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Zollman's Four Corners and a Diamond Graphic Organizer as a Solving Strategy in Secondary Mathematics Word Problem

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Abstract

This action research examined the effectiveness of the Zollman's Four Corners and a Diamond graphic organizer as a strategy to improve Year 10 students' performance in mathematics word problems. Quantitative data from twenty-four students from a secondary school in Brunei Darussalam was collected through the use of a pre-test and post-test. Results from the pre-test and post-test were analyzed and it was found that there was a significant difference in students' performance before and after introducing the Zollman's Four Corners and a Diamond graphic organizer. A paired sample *t*-test on the pre-test and post-test showed a significant improvement in students' mean marks, $t(23) = -3.415$, $p = .002$. Additionally, it was found that the Zollman's Four Corners and a Diamond graphic organizer is capable of helping students of all abilities and particularly the lower ability students. Hence for this study, the Zollman's Four Corners and a Diamond graphic organizer successfully enhanced the Year 10 students' performance in solving mathematics word problems.

Keywords: Diamond graphic organizer, word problems, Zollman's four corners

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INTRODUCTION

The new National Education System for the 21st Century (SPN 21) introduced in Brunei Darussalam in 2008 is aimed at equipping students in Brunei with the knowledge and skills required to fulfill the needs and challenges of the developments of the 21st century (Ministry of Education, 2013). Problem solving skill is one of the essential skills identified in the SPN21 curriculum. As such, developing students' competencies in problem solving is an integral part of mathematics across all grade levels (National Council of Teachers of Mathematics, 2010).

Mathematics word problems are one of the most challenging topics to learn and teach in both primary level (Raimah, 2001; Saman, 2000; Yusof, 2003) and secondary level (Abdul Gani et al., 2019; Khoo et al., 2016; Madani et al., 2018; Sai et al., 2018; Said & Tengah, 2021). In particular, solving mathematics word problems involving algebra is one of the main difficulties for many students all over the world (Bush & Karp, 2013; Carpraro & Joffrion, 2006; Van Amerom, 2003). Matzin and Shahrill (2015) concluded that students in Brunei were unable to successfully solve word problem due to inability to transform word problems to algebraic equations.

To be able to successfully solve a word problem, students first must be able to understand the problem and what is being asked, and then must know how to extract

the correct information and form an equation to calculate what is being asked. This means that both the reading comprehension and computation of word problem play a major role in a student's ability in successfully solving a word problem. Gurung (2003) found that students were unable to perform well in word problems presented in the English language. However, Rasidah (1997) reported that there was no significant difference in students' performance by Year 8 students in solving the same word problems that are presented in Malay or English language. Study done by Pungut and Shahrill (2014) concluded that there was a weak correlation between students' English competency and their ability to solve mathematics word problems. Similarly, Yusof (2003) found that the comprehension and transformation errors in word problems are not because language. Hence, even though students are able to read the word problems presented in the English language, Khalid and Tengah (2007) stated that the major factor of students' poor performance in word problems is that students are simply unable to understand what is being asked. This leads to students' failure in extracting the correct information to enable them to successfully solve the word problem.

Furthermore, the teaching and learning of mathematics in Brunei is very teacher-orientated (Clements, 2002; Khalid & Tengah, 2007; Khoo, 2001; Lim, 2000). Due to this, students adopt a passive role and view mathematics as a set of procedures and rules which they have to memorize to solve a problem. Veloo and Wong (1997) found that most students in Brunei are too reliant on rules rather than understanding what the problem is asking for. In addition, the external examinations and standardized tests at the end of the level push teachers to continue to provide drills and practice to enable their students to get good results (Khalid, 2009). This is further supported by the study done by Rosney (2008) and Sakdiah (2008), who both reported that teachers put less emphasis on understanding but more focus on finishing the syllabus.

Hence, it can be seen that whichever the reasons are behind the difficulties students face in solving mathematics word problems; whether it is the limited mathematical strategies (Nayan, 1998), or limited language proficiency (Gurung, 2003; Raimah, 2001; Saman, 2000), it is perhaps the teaching and learning of mathematics that needs to be modified (Pungut & Shahrill, 2014).

Various strategies have been introduced over the years to solve mathematics word problems and all of these approaches have the same principles adapted from the Polya's (1944) model. Nayan (1998), Raimah (2001), Saman (2000), and Ulat (2006) reported that most students employ the key words approach when attempting to solve a mathematics problem. However, this approach to problem solving has limited value due to the use of misleading key words in word problems.

