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Bar Model as Intervention in Solving Word Problem Involving Percentage

[1]Maimunah Abdul Gani, [2]Khairul Amilin Tengah, [2]Hardimah Said
[1]Raja Isteri Pengiran Anak Saleha Secondary School, Ministry of Education, Brunei Darussalam
[2]Sultan Hassanal Bolkiah Institute of Education, Universiti Brunei Darussalam, Brunei Darussalam
e-mail: maimunah.gani@ripas.moe.edu.bn

Abstract

This experimental case-study examined the performance of convenient sampling of fourty-five Year 9 students in solving word problems involving percentage from two classes in one government secondary school in Brunei Darussalam, using Bar Model as a solving strategy. Data was gathered quantitatively through written tests in the form of six word problem items as pre-test and post-test. The mean score of the pre-test was 0.93 indicating that the performance of the participating Year 9 students in solving word problems involving percentage was low prior to intervention. Intervention lessons produced a gain in the post-test mean to 2.87. Although the mean of post-test marks is still lower than the passing mark of the test, paired-sample t-test provided evidence of significance, thus proving that Bar Model Method had positive effect to the performance of word problem involving percentage. Evidence also indicated an increase in the students' overall marks from pre-test to post-test, with almost all except two students failed the pre-test to twenty-six students achieving marks above passing mark of 3 in post-test. Item-by-item analysis showed increase in correct responses in every item in post-test, even those with no attempts in pre-test. These provided further evidence that there is overall improvement in students' performance in word problems related to percentage after the use of Bar Model as intervention.

Keywords: Bar Model, Word Problem, Percentage

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INTRODUCTION

The current Brunei educational system, National Education System for the 21st Century, known in Malay language as *Sistem Pendidikan Negara Abad Ke-21 (SPN21),* was implemented with aims of preparing Bruneian students towards the challenges of the globalized world of the 21st century, in line with the Brunei Vision 2035 for the need of the country to develop well-educated and highly-skilled people (Ministry of Education, 2011). While the 20th century learning focused on the memorisation and recall of information for examination purposes, a 21st century classroom gears towards developing skills for lifelong learning, such as solving real-world problems innovatively. Problem solving is a basic skill that needs to be nurtured in students. One of the aims of the new education system is that students should be able to apply problem solving skills in any given problem or situation (Ministry of Education, 2011).

Problem-solving is one skill that needs to be developed in teaching mathematical content in the Brunei Mathematics Framework in the form of word problem (Curriculum Development Department, 2009). However, majority of Bruneian students are unable to successfully attempt problem-solving, more specifically word

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problem questions due to their lack of knowledge on how to apply and use appropriate strategies. Khalid and Tengah (2007) claimed that when attempting word problem tasks, most Bruneian students do not understand what is being asked. Evidence from a study has shown that Bruneian students: rely mostly on algorithm and rules, rather than understanding; have limited practical experiences with mathematics concepts; and lacked problem-solving strategies particularly involving the successful use of diagrams (Veloo & Wong, 1997).

Recent research in Singapore also reported several word-problem related difficulties: the lack of understanding of the definition of the algebraic symbols; hindrance in converting data from natural language to mathematical equations; the incorrect interpretation of texts, resulting in the misunderstanding of the relationships between quantities; and the difficulties to bring the semantic evidence from phrases to mathematical equations (Ng & Lee, 2009). Pape (2004) claimed that combination between the relationships and the consistency of language contributes to additional complexity to problem-solving.

The new SPN21 mathematics curriculum also suggested that the learning tasks and activities should allow students to use variety of strategies or explore alternative strategies for word problem. Thus, there is a need for investigation on different strategies that can be employed by the students to solve mathematical word problems in class (Han, Shahrill, Tan, Tengah, Jaidin, & Jawawi, 2016; Khoo, Shahrill, Yusof, Chua, & Roslan, 2016; Simpol, Shahrill, Li, & Prahmana, 2017; Tengah, 2011; Ulat, 2006; Wong, 2018).

