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GRAPHIC ORGANIZER IN ACTION: SOLVING SECONDARY MATHEMATICS WORD PROBLEMS

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Abstract

Mathematics word problems are one of the most challenging topics to learn and teach in secondary schools. This is especially the case in countries where English is not the first language for the majority of the people, such as in Brunei Darussalam. Researchers proclaimed that limited language proficiency and limited Mathematics strategies are the possible causes to this problem. However, whatever the reason is behind difficulties students face in solving Mathematical word problems, it is perhaps the teaching and learning of the Mathematics that need to be modified. For example, the use of *four-square-and-a-diamond* graphic organizer that infuses model drawing skill; and Polya's problem solving principles, to solve Mathematical word problems may be some of the strategies that can help in improving students' word problem solving skills. This study, through quantitative analysis found that the use of graphic organizer improved students' performance in terms of Mathematical knowledge, Mathematical strategy and Mathematical explanation in solving word problems. Further qualitative analysis revealed that the use of graphic organizer boosted students' confidence level and positive attitudes towards solving word problems.

Keywords: Word Problems, Graphic Organizer, Algebra, Action Research, Secondary School Mathematics

Abstrak

Masalah kata Matematik adalah salah satu topik yang paling mencabar untuk belajar dan mengajar di sekolah menengah. Hal ini terutamanya terjadi di negara-negara di mana Bahasa Inggeris bukan bahasa pertama bagi majoriti rakyat, seperti di Brunei Darussalam. Para penyelidik menyatakan bahawa bahasa penguasaan yang terhad dan strategi Matematik yang terhad adalah kemungkinan punca kepada masalah ini. Walau bagaimanapun, apa-apa sebab di sebalik kesukaran yang pelajar hadapi dalam menyelesaikan masalah kata Matematik, mungkin pengajaran dan pembelajaran Matematik yang perlu diubah suai. Sebagai contoh, penggunaan *four-square-and-a-diamond graphic organizer* yang menerapkan kemahiran lukisan model; dan menyelesaikan masalah prinsip Polya, untuk menyelesaikan masalah kata Matematik boleh menjadi sebahagian daripada strategi yang dapat membantu dalam meningkatkan pelajar kemahiran menyelesaikan masalah kata. Kajian ini, melalui analisis kuantitatif mendapati bahawa penggunaan pengurusan *graphic organizer* meningkatkan prestasi pelajar dari segi pengetahuan Matematik, strategi Matematik dan penjelasan matematik dalam menyelesaikan masalah perkataan. Analisis kualitatif lanjut mendapati bahawa penggunaan *graphic organizer* meningkatkan tahap keyakinan pelajar dan sikap positif ke arah menyelesaikan masalah kata.

Kata kunci: Masalah Kata, *Graphic Organizer*, *Algebra*, Penyelidikan Tindakan, Mathematik Sekolah Menengah

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English language is the second most common spoken language in Brunei Darussalam, which comes after the national language, Malay language. With the new implementation of the *Sistem Pendidikan Negara Abad Ke-21* or in English language recognized as the National Education System for the 21st Century (SPN 21) in January 2009 (Ministry of Education, 2013), English language has become the most predominant language in Brunei's education. Cummins (2000) states that it may take five to seven years, or even more, for a student to

have sufficient language skills required in educational subjects. Thus, this has been a concern in our education especially in an English-medium subject such as Mathematics.

According to Pungut and Shahrill (2014), Mathematical word problems are Mathematical problems that are expressed in words rather than using signs or symbols. To solve a Mathematical problem, particularly word problems, students must first understand or comprehend the problem before they are able to solve the problem that involves reading skills. However, Veloo and Wong (1997) claimed that most of the students in Brunei are too reliant on rules rather than understanding on what the problem is asking for. Moreover, Nayan (1998) mentioned that Brunei students frequently struggle in translating word problems into algebraic expressions. Subsequently, a common reaction that students in Brunei have towards word problems is that, "*I can't solve the word problems, I don't understand*" (Nayan, 1998).

On the other hand, Yusof (2003) reported that comprehension and transformation in word problem does not correlate with language. Hence it can be seen that whichever the reasons are behind the difficulties students faced in solving Mathematical word problems; whether it is the limited Mathematical strategies (Nayan, 1998), or limited language proficiency (Gurung, 2003; Mawang, 2001; Anit, 2000; Mukunthan, 2013), it is perhaps the teaching and learning of the Mathematics that needs to be modified (Pungut & Shahrill, 2014). For example, the use of new instructional tools or strategies may help students in solving Mathematical word problems.

Zollman's *four-corners-and-a-diamond* graphic organizer (2011; 2009a; 2009b) is adapted from Gould and Gould (1999) and embedded the Polya's (2014) four-steps Mathematical problem solving principles.

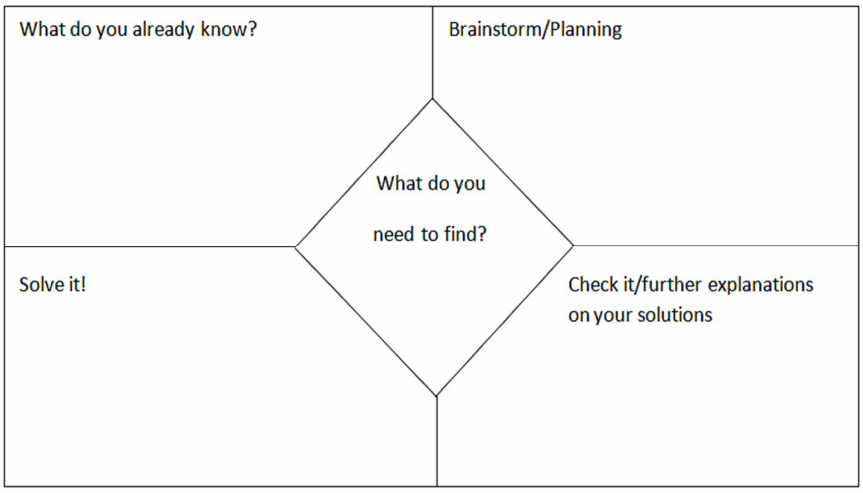

Figure 1. Four-corners-and-a-diamond Mathematics graphic organizer