

Problem Based Learning in Mathematics

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Abstract

Research shows that the introduction of problem based learning (PBL) could foster student-centered learning, enhances students' abilities in learning, change their perception towards the subject matter and creates active learners. Although this approach has been applied in other disciplines, there is still lack of research focusing on the adoption of PBL approach in the Mathematics curriculum in countries such as Malaysia. Thus, this paper examines and summarizes some of the research conducted in the area of PBL in teaching and learning Mathematics and its effectiveness from students' perspective. The review shows PBL adoption in Mathematics is gaining positive feedbacks from students even though there are no convincing evidence to prove that PBL does in fact increase students' performance.

Introduction

In this global economic era, graduates from higher learning institutions are faced with the challenges of finding adequate jobs. Most of the employers seek graduates who have the ability to solve authentic problems encountered in the workplace. Unfortunately, the current curriculum and pedagogy employed in higher learning institutions in Malaysia often fail to prepare graduates for the challenging workplace (Sharifah & Lee, 2005). Moreover, most undergraduates in Malaysia came from a schooling system which is exam oriented and pay less emphasis on development of soft skills needed in workplace (Hussain, Ahmad et al, 2007).

In addition, the high unemployment rate of 70% among graduates has captured the attention of many parties and there is a strong urge for immediate remedy (Suresh Ram, 2006). The high unemployment rate in Malaysia is due to lack of the basic skills, expertise, communication skills and knowledge among Malaysian graduates. Most of the employers who hire fresh graduates claimed that fresh graduates also lack the soft skills which are the core requirement for any jobs (Woo, 2006). Generally soft skills can be categorized into three areas; character, interpersonal skill and critical and creative thinking (Nor Hartini, 2007). These skills enable one to communicate effectively, manage relationships, lead a team, and solve problems. However, many employers particularly from the private sectors claimed that they are not interested in recruiting local graduates because they lack these soft skills and expertise required in their area (Woo, 2006).

In order to solve this problem, the educators should continuously encourage the students to gain work experience and soft skills on campus and off campus. Most of the students seem unaware of the importance of work experience. In order to assist students, an educator may use several approaches to enhance their skills and knowledge; for example stimulating the minds of students with discussions and case studies. It is suggested that these educators may consider introducing problem based learning (PBL) approach in teaching which is believed to increase soft skills and independent learning (Sharifah & Lee, 2005).

PBL is a student-centred learning approach in which students work collaboratively in small groups to solve problems given. These small groups of students normally are guided by lecturers/teachers who play the role of 'facilitators'.

PBL was pioneered and used extensively at the medical school of McMaster University, Ontario, Canada in order to overcome students' limited ability to apply coursework knowledge into clinical problems (Torp & Sage, 2002). Today, PBL is used extensively in many learning institutions worldwide and in many fields of professional training such as nursing, engineering and architecture. Table 1 shows the PBL implementation in local universities in Malaysia.

Table 1: Implementation of PBL in Malaysia

LOCAL INSTITUTIONS	FIELD
University Islam Malaysia	Environmental Law
Universiti Malaysia Sarawak	Medical
Universiti Kebangsaan Malaysia	Medical
Universiti Sains Malaysia	Physics
Universiti Malaya	Information Technology, Mathematics
Universiti Teknologi Malaysia	Information Technology
Universiti Tun Hussein Onn Malaysia	Engineering

(Source: Adapted and modified from Faaizah & Halimah, 2008)

Definition of PBL

Hmelo-Silver (2004) described PBL as an instructional method in which students work collaboratively to find possible solutions for a problem scenario. The author noted that students formulate and analyze the problem to generate hypotheses about possible solutions which leads to a brainstorming session and self-directed learning. This encourages the students to do more research and to find new possible solutions for the problem. The author added that the educators/teachers act as facilitators throughout the PBL session. The underlying principle of PBL is that "all learning begins with a problem" where it provides a new dimension, direction and motivation for learning. Students are provided with "real world" problems which help them to enhance their problem solving skills, analytical skills and gain new knowledge on subject matter (Barrows & Tamblyn, 1980; Boud & Feletti, 1991; Schmidt, 1983).

The characteristics that differentiate PBL with other learning approach is that in PBL the problem comes first before the information needed to solve it which is contrary to the 'traditional' approach where information is given prior to the problem (Mills, 2006). Torp and Sage (2002) described PBL as focused, experiential learning which rotates around the analysis and resolution of real-world problems. They describe students as active learners who identify the root cause of a particular problem and find ways to resolve the problem.

Effectiveness of PBL

The review of evaluation of PBL adoption in medicine appeared after 15 to 20 years of experience (Albanese & Mitchell, 1993; Berkson, 1993; and Vernon & Blake, 1993). Medicine is the discipline where PBL has been most thoroughly evaluated. The evaluation of PBL adoption later spread into other disciplines like engineering, architecture, economics and mathematics.