Percentage, being strongly present in real-world application, is a vital topic in the school mathematics curriculum (Sparrow, Kissane, & Hurst, 2010). The percentage topic is first introduced to pupils in Year 4 in the Brunei mathematics curriculum. The curriculum continues to revisit percentage at different depth up to secondary education. At secondary level, percentage is incorporated into other topics such as everyday arithmetic, statistics and mensuration. Many studies have confirmed that teaching and learning of percentage present challenges to learners (Cole & Weissenfluh, 1974; Dole, Cooper, Baturo, & Conoplia, 1997; Parker & Leinhardt, 1995; Smart, 1980). Koay (1998) claimed that greater understanding of percent would arise from teaching via effective visual models and the use of appropriate real-life examples, instead of the common and rigid rules.

Many researchers have reported effective use of visual diagram in translating information and conditions in problem statement in facilitating success in solving word problem (Veloo, 1996). Larson (1985) suggested drawing and labeling a figure, diagram or a graph as an initial step in understanding a problem. When teachers use diagrams to elicit appropriate mental images, children were found to perform better in mathematical problem-solving situations (Yancey, Thompson, & Yancey, 1989). Xu (2006) found that diagram-presentation significantly promote success in problem-solving and, within a certain range of mathematical task difficulty, the effect increased with the difficulty. Diagram-presentation is a way of understanding in solving word problems. Bar Model diagram is one form of diagram-presentation that might help students in solving word problems.

Bar Model

The Bar Model method is a distinctive feature of the Singapore Primary Mathematics Curriculum. It was an innovation in pedagogy developed by the Ministry of Education, Singapore, to address a nationwide problem in the 1980s with the

purpose of raising mathematical competencies and improving problem-solving abilities (Kho, Yeo, & Lim, 2009). Since its introduction, it has played an important role in the primary school mathematics curriculum in Singapore.

Following the introduction of this method and Singapore's emphasis on problem-solving in its revised curriculum, Singapore made dramatic improvements in its mathematics performance. In the international study Trends in International Mathematics and Science Study (TIMSS), Singapore ranked first in the world in mathematics achievement in 1995 (4^{th} grade), 1999 (8^{th} grade) and 2003 (4^{th} & 8^{th} grade). This study also showed that Singapore students consistently performed among the top three in mathematics at both grades, largely due to the successful application of Bar Model. Through the Bar Model method, students solve word problems using visual representation of either part-whole or comparison models to represent the quantities given in a word problem, enabling them to communicate their understanding of the problem and relate the known and unknown quantities so that appropriate operation could be used to solve the word problem.

The use of Bar Model method can also be an alternative strategy that helps in bridging the difficult transition from reading a word problem and creating a mathematical expression. The Bar Model method helps students to visualise situations; satisfies the students' learning through seeing and doing; helps transform words into recognisable pictures for young minds (Ng & Lim, 2001). The Bar Model method is highly appropriate when the solution is required to follow a model or diagram (Kho, 1987). The visual nature of Bar Model allows students to first make sense of the problem for information organisation to come up with solutions, particularly involving challenging and complex mathematical problems (Garelick, 2006).

There are two types of models used in the Bar Model method: the part-whole model and the comparison model (Yeap, 2014). In the part-whole model (Figure 1), two or more subsets (the parts) make up a set (the whole). In the Bar Model method, the rectangular bars represent the quantities that form the 'parts' as illustrated in Figure 1.

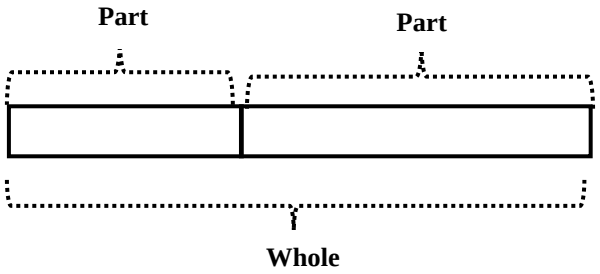

Figure 1. Part-whole model taken from Yeap (2014)

There are two types of comparison model namely, additive comparison and multiplicative comparison. In additive comparison (Figure 2a), one quantity is a certain amount more or less than another quantity, while in multiplicative comparison (Figure 2b), one quantity is a certain number of times of another quantity.

