ASSESSING THINKING SKILLS: A CASE OF PROBLEM-BASED LEARNING IN LEARNING OF ALGEBRA AMONG MALAYSIAN FORM FOUR STUDENTS

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ABSTRACT
The teaching and learning of mathematics is a complex and dynamic process involving interaction between previously acquired levels of understanding and conceptualization of mathematical knowledge which consists of mathematical concepts and skills of problem solving in a student centered learning environment. The objective of the study was to examine the effectiveness of PBL in teaching algebra among Form Four students. PBL is a teaching strategy which simultaneously develops higher-order thinking (HOT), disciplinary knowledge bases and practical skills by placing students in an active role as problem solvers confronted with ill-structured problems that mirror real-world problems. The results suggest that the experimental group following the PBL approach performed significantly better than the control group following the traditional approach in the overall performance in algebra, lower-order thinking questions and also higher-order thinking questions. Therefore, PBL is a powerful tool in teaching abstract and intricate concepts of mathematics like algebra.

KEYWORDS: Problem-Based Learning, Higher Order Thinking Skills, Lower Order Thinking Skills, Mathematics Learning, Algebraic Thinking

1 INTRODUCTION
The teaching and learning of mathematics is a complex and dynamic process involving interaction between previously acquired levels of understanding and conceptualization of mathematical knowledge. As such, many programs and policies in mathematics education have been implemented in order to improve the instructional approaches. Some of these program and policies have undergone tremendous changes over the years. For instance, the role of teachers and students in the process of learning has been changed and students are now not only passive observers, but are instead active learners, who develop new ideas to improve their learning. The teachers are now not only knowledge and information transmitters, but also function as leaders and facilitators guiding students in discovering knowledge (Sharifah Maimunah Syed Zin, 2007; Rohani Ahmad Tarmizi, 2008).
Nowadays, Mathematics Curriculum is focused on students' needs to think mathematically rather than just doing mathematical computation. Students should be able to develop more complex, abstract, and powerful mathematical structures. This can dramatically enable them to solve a broad variety of meaningful problems. Furthermore, students ought to become autonomous and self-motivated in their mathematical activities such as learning and solving problems. In addition the mathematics curriculum should emphasize on acquiring mathematical knowledge which consists of mathematical concepts and skills of problem solving in a student centered learning environment.

The basis of PBL is rooted in Dewey’s “learning by doing and experiencing” principle (Dewey, 1938). The PBL is an active learning which enables students to become aware and determine his or her problem solving ability and learning needs, to learn to learn, to be able to make knowledge operative and to perform group works in the face of real life problems. According to Finkle and Torp (1995), PBL is a teaching strategy which simultaneously develops higher-order thinking (HOT), disciplinary knowledge bases and practical skills by placing students in an active role as problem solvers confronted with ill-structured problems that mirror real-world problems. Based on this definition, the acquisition of professional knowledge is as important as the development of problem solving skills and social skills.

In some definitions, PBL is not merely viewed as an instructional methodology, but structured as the entire curriculum itself. The curriculum consists of attentively chosen and constructed problems that require the learner to acquire ‘critical knowledge’, ‘problem solving proficiency’, ‘self-directed’ learning strategies, and ‘team participation’ skills. These processes replicate the systemic approach used to resolving problems and challenges that are faced in life and career (Barrows & Kelson, 2002). Today, many mathematics educators are considering this approach and have increasingly started to apply PBL approach in the teaching and learning of mathematics (Hmelo-Silver, 2004). It is agreeable that learning mathematics by understanding the concepts is much more effective than trying to memorize the procedures of getting the correct answer. This nature of mathematics education being based on practice and conceptualization makes it so connected to real life and is well facilitated in a PBL environment. In a PBL environment, students learn and acquire concepts while in active battle with problems and when receiving immediate corrective feedback about the solution. Also, using ill-structured problems with missing information helps students understand the extent of the problem at hand and forces them to decide on an action plan for
resolution. This urges students to adopt various learned mathematical strategies to derive a solution and at the same time develop their mathematics literacy.

The teaching and learning of Mathematics and Additional Mathematics at the secondary level in Malaysia appears to be a formidable obstacle. Among the facets, teachers stated that algebra was the area of Mathematics that was most difficult for them to teach (Hmelo-Silver, 2004). Teachers felt that they needed to prepare more for these lessons. The teachers also felt that some student’s misunderstandings resulted from an over-emphasis on routine skills at the expense of developing students’ conceptual understanding. Clearly, numerous issues surround the learning of algebra mainly because of the difficulty students face to grasp and work with abstract concepts. Moreover, students’ difficulties with algebra results not only from algebra curriculum that lack meaning and coherence, but also from instructional approach that fail to develop students’ abilities to reason about complex additive and multiple relationships. Therefore, an effective pedagogical approach is necessary to help students develop a good understanding of the abstract concepts and intricate relationships. Hence with PBL instructional approach, algebraic knowledge and reasoning could be enhanced and developed. Moreover, using real-life representations in a problem scenario allows students to make a safe transition from concrete understandings (arithmetic) to abstract concepts (algebra) pertaining relationships which would directly prepare them to handle HOT questions that require analysis, synthesis and evaluation.