Musal, Taksiran and Kelson (2003) have conducted a research to determine the opinions of tutors and students about the effectiveness of Problem-based Learning in Dokuz Eylul University School of Medicine. They used a questionnaire with a five-point Likert scale to collect data from respondents. According to the results of this study, both tutors and students gave positive feedback towards the effectiveness of PBL approach. Both group of participants agreed that adoption of PBL in their curriculum did assist them in acquisition of clinical reasoning skills, communication skills and problem solving skills. However, both groups gave lowest ratings for the area of gaining basic science knowledge.

Duch, Groh and Allen (2001), in their book "The Power of Problem Based Learning" noted that the approach used in PBL helps the students to "think critically and be able to analyze and solve complex, real-world problems; find, evaluate and use appropriate learning resources; work cooperatively in teams and small groups; demonstrate versatile and effective communication skills, both verbal and written; and use content knowledge and intellectual skills acquired at the university to become continual learners"(pg. 3).

McParland, Noble and Livingston (2004) conducted a research among Year 2 clinical medical students of a British medical school to identify the effectiveness of problem-based learning compared to traditional teaching in undergraduate psychiatry students. The students were divided into two cohorts, traditional, lecture-based group and PBL group respectively. Both groups went through 12 days of session and were requested to answer questionnaires to assess their learning styles and the Attitudes to Psychiatry Scale at the beginning and the end of attachment; and two end of attachment examinations (multiple-choice and viva). From the survey results, the authors concluded that the examination performance of the students who participated in the PBL session was better than those in the traditional teaching method. However, they claimed that the PBL students' learning style and attitudes did not demonstrate any significant difference compared to the students who adopt the traditional learning method.

PBL in Mathematics

Many researchers have conducted research on PBL adoption in the field of medicine and engineering. Similarly, there is a large body of research that has investigated mathematics taught via a problem-based approach (Crist, 2006). According to Lambros (2004), PBL has been embraced by several hundred schools in the United States of America within the past 10 years with several thousand additional schools considering the adoption of PBL programs.

PBL is believed to increase the self-efficacy of the students. To prove this belief, in 2004, Cerezo conducted a qualitative study among 14 at risk females who enrolled in mathematics courses to investigate the correlation between PBL and self-efficacy. It is believed that self-efficacy can motivate self regulated learning where it can endorse self confidence, motivation and concentration; help in obtaining relevant information, working with deadlines and inquiring information from peers and teachers when needed (Cerezo, 2004). The researcher conducted an interview session with the students from various grades in different schools in USA. These students had experienced in PBL sessions and they were selected randomly by their teachers. All the respondents of the interview stated that they like the PBL session very much because of the interesting problem formulation and they are able to work in groups. Furthermore, the result of the survey also revealed that there is a positive correlation between self-efficacy and PBL. According to the interview results, all the respondents agreed that PBL had changed their learning process, increased their motivation, helped them learn more about the topic and created a feeling of excitement about coming to class.

In 2005, Low and Ng carried out a research to highlight the effects of the PBL approach on students' self-directed learning behaviours in mathematics in Singapore. The survey was conducted among students who enrolled in Engineering Mathematics. The focus area of the survey was divided into four categories: to identify students' perception on the impact of PBL on their attitude in learning mathematics; students' perception of the self-directed

learning process in learning mathematics; students' perception on the use of reflection journal towards their learning in mathematics and students' overall perception of the PBL approach in mathematics learning. The authors noted that many students agreed they have become more self-directed learners after experiencing PBL in mathematics. However, a majority of the respondents felt that they did not enjoy learning mathematics using PBL approach and PBL does not help them to better understand the work that they do in mathematics. This is because a majority of the respondents have very limited fundamental knowledge of the subject and felt PBL does not allow them to learn through more practice which they think is an essential skill for learning mathematics. The authors also concluded that most of the respondents still prefer to learn mathematics in the conventional way which seems much easier for the students to understand mathematics compared to the PBL approach.

PBL is also believed to increase the ability of the students to see the connection between real world problem and mathematics. A study conducted by Portal and Sampson (2001) found that, PBL was effective in giving students opportunities to see the connection between mathematics and the real world and gave students the opportunity to use higher order thinking skills. In addition, the author also found that there is an increase in the number of students who are comfortable with mathematics.

Implementation of PBL in mathematics can increase the performance of the students. A research conducted by Webb (1996) on PBL mathematics program titled the Interactive Mathematics Program (IMP) covering material from algebra, geometry, trigonometry, statistics, and probability proves this. Based on its result, he found that students participating in the pilot IMP program perform as well as, and sometimes even better compared to their peers in the traditional high school math courses. Regarding problem solving skills and quantitative reasoning, Webb (1996) found that IMP students showed tremendous improvement than their peers who follow conventional method.

Examples of Mathematics Questions Based on PBL Approach

Problem Based Learning Activity 1: The Pool Dilemma

Mrs. Shannon wants to build a 729 square feet sized swimming pool in her backyard. Mrs. Shannon has been doing some research through catalogs and has narrowed her choice between two pools – a rectangular pool and a circular pool. The rectangular pool is 30' x 25' with a height of 15 feet. The circular pool has a diameter of 15 feet and a height of 15 feet. To help the principal in her decision, she has hired your team of experts to advise her on which pool she should select that will fit in her backyard and would be the most cost efficient. Mrs. Shannon has informed you that she wants to put fencing around the pool for safety concerns and wants to pick the pool that will have the cheaper water expenses. Use your expertise to help Mrs. Shannon select the pool that meets all of her requirements.

