. Results indicated that the use of PBL positively increases students' achievement and added value of game to PBL learning enhanced students' skills in problem solving. It is recommendable in the future on the development of advanced game resources or games bank for the inclusion of many topics on mathematics learning.

Key words: Problem based learning, Educational games, Mathematics learning, Calculus, Student centered learning.

INTRODUCTION

In global needs, it is important to produce knowledge workers in science and technology. Thus, it requires graduates who are knowledgeable and skilled in mathematics. Nevertheless, most of the university students found that it is difficult and tedious that resulting poor performance in students' achievement (Costu, S., S. Aydınb and M. Filiza, 2009; Suthar, V. and R. Ahmad Tarmizi, 2010; Floyd, R.G., *et al*., 2003). Many students do not like learning mathematics and often perceive mathematics as an unpleasant experience and hard to learn the subject. Mathematics is usually taught in conventional ways that resulted information become uninteresting, irrelevant and disconnected to students' experiences (Sam, H.K., *et al*., 2009; Ahmad Tarmizi, R., *et al*., 2010; Zakaria, E., *et al*., 2010). Thus, this paves the way toward an ever growing population of individuals with mathematical anxiety (Sam, H.K., *et al*., 2006). It is therefore important to identify and recognize the factors that could enhance students' mathematics achievement in order to help them to improve and make substantial academic progress. PBL is one of the important approaches in education in last decades (Ahmad Tarmizi, R., *et al*., 2010; Akinoglu, O., and R.O. Tandogan, 2007; George, Watson University of North Carolina, 2002). It is a research in the cognitive sciences that expose to learning as it improves learning. The PBL learning environment gives students the opportunity to examine and try out their previous knowledge, discover what they need to learn, develop skills while solving problems, improve communication skills, state and defend with sound arguments and evidence on their own ideas, and become more flexible in their approach to solve problems (Ahmad Tarmizi, R., *et al*., 2010; Akinoglu, O., and R.O. Tandogan, 2007).

PBL in mathematics is an instructional approach where students are confronted with a real problem and challenged to work towards a solution (Ahmad Tarmizi, R., *et al*., 2010). In order to solve the problem, students will have to engage in a variety of activities such as analyzing problem, gathering information and forming solutions. As students tackle these activities, the students have more opportunities to think critically and represent creative ideas and communicate with peers through the mathematical activities (Ahmad Tarmizi, R., *et al*., 2010; Zakaria, E., *et al*., 2010). In such a way, PBL may build intrinsic motivation among students as it has been proven by (Akinoglu, O., and R.O. Tandogan, 2007) that PBL had positive effect on academic achievement and attitudes toward students' development.

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The significance of PBL in education cannot be denied. With the entry of technology into the classroom, the teaching of mathematics has changed. The challenge of creating and integrating educational technologies to enhance PBL environment has been an issue. Educational technologies that are well-designed could complement and support the PBL environment (Ishikan, U. and M. Sevgi, 2010). The technology enables teachers to be creative, passion, with the resources available that could help them to implement various techniques and strategies into the classroom to make learning more meaningful and interesting to students (George, Watson University of North Carolina, 2002). In addition, with the advent of technology-rich teaching on a large scale, there are now many new opportunities for creative and innovative teaching. Thus this builds a new relationship that shapes students into shifting world of knowledge. The development of technology in recent years has prompted changes in teaching and learning strategy especially in higher education.

Games are seen as a model that can improve learning environments by providing the elements of goals, challenges, and collaboration. Thus in PBL, students have control over their learning process and incorporate novelty into the environment. The usage of game in education can attract students in the teaching and learning process (Papastergiou, M., 2009). Thus, the teaching of mathematics should take the advantages offered by the technology as the usage of computers in teaching and learning mathematics does not only improve the quality to the teaching but to the learning process as well (Ishikan, U. and M. Sevgi, 2010; Alan, A., *et al*., 2000).

The objectives of this paper are two-folds, namely to (a) determine the effectiveness of PBLMathGame in enhancing mathematics learning in PBL environment, and (b) assess the impact of games in enhancing students' skills in problem solving and examines students' achievement based on academic performance.