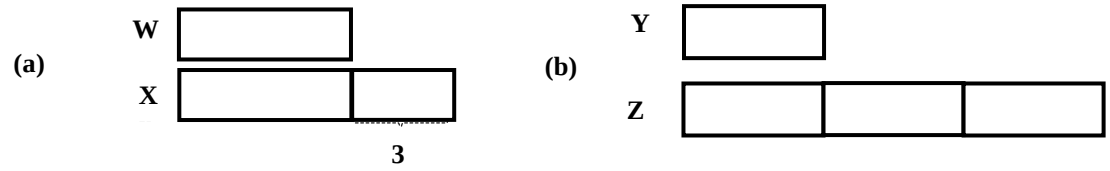

Figure 2. Additive comparison model in (a) indicating X is 3 more than W, and Multiplicative comparison model in (b) indicating Z is thrice compared to Y

The main purpose of the study is to investigate the impact of the bar model method in enhancing students' performance on problem-solving involving percentage and whether the Bar Model method could be used as one of the strategies in solving mathematics problems particularly at secondary level. This study is guided by the research question: *What is the effect of Bar Model on students' performance in word problem involving percentage?*

RESEARCH METHOD

A convenient sampling of year 9 students of mixed ability with an average age of 15 years old from one co-ed government secondary school in Tutong district in Brunei was used. The selected fourty-five students came from two classes in the school and were never previously exposed to specific word problem session involving percentage.

For the written pre-test and post-test, three problems on percentage that would require application of part-whole models and three on percentage involving comparison models were used. The test questions, and questions used in intervention lessons, were carefully selected from past examination papers (Cambridge International Examinations 2004 – 2014) and from a book of Mathematical Problem Solving – The Bar Model Method (Soo & Liu, 2013). Questions for both pre-test and post-test were the same, however reordered in post-test to avoid memory effect. Each item was allocated 1 mark for correct answer and zero for wrong and unattempted questions, and students were required to show their working on how they obtained the answers.

The test items were first tested to a class of twenty mixed ability Year 9 students of the same secondary school, who were not involved in the main study, producing a Cronbach alpha value of 0.505, indicating moderate reliability. Two experienced teachers, both having at least 10 years of teaching experiences, verified the face and content validity of the test items, and found the items to be suitable for the intended participants.

Pre-test was conducted to not only test students' initial ability in attempting word problem involving percentage, but also to determine the different approaches applied by the students. Four intervention lessons, totalling 4 hours, were conducted to introduce the two types of Bar Model to the students. The first two lessons were on solving problems involving part-whole Bar Model, while the final two lessons were on solving problems involving comparison Bar Model. During the class activities, to enhance students' understanding on how to apply Bar Model method, students were given more questions to practise either as a group task or as an individual task. Post-test was carried out almost immediately after the intervention lessons to measure students' performance after the intervention.

Paired-sample t-test was done to compare the mean of pre-test and post-test to determine whether the intervention lessons had significant effect on the students' performance. Answer script analysis from both pre-test and post-test were also done

to further support claim of changes in students' overall performance after using Bar Model.

RESULTS AND DISCUSSION

Table 1 showed that the mean score of the pre-test was 0.93 (SD = 0.915), indicating that the performance of the participating Year 9 students (N=45) in solving word problems involving percentage was low to begin with. Intervention did produce a gain in the post-test mean to 2.87 (SD = 1.531).

Table 1. Descriptive Statistics of Pre-test and Post-test

	Mean(M)	N	Std. Deviation(SD)	Std. error Mean
Pre -Test	0.93	45	0.915	0.136
Post-Test	2.87	45	1.531	0.228

Although this mean post-test mark was still lower than the passing mark of the test, paired-sample t-test (Table 2) provided evidence of significance at $p<0.05$, thus proving that Bar Model Method had positive effect on the performance of word problem involving percentage (mean increase of 1.933).

Table 2. Paired Sample T-Test

Paired Differences								
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of Difference		t	df	Sig. (2-tailed)
				Lower	Upper			
Pre - Post	-1.933	1.572	0.234	-2.406	-1.461	-8.248	44	0.000

Further analysis of comparison between the students' overall marks in pre-test and post-test (Figure 3) also provided evidence that there was an increase in students' overall marks. This is indicated in the overall right shift of line graph from pre-test to post-test. Almost all, except two, students failed the pre-test, while the number of students achieving marks above passing mark of 3 increased to twenty-six in the post-test.