- A. Which swimming pool would fit in the backyard?
Mathematical Calculations:
Rectangular Circular
- B. Which swimming pool will be cheaper to put fence around?
Mathematical Calculations:
Rectangular Circular
- C. Which swimming pool would have the cheaper water expense?
Mathematical Calculations:
Rectangular Circular

(Source: Adapted from <http://www.idecorp.com>)

Problem Based Learning Activity 2: The Restaurant

Your restaurant has been selected by Sean "P. Diddy" Combs for his Saturday business meeting with his new recording artist, M. C. Math. Your guest services team has been hired to plan P. Diddy's and his artist's culinary experience at your restaurant. Your team's responsibilities include selecting the guests' menu choices, calculating and filling out their food bill and ensuring that all your guests' needs are met. Mr. Combs and his artist have no dietary restrictions and would like to have a meal which includes four courses. Use your expertise to plan a great dining experience for Mr. Combs so that he will use your restaurant for future events.

Below is a list of all the activities that you have to complete.

- A. Select menu choices for Mr. Combs and his artist.
- B. Fill out the Guest Meal Check for Mr. Combs and his artist.
- C. Calculate food bill subtotal for Mr. Combs and his artist.
- D. Calculate Sales Tax amount for the food bill.
- E. Calculate the Gratuity or Tip amount for the food bill.
- F. Complete Guest Meal Check Math Quiz.
- G. Mr. Combs completed Guest Meal Check is due.

How to Calculate Sales Tax

- Step 1 : Find the subtotal or cost of the item.
- Step 2 : Identify the local sales tax rate.
Remember sales tax is assessed on each dollar amount charged. In addition, the amount of sales tax is assessed based on where you live.
Rockland county sales tax rate = 8.125%.
- Step 3 : Change the local sales tax rate to a decimal by omitting the percent sign and moving the decimal point two (2) places to the left. Example: $8.125\% = 8.125 \Rightarrow .08125$
- Step 4 : Multiply the subtotal or cost by the decimal representation of the sales tax rate.

Remember finding the sales tax amount is equivalent to finding the part of a number.

Step 5 : The result is the sales tax amount.

(Source: Adapted from <http://www.idecorp.com>)

PBL in Mathematics: Cases in Malaysia

Halimah and Faridah (2008) have developed an interactive multimedia courseware using PBL for mathematics (PBL MathS-Set) Form 4 to test the students' attitude towards the use of interactive multimedia courseware using PBL approach for the Set subject matter. The courseware developed is believed to bring an authentic scenario which helps the students to realize the relationship between mathematics concepts and their future career. The authors noted that, the approach adopted by them will encourage active learning which emphasizes on conceptual learning rather than memorizing. In this courseware, students were given ill-structured problems which will derive many possible set of solutions and give the students a chance to think as professionals. A group of 25 students from one of the technical schools in Selangor participated in this survey. A set of questionnaire were distributed to collect data about effectiveness, learnability, ease of use, flexibility and attitude of the students towards this courseware. A five point Likert scale was used to assess each usability properties. The results showed all the criteria scored a mean value of more than 4. Based on the result, the authors concluded that the usage of the courseware is effective for the students in learning mathematical concepts and solving problems. They further added that the development of PBL MathS-Set multimedia courseware has succeeded in assisting the users by enabling hands-on and minds-on teaching and learning activities.

In 2005, Sharifah and Lee had conducted a research in the Faculty of Mathematics, University of Malaya to identify the differences in students' attitude before and after implementing PBL; the activities that students experience during the PBL session and students' general perception of the PBL approach. About sixty three students who were enrolled in the Mathematics Method course participated in this survey. From the survey result, the authors concluded that attitude of students towards working in group have shown significant difference before and after implementing PBL. They claimed respondents of this survey became good listeners, more open minded, organized, systematic, practice good time management, improve team work and learned to find, evaluate and use appropriate learning resources. The authors also concluded that majority of the respondents did enjoy PBL approach and were able to enhance their ability to solve real-world problems by generating alternative solutions for a problem. Majority of the respondents admitted they have become active learners after engaging in PBL approach.

Conclusion and Suggestion

Problem based learning (PBL) has become a recognised and accepted educational approach to curriculum delivery. Profoundly different from the traditional approach to education, it aims to optimise students' growth in knowledge and understanding, promotes

critical reasoning, enhances team building and fosters active learning. The above reviews also concluded that PBL promises enormous advantages to students. Result from the review shows that students engaged in PBL approach become active learners, hone their leadership skills, enjoy learning mathematics and enhance the ability to find and evaluate subject materials.

However, research on PBL in mathematics in Malaysia only focuses on evaluating its effectiveness from students' perspectives. It is suggested future research needs to examine the role of the facilitators in the PBL approach and the arising difficulties of educators in adopting PBL approach. This is because most of the new PBL facilitators face difficulties in preparing standard material adequate for PBL session (Jamieson & Macpherson, 2006)

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