Pattern discovery is an approach where students can develop to aid them in solving word problems by looking for patterns in the data presented in the word problem. A way to do this as suggested by Tengah (2011) is the use of a Sudoku puzzle in mathematics classroom to develop this skill among students from an early age. However, pattern discovery is a skill that cannot be taught and must be developed among students over a long period of time.

Research conducted by Ulat (2006), Veloo and Real (1994) and Veloo (1996) made use of model drawings strategy in Brunei to help solve mathematics word problems. Their studies reported that drawing diagrams as a good strategy to help students to improve their understanding. However, the limitation of such a strategy as

reported in their studies, is that not all word problems can be represented fully or fit well in diagrams and drawings.

Given the success of the bar model approach in Singapore, the mathematics curriculum in Brunei has included it as one of the problem-solving strategies and teachers in schools are expected to use the bar model method as one of the tools in solving mathematical word problems. Furthermore, research conducted by Abdul Gani et al. (2019), Madani et al. (2018), and Said and Tengah (2021), found success in students using the bar model method to solve word problems across different secondary mathematics topics. However, it was revealed that students are still accustomed to using algorithms and formulae when solving mathematical word problems.

Furthermore, the Zollman's Four Corners and Diamond graphic organizer has shown positive outcomes. Hence the Zollman's Four Corners and Diamond graphic organizer will be the instructional tool used in this study.

Zollman's four corners and a diamond graphic organizer

Previous problem-solving processes employed by the students involve a step-by-step approach to mathematical word problem solving where students are limited by this approach. Hence, the Four Corners and a Diamond graphic organizer designed by Alan Zollman (2009a; 2009b; 2011a; 2011b) was selected and modified as illustrated in Figure 1 to encourage students to apply a nonhierarchical technique for solving mathematics word problems. A graphic organizer is a tool used to help students organize information, structure the information and concept to relate with other concepts. Ausubel (1968) described the graphic organizer as a tool that bridges the gap between what the learners already know and what they have to learn. Zollman's Four Corners and a Diamond is a graphic organizer that is adapted from Gould and Gould (1999) and embedded the Polya's (1944) four steps mathematical problem-solving principles.

Zollman (2011a; 2011b) found that the graphic organizer promotes students and teachers to identify the missing information or relationship in each individual's strategic thinking. Teachers can pinpoint on each student, the areas of difficulty they face, whether it is the ability to read and comprehend the word problem, what strategy to apply in solving or the ability to label answer correctly (Schwanebeck, 2008). This result reflects the findings from Khoo et al.'s (2016) study on the use of Zollman's Four Corners and a Diamond graphic organizer to solve word problems in secondary level, as presented in Figure 1.

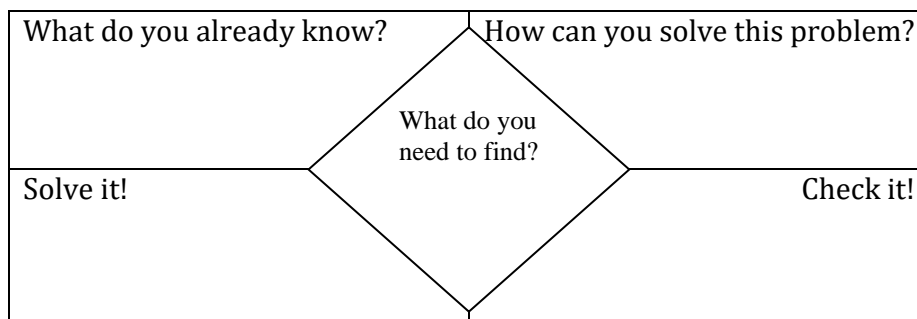


Figure 1. Adapted Zollman's four corners and a Diamond graphic organizer

Moreover, Ellis (2012) described that the visual and graphic representation in a graphic organizer portray spatially the relationships between statements, terms, concepts and ideas within a learning task. It is also supported by Abdullah et al. (2012) that visual representation in a graphic organizer can act as a medium to aid students in understanding the word problems and eventually enhance their conceptual understanding. Furthermore, Sai et al. (2018) concluded that Zollman's Four Corners and a Diamond graphic organizer is effective in improving students' performance as students are able to break the word problem into smaller sections to enable them to successfully solve the mathematics word problem.