Methods:

This study was conducted using quasi experimental design which comprised of two groups of students. The respondents of this research comprised of 50 Engineering students in Year Two who enrolled into Mathematic Engineering course in Politeknik Merlimau, Melaka. The research was conducted in Engineering Mathematics course during the implementation of *Rate of Change* topic.

This group was given a pre-test and post-test before and after the PBL session. Based on the pre-test, the students were randomly selected based on average of scores in terms of academic success and knowledge. They have been divided equally: 25 students into PBL Group (EG) and 25 students in non PBL Group (CG). The results for the both tests were analyzed to measure if there is any difference in terms of students' achievement for the non PBL user and PBL user.

Hence for the PBL user (25 students), they were further divided into PBLMathGame group (13 students) and non PBLMathGame group (12 students). Both groups used the PBL prototype courseware for their learning session. In the PBLMathGame courseware, game element was added in the learning resources module in order to test on the impact of using game in developing problem solving skills. The game that embedded in the courseware was designed based on game of skill theory. A game of skill is a game design that has the element of chances and the skills plays important rule in completing the mission of the game. The advantage of this design was it explores players' capability by encourage player to look at, understanding and experience things. The prototype is used as a proof to obtain the effectiveness of using educational games in enhancing students' skill in mathematics problem solving.

The prototype with limited interactivity is developed based on *Rate of Change* topic. The topic is chosen based on the justification from the preliminary results analysis that showed *Rate of Change* topic is the hardest topic in subject Mathematics Engineering 2. A rubric score is used to determine the impact of using games in enhancing students' skills in problem solving in the experiment. The experimental framework is shown in Figure 1.

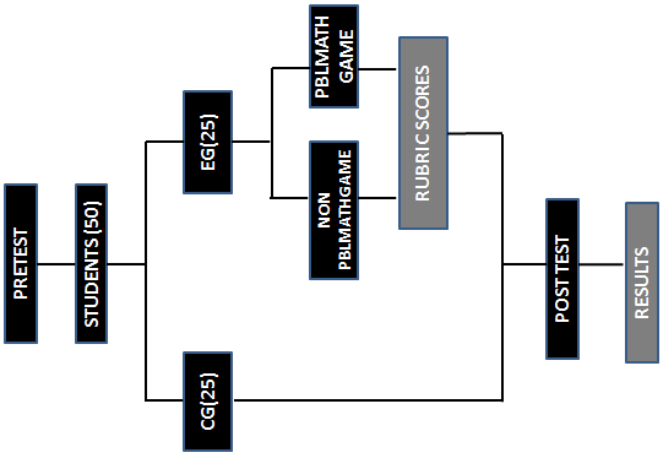

Fig. 1: Experimental Framework

The design of the prototype based on PBL courseware design that consists of: (a) problem scenario; (b) lecturer modules or notes; (c) learning resources and games; (d) problem solving;(e) assessment and (f) forum. The game element is added into the PBL courseware in section learning resources. This element contributes to stimulate students' interests and develop students' skill that helps students to understand in solving mathematic problem effectively. This statement is agreed by (Akinoglu, O., and R.O. Tandogan, 2007).

In this study, two data collection tools were used. The first one is the rubric for problem solving strategies based upon Polya's stages (Polya, G., 1957). This rubric is used to evaluate the students' problem solving skills scores upon using PBLMathGame in their learning. The second one is the pre-test and post-test marks to measure students' achievement upon using PBL courseware in learning Mathematics.

With regard to the scope of study, the rubric scale is used to examine the students' ability to solve mathematics problem based on Polya's problem solving steps. (Polya, G., 1957) states that successful problem solving involves four steps: (a) understanding the problem; (b) selecting strategy; (c) solving the problems and (d) looking back. Table 1 illustrate the procedure for data collection and data analysis used in the study:

Table 1: Research procedure

	Research Question	Procedure	Data Analysis
1	Is there any difference in term of students' achievement between PBL user and non PBL user?	Pre-test and Post-test marks 50 samples PBLMathGame courseware	Independent Samples T-Test
2	Is there any relationship between the use of game and students ability in solving mathematics problem between PBLMathGame and non PBLMathGame user?	Rubric scores 25 samples PBLMathGame courseware	Independent Samples T-Test

RESULTS AND DISCUSSION

Effectiveness of using PBL in learning mathematics:

The purpose of study 1 was to measure the effectiveness of using PBL in learning Mathematics based on academic performance. Approximately there are 50 students from Year 2 engineering students involved in the study. They were divided into 2 groups PBL group (EG) and non PBL group (CG). The EG group undergo PBL learning session for the *Rate of Change* topic with the supervision of the tutor. On the other hand, the CG group remain use the conventional method in learning. A set of pre-test and post-test questions given to the respondents before and after the experiment took place. The scores for both tests are measured for result purpose as shown in Table 2 and Table 3.