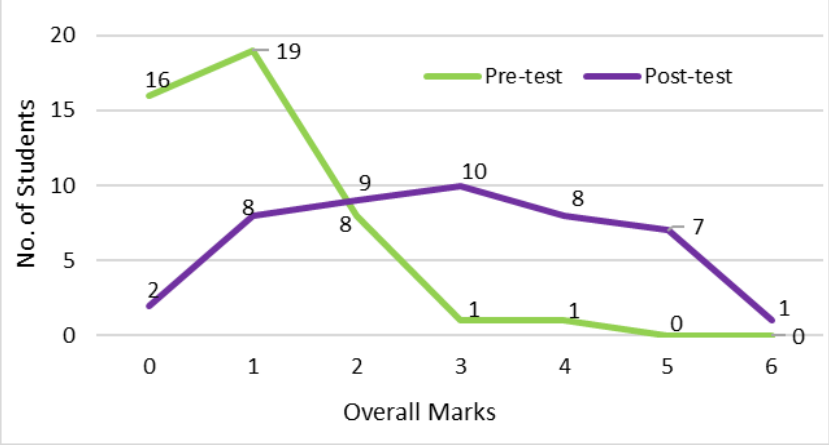

Figure 3. Distribution of students'overall marks in pre-test and post-test

When item-by-item correct attempts by students in the pre-test and post-test items were compared (Figure 4), the post-test showed increased correct attempts compared to pre-test in every item, even those with no attempts in the initial pre-test (item 4 and 6). The biggest increase was seen in item 2. This provides further evidence that there is an overall improvement in students' performance in word problems related to percentage after the use of Bar Model as an intervention.

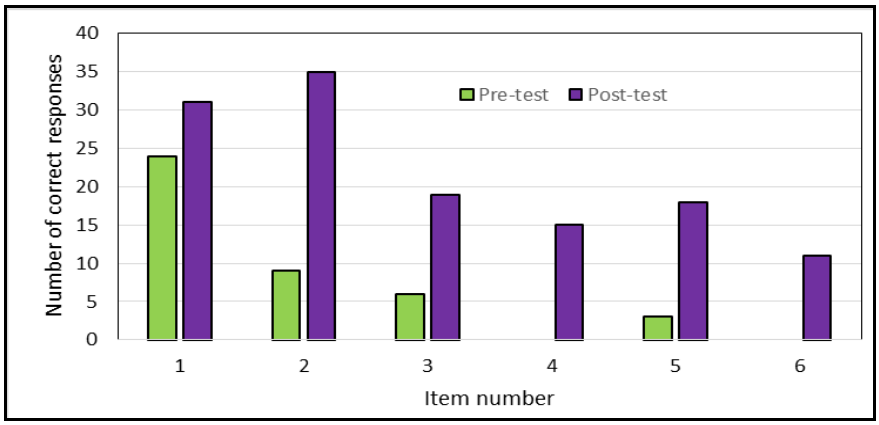

Figure 4. Comparison of number of correct items between pre-test and post-test.

CONCLUSION

The low mean score of the pre-test being 0.93 indicated that the performance of the participating Year 9 students in solving problems involving percentage was low before the intervention lesson was conducted, possibly indicating low ability group of students. Intervention lesson produced a slight increase of the post-test mean to 2.87. Although the mean post-test mark is still lower than the passing mark of the test, paired-sample t-test provided evidence of significance, thus proving that Bar Model method had positive effect to the performance of word problem involving percentage, in particular, of low-ability students. It is suggested that further studies should be done for students at different abilities, level and school to determine if similar positive effect would be achieved.

Evidence also indicated an increase in students' overall marks from pre-test to post-test, with almost all except two students failed the pre-test to twenty-six students achieving marks above passing mark of 3 in post-test. Item-by-item analysis also showed increase correct responses in every item in post-test, even those with no correct attempts in initial pre-test. These provided further evidence that there is overall improvement in students' performance in word problems related to percentage after the use of Bar Model as intervention. This positive result is in line with several recent positive outcome Bar Model Intervention lessons on Brunei students' performance at secondary level on the topic of profit, loss and discount (Mahadi, Tengah, & Prahmana, 2018) and ratio (Said, 2016).

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