Purpose, limitation and research question

The purpose of this study is to improve secondary students' performance in mathematics word problems through the use of the Zollman's Four Corners and a Diamond graphic organizer. As only two other researches (Khoo et al., 2016; Sai et al., 2018) have been done in Brunei, it is hoped that the findings from this study will provide more concrete evidence to encourage teachers and students to employ Zollman's Four Corners and a Diamond graphic organizer as an alternative strategy to solve word problems. Since this study was only able to focus on a small number of participants, the outcome cannot be used to generalize all the Year 10 students in Brunei, but could be used as a pilot study result for larger and more in depth future studies in this area. The study is guided by the research question, *"What are the effects of students' performance in solving mathematics word problems after the implementation of Zollman's Four Corners and a Diamond graphic organizer?"*

RESEARCH METHOD

The study followed an action research design and made use of quantitative data gathered from students' scores from pre-tests and post-tests. Twenty-four Year 10 students from two classrooms (Class X and Class Y) from a co-ed government secondary school in the Belait district in Brunei made up the participant size. Class X comprised of six male students and seven female students, whereas Class Y comprised of four male students and seven female students. The two classes were made up of students with different mathematical ability ranging from high to low. Students from both classes have had experiences in solving word problem-solving questions.

A five-questions pre-test and post-test was used to collect evidence of changes in students' performance in solving mathematics word problems (See Appendix). The participants were allocated forty minutes to complete the test. The orders of the questions in the pre-test and post-test was altered to avoid memory effect from the pre-test. Students were required to show their working for each question and the use of calculators was allowed in both tests. Each question was allocated two marks and the total marks of the pre-test and post-test was ten. The questions were validated by two experienced teachers at the participating school. The reliability of the items, determined from results of 19 participants who were not part of the main study, was tested via its internal consistency and the Cronbach alpha reliability was found to be 0.897. The positive correlation between the two test shows that the test questions produce stable and consistent results.

In the main study, the pre-test was first given to the selected classes of Year 10 students to determine students' initial performance in solving mathematics word problems before the intervention. After the implementation of intervention lessons,

the post-test was carried out to determine if the performance of students towards solving word problems have improved compared to the pre-test.

The intervention lessons were conducted after the pre-test were given to students of the two classes. There was a total of three intervention lessons on using the Zollman's Four Corners and a Diamond graphic organizer in solving mathematics word problems. The Zollman's Four Corners and a Diamond organizer was first introduced to students by discussing the different categories represented in the five areas of the organizer. Then, students were guided through the process of solving mathematics word problems with the Zollman's Four Corners and a Diamond organizer through group practice and then individual practice using several prepared word problems.

The quantitative data was collected from the numerical values of the pre-test and post-tests and was analyzed using SPSS. Descriptive statistics of the pre-test and post-test and graphical representation of the overall marks obtained in the pre-test and post-test were used to determine the performance of Year 10 students before and after the intervention. Comparison of students' overall marks of the pre-test and post-test to determine whether there was any significant improvement in their overall marks after the intervention via paired-sample *t*-test. An item by item analysis of correct and incorrect responses was done in the pre-test and post-test to determine the performance of the students in each item before and after the intervention. Similarly, paired sample *t*-test was also used to determine if there were any significant differences in the mean scores of the pre-test and post-test in the individual classes, despite knowing the small number of sample in each class will produce a limitation of accuracy of result in the *t*-test.

RESULTS AND DISCUSSION

As shown in Table 1, the overall mean score of the post-test was 3.50 whereas the overall mean score of the pre-test was 2.21. The overall maximum score improved from eight marks in the pre-test to ten marks in the post-test. These results indicate that both the Year 10 classes showed an improvement albeit a little in solving mathematics word problems using the Zollman's Four Corners and a Diamond graphic organizer after the intervention lessons.

Table 1. Descriptive statistics of pre-test and post-test results for both classes

	N	Time	Minimum	Maximum	Mean	Standard Deviation
Combined	24	Pre-test	0	8	2.21	2.686
		Post-test	0	10	3.50	3.336

A paired-sample *t*-test was used to further analyze and determine whether the improvement was significant. Based on the results shown in Table 2, there was a significant difference in the mean scores between the pre-test ($M = 2.21$, $SD = 2.686$) and post-test ($M = 3.50$, $SD = 3.336$; $t(23) = -3.415$, $p = .002$) at $p < 0.05$ level. This result indicates that there was a significant improvement on Year 10 students' performance in solving mathematics word problems using the Zollman's Four Corners and a Diamond graphic organizer after they were introduced in the intervention lessons. Thus, for this research, it can be implied that the Zollman's Four Corners and

a Diamond graphic organizer used in the intervention helped to significantly improve the Year 10 students' performance in solving mathematics word problems.