Therefore, to address these issues, a more holistic instructional approach is needed where learners can take much more responsibility for their own learning and become independent from their teachers gradually; hence able to pursue in life-long learning. These are possible only with an instructional methodology that promotes active participation of students, such as the PBL approach.

The general objective of the study was to examine the effectiveness of PBL in teaching algebra among Form Four students. The following are the specific objectives of this study:

1. To compare the overall performance in algebra between students following the PBL approach and traditional approach.
2. To compare the performance in algebra lower-order thinking (LOT) questions between students following the PBL approach and traditional approach.
3. To compare the performance in algebra higher-order thinking (HOT) questions between students following the PBL approach and traditional approach.
2 Method
This study uses the quasi-experimental research design, based on two-group (experimental and control) post test-only research design. According to Fraenkel and Wallen (2009), the two group post test-only design is stronger compared to the one group pre test-post test design because the usage of two randomized groups would be adequate to overcome the threats against validity and provides a more accurate representation of the independent variables tested. The instructional approaches were used to teach the lessons on Simultaneous Equation and Coordinate Geometry. The experimental group was taught using the PBL approach whereas the control group was taught using the traditional approach. The differences in the mode of teaching between the two instructional approaches are shown in Table 1 below.

Table 1: Difference between the instructional approaches used in the study

<table>
<thead>
<tr>
<th>Traditional teaching approach</th>
<th>PBL approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher showed step-by-step on how to solve questions</td>
<td>Students solved questions in groups of 5 and presented their findings to the class.</td>
</tr>
<tr>
<td>Teacher-centered</td>
<td>Students-centered</td>
</tr>
<tr>
<td>Learning is done through examining worked examples</td>
<td>Learning is done through knowledge construction.</td>
</tr>
<tr>
<td>Three questions were chosen from the textbook and presented to students</td>
<td>Three specially formulated PBL questions reflecting on real life scenarios were used.</td>
</tr>
<tr>
<td>Only the solution pathway taught by the teacher is accepted.</td>
<td>Any mathematically correct pathway of deriving solution was accepted.</td>
</tr>
</tbody>
</table>

Posttest performance refers to the acquisition of total intended knowledge indicated by the level of achievement of students in algebra based on the lesson outcome throughout the 6 sub-topics taught during the treatment phase. In this sense, performance of the students consists of the ability to do well in questions pertaining both the LOT questions and HOT questions based on the learnt conceptual and procedural knowledge. From the post test, three questions were analysed as the lower-order questions. These questions were formulated to measure the extent to which students were capable enough to carry out their LOT skills, namely, knowledge, comprehension and application. In a typical lower-order question, students were expected to simply write out the formulas memorized and substitute the formulas with the matching information from the question. Students with good comprehension of algebraic concepts were expected to perform well in the lower-order questions. The ability to apply what they have learnt previously in similar situations is the key factor to achieving high scores in these questions. Similar to the lower-order questions,
three questions from the posttest were analysed as higher-order questions. Through this analysis, the extent to which students were capable to carry out their HOT skills was measured. The learning objectives involved in the HOT skills are analysis, synthesis and evaluation.

3 Results

Based on the exploratory data analysis (EDA), it was concluded that the post test scores were not distributed normally. Therefore, the researcher resorts to abide the results of the normality assessment by using the non-parametric statistical analysis. In this study, the Mann Whitney U Test is used as an alternative to the Independent-samples t-test. In order to study the overall performance of students in algebra, the researcher looks into the difference in the post test median between the experimental and control group. The findings acquired in the post test of the experimental and control groups were drawn in Table 2, and some comments were made in parallel to these findings.

Table 2: Mann Whitney U-Test of Overall Performance in algebra

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean Rank</th>
<th>Sum of Ranks</th>
<th>Mann-Whitney U</th>
<th>Z</th>
<th>Asymp. Sig (2 tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental</td>
<td>42</td>
<td>48.90</td>
<td>2054.00</td>
<td>487.0</td>
<td>-3.197</td>
<td>.001</td>
</tr>
<tr>
<td>Control</td>
<td>39</td>
<td>32.49</td>
<td>1267.00</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The values examined based on the overall performance scores are the Z value and the significant level. Based on the Table 2 above, it was observed that the experimental group obtained higher mean rank (48.90) as compared to the control group (32.49). The Z value obtained was -3.197 with a significant level less than .05 (refer to appendix page 150). This indicates that there is a significant difference in the overall performance between the experimental group and the control groups. The results suggest that the experimental group following the PBL approach performed significantly better than the control group following the traditional approach in the overall performance in algebra. Based on these results, hypothesis seven is rejected and the alternative hypotheses (There is significant difference in the overall performance in algebra between the students following the PBL approach and the traditional approach) is accepted.

Since the scores on the performance on algebra LOT questions were taken from the scores of the Post test which violated the assumption of normality, the non-parametric statistical analysis (Mann Whitney U-test) was used by the researcher for the purpose of analysis. In
order to study students’ performance in algebra LOT questions, the researcher looks into the difference in the median between the experimental and control group.

Table 3: Mann Whitney U-Test of the Performance in algebra LOT questions

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean Rank</th>
<th>Sum of Ranks</th>
<th>Mann-Whitney U</th>
<th>Z</th>
<th>Asymp. Sig (2 tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental</td>
<td>42</td>
<td>45.89</td>
<td>1927.50</td>
<td>613.500</td>
<td>-2.354</td>
<td>.019</td>
</tr>
<tr>
<td>Control</td>
<td>39</td>
<td>35.73</td>
<td>1393.50</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

It was found that the mean rank of the scores of the experimental group was 45.89 which was found to be higher than the control group that faired 35.73. However, based on Mann-Whitney U Test as shown in Table 3, the z value obtained when the groups were compared was -2.354 with a significance level of p=.019, suggesting that there is a significant difference in the median scores on the LOT questions for the experimental and control group. The findings provide evidence that the experimental group performed better than the control group as far as the LOT questions is concerned. Thus, it can be concluded that the PBL approach is a more efficient mode of instruction than the traditional teaching approach in fostering the mastery of knowledge, comprehension of content and application of the new knowledge learned.

Similar to the LOT questions, the scores for the analysis of the HOT questions was also taken from the scores of the Post test. As the scores of the Post test violated the assumption of normality, the non-parametric statistical analysis (Mann Whitney U-test) was used by the researcher for analysis.

Table 4: Mann Whitney U-Test of Performance in algebra HOT questions

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean Rank</th>
<th>Sum of Ranks</th>
<th>Mann-Whitney U</th>
<th>Z</th>
<th>Asymp. Sig (2 tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental</td>
<td>42</td>
<td>46.17</td>
<td>1939.00</td>
<td>602.000</td>
<td>-2.110</td>
<td>.035</td>
</tr>
<tr>
<td>Control</td>
<td>39</td>
<td>35.44</td>
<td>1382.00</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

When the performance in algebra HOT questions of the experimental group and control group were examined, it was found that the mean rank of the experimental group was 46.17 and the respective figure for the control group was 35.44. Based on the Mann-Whitney U Test above in Table 25, the z value obtained was -2.11. Therefore, there is a significant difference in the performance in algebra HOT questions between students following the PBL approach and the traditional approach. Based on the findings, it is evident that the experimental group following the PBL approach performed significantly better then the control group where algebra was taught using the traditional approach.
4 Conclusions and Implications

These findings on overall performance seem to be similar to the research reported by Kilic (2006) and Ronis (2007). Kilic showed that active learning methods are more effective than the classic method by relying on the findings of their research conducted on the basis of PBL, brainstorming and cooperative learning. Ronis (2007) used PBL approach in grade 7th science. In the light of the findings, the researcher determined that the PBL approach is more influential than the traditional teaching approach. Similarly, Rohani Ahmad Tarmizi & Nur Izzati Lojinin (2010) found positive results on students undergoing PBL in learning statistics at Form Four level as compared to the traditional teacher-centered approach. As explained by the experts of PBL, creating an environment conducive for learning is crucial to knowledge construction. Students studying in a PBL environment have to identify the problem and the relevant peripheral information in order to use the appropriate formula. In a PBL questions, important information were broken down into their original context. Therefore students need to comprehend the representations and understand their relationship before they can even use the information. Ideally, they were constructing their own knowledge unlike students following the traditional approach who regurgitate their work.

All these processes inevitably promote student’s conceptual understanding of the subject matter and strengthens their procedural knowledge. When solving an algebraic question in a problem scenario, students may consider reasoning patterns and generalizing terms to interiorize the relationship between the representations. Therefore, in shifting the emphasis of problem solving from simply finding a specific answer to also including a focus on algebraic thinking and reasoning, a powerful way of teaching and learning algebra can be discovered. It is therefore implied that students would be able to enhance their conceptual knowledge of algebra and ability of resolving HOT questions when taught in a PBL environment. As claimed by many proponents, it is therefore agreeable that PBL is a powerful tool in teaching abstract and intricate concepts of mathematics like algebra.

REFERENCES