Table 2: Statistical data of the effectiveness of using PBL in learning mathematics

	Stud_id	N	Mean	Std. Deviation	Std. Error Mean
PretestMark	Non-PBL Group	25	18.00	15.275	3.055
	PBL Group	25	18.00	15.275	3.055
PostTestmark	Non-PBL Group	25	56.40	23.784	4.757
	PBL Group	25	74.00	21.794	4.359

Table 3: Data analysis of the effectiveness of using PBL in learning mathematics

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
PretestMark	Equal variances assumed	.000	1.000	.000	48	1.000	.000	4.320	-8.687	8.687
	Equal variances not assumed			.000	48.000	1.000	.000	4.320	-8.687	8.687
PostTestmark	Equal variances assumed	.288	.594	-2.728	48	.009	-17.600	6.452	-30.572	-4.628
	Equal variances not assumed			-2.728	47.638	.009	-17.600	6.452	-30.575	-4.625

Inspection of Q-Q Plots revealed that post-test marks was normally distributed for both groups and there was homogeneity of variance as assessed by Levene's Test for Equality Variances. Therefore, an independent t-test was run on the data as well as 95% confidence intervals (CI) for the mean difference. It was found that the mean for PBL group were significantly higher than the non-PBL group ($t(48) = -2.728$ $P=0.009$) with a difference of -17.6 (95% CI, -30.75 to -4.63). It showed that there is an improvement in term of students' achievement for PBL group compared to non-PBL group

Enhancing Students' Skills in Problem Solving:

The purpose of study 2 was to determine the effect of educational game (PBLMathGame) in enhancing students' skills in problem solving. There were 25 students from PBL user group participated in the study. They were divided into two groups namely PBLMathGame group and non PBLMathGame group. Both groups have undergone the same PBL learning sessions but an additional game element in the learning resources module was introduced for PBLMathGame group only. During the problem solving sessions, both groups were evaluated by a rubric score. These scores were used to determine the impact of game use in the learning session. The statistic the study and the data analysis are shown in Table 4 and Table 5.

Table 4: Statistical data of rubric scores for PBLMathGame and non-PBLMathGame

Group Statistics

	stud_id	N	Mean	Std. Deviation	Std. Error Mean
RubricScores	PBLMathGame	12	79.17	16.214	4.680
	Non-PBLMathGame	13	69.23	25.646	7.113

Table 5: Data analysis of rubric scores for PBLMathGame and non-PBLMathGame

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
RubricScores	Equal variances assumed	2.187	.153	1.146	23	.263	9.936	8.668	-7.996	27.868
	Equal variances not assumed			1.167	20.458	.257	9.936	8.515	-7.800	27.672

The correlation between rubric scores for PBLMathGame and non-PBLMathGame group was 9.94; the 95% confidence interval was -7.8 to 27.67. Thus, it showed that for the PBLMathGame group, by using game element in PBL, it helps the students in improves problem solving skills based on the rubrics scores they gained.

Conclusion:

Students with PBL environment gained better marks compare to non-PBL group. The element of real world problem, critical thinking, self-exploration and group discussion in PBL environment helps in the learning process. Thus, PBLMathGame is an effective tool to be used in enhancing mathematics learning. Students who use game in PBL gained better scores in their problem solving rubric supporting that games gives impact in enhancing students' skills in problem solving. PBL and game in Mathematics showed an improvement in terms of strategies of learning mathematics and also students' achievement in mathematics. It can be implied from this study that the use of PBL and game in Mathematics learning can foster students' interest in learning and achieving better results. This in turn will help the government in producing a knowledgeable and skill able engineers in the future. It can be suggested that the development of game resources or games bank should include many topics on mathematics learning that can be use in any lower and higher learning institutions.

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