Table 2. Results of the paired-sample *t*-test of pre-test and post-test for both classes

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Standard Deviation	Standard Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pretest-Posttest	-1.292	1.853	.378	-2.074	-.509	-3.415	23	.002

For both classes, there is an increase in mean scores in the post-test compared to the pre-test as shown in Table 3. The mean scores of pre-test and post-test for Class X was much higher than that of Class Y. This is most likely due to Class X being of higher ability in terms of solving word problems than Class Y, as indicated with slightly higher mean value of pre-test for Class X than Class Y. However, it is worth noting that the difference in mean scores in the post-test from the pre-test is higher in Class Y than in Class X. This implies that the use of the Zollman's Four Corners and a Diamond graphic organizer as a strategy to solve mathematics word problems is more impactful for lower ability students in this study.

Table 3. Descriptive statistics of pre-test and post-test results for both classes

Class	N	Time	Minimum	Maximum	Mean	Standard Deviation
X	13	Pre-test	0	8	3.31	3.066
		Post-test	0	10	4.54	3.573
Y	11	Pre-test	0	4	0.91	1.375
		Post-test	0	9	2.27	2.687

A paired sample *t*-test was done on Class X and Class Y individually to further evaluate whether the mean marks of the two classes significantly differed after the introduction of Zollman's Four Corners and a Diamond graphic organizer. The results is presented in Table 4.

Table 4. Results of the paired-sample *t*-test of pre-test and post-test for both classes

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Standard Deviation	Standard Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Class X Pre-test- Post-test	-1.231	1.964	.545	-2.418	-.044	-2.25	12	.043
Class Y Pre-test- Post-test	-1.364	1.804	.544	-2.576	-.152	-2.507	10	.031

Based on the results in Table 4, there was a significant difference in pre-test marks ($M = 3.31$, $SD = 3.066$) and post-test marks ($M = 4.54$, $SD = 3.573$; $t(12) = -2.25$, $p = .043$) for Class X at $p < 0.05$ level. Similarly, there was also a significant difference in Class Y's pre-test marks ($M = 0.91$, $SD = 1.375$) and post-test marks ($M = 2.27$, $SD = 2.687$; $t(10) = -2.507$, $p = .031$) at $p < 0.05$. These results further indicate that the Zollman's Four Corners and Diamond graphic organizer has a positive effect on Year 10 students' performance in solving mathematics word problems. Hence, it can be concluded that the Zollman's Four Corners and a Diamond graphic organizer has significantly improved the Year 10 students' performance in solving mathematics word problems in this study.

Figure 2 shows that there is an overall improvement in the number of correct responses in each item except for Item 4 after the students were introduced to the Zollman's Four Corners and a Diamond graphic organizer. This indicates that more students were able to solve the problems correctly in the post-test as opposed to in the pre-test. Item 2 had the largest increase in correct responses in the post-test with eleven out of twenty-four students who managed to answer correctly. Through the analysis of students' responses for this item, a majority of the students were unable to transform the information from the word problem to an algebraic expression to be able to successfully solve the word problem. There was only a slight increase in the number of correct responses in Item 5 with ten students who responded correctly in the pre-test and thirteen students who responded correctly in the post-test. Through analysis of students' responses, most of the students who did not managed to provide the correct answer were able to understand the question but were not able to form the correct algebraic equation.

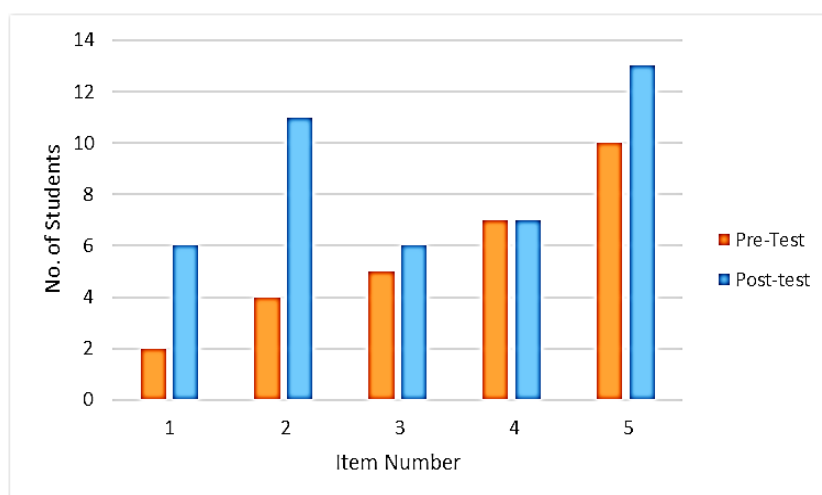


Figure 2. Comparison Bar Chart of students' correct responses between the pre-test and post-test

Although there was an increase in the number of correct responses in Items 1 and 3, the number of correct responses still remained low in the post-test with only six students who managed to answer correctly for both questions. For Item 1, though the majority of the students understood that there were two unknown variables, they were confused by the wording of the question and hence were unable to form the correct expression to successfully solve the word problem. On the other hand, for Item 3, the majority of the students were not able to comprehend the information

from the word problem which again led them to unsuccessfully solving the word problem. The number of correct responses in Item 4 remained unchanged for both the pre-test and the post-test, in which seven out of twenty-four students managed to answer the question correctly. Through the analysis of students' responses, majority of the students were confused by the multiple unknown variables and also did not know how to properly form the equations which would enable them to successfully solve the word problem.

Implications to teaching

The findings of this study revealed that the Zollman's Four Corners and a Diamond graphic organizer has the potential to improve students' performance in solving mathematics word problems. These findings suggest that teachers should consider employing the Zollman's Four Corners and a Diamond graphic organizer as a strategy to improve students' performance in solving word problems. The Zollman's Four Corners and a Diamond graphic organizer is aligned with Polya's (1944) four steps mathematical problem-solving principles. With the Zollman's Four Corners and a Diamond graphic organizer, students are able to make sense of the word problem by organizing any given information in a visual form where they are able to plan, execute and check their solutions.

In addition, the findings from the study provide evidence about the importance of using alternative approaches to enhance the Year 10 students' ability to solve mathematics word problems. The teaching and learning of mathematics in Brunei is very teacher orientated so teachers needs to steer away from this method of teaching and learning and start implementing strategies that will cultivate students' problem-solving competencies and also boost their confidence in solving mathematics word problems. Besides the Zollman's Four Corners and a Diamond graphic organizer, there are already a number of strategies that have been introduced in Brunei which includes, using Sudoku to develop students' pattern discovery skills (Tengah, 2011) and using bar models (Abdul Gani et al., 2019; Madani et al., 2018; Said & Tengah, 2021). All these strategies are valuable and useful tools in solving mathematics word problems.

Furthermore, from the study, due to the nature of the Zollman's Four Corners and a Diamond graphic organizer, teachers can pinpoint the areas of difficulty students face with a mathematics word problem and this is supported by Schwanebeck (2008). Following this, teachers can make adjustments to their teaching strategy to tackle the issues faced by the students.

CONCLUSION

The main aim of this study was to examine the effects of using the Zollman's Four Corners and a Diamond graphic organizer on secondary students' performance in solving mathematics word problems. The results of the paired-sample *t*-test revealed that there was a significant difference in the students' mean marks between the pre-test and the post-test results. Furthermore, the results also show that students performed significantly better after they were introduced to the Zollman's Four Corners and Diamond graphic organizer as indicated by the higher overall marks and more number of correct responses. Lower ability students particularly benefitted more from the introduction of the Zollman's Four corners and a Diamond graphic organizer. Hence for this study, the Zollman's Four Corners and a Diamond graphic organizer successfully enhanced the secondary students' performance in solving

mathematics word problems. In conclusion, it is evident from this study that the use of the Zollman's Four Corners and a Diamond graphic organizer as a tool to solve word problems is capable of aiding students of different learning abilities and can be an effective alternative strategy to solve mathematics word problems.

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APPENDIX**Pre-test and Post-test Questions**

1. One number is 11 more than three times another. Their sum is 111. What are the numbers?
2. Arifin is N years old. Arifin's father is twice as old as Arifin. In 20 years, Arifin will be two-thirds as old as his father. How old is Arifin and Arifin's father now?
3. Yasir and Rifhan worked as electricians at \$40 and \$44 per hour respectively. In one month, Yasir worked 10 hours more than Rifhan. If their total income for that particular month was \$11320, how many hours did each work during the month?
4. Tickets for the baseball games were \$2.50 for general admission and 50 cents for kids. If there were six times as many general admissions sold as there were kids' tickets, and total receipts were \$7750, how many of each type of ticket were sold?
5. Rahim got a job as an engineer at an annual starting salary of \$28000. Minah got a job as an accountant at an annual starting salary of \$24000. Rahim will receive an annual increase of \$600 and Minah's annual increase will be \$1100. In how many years will their salaries be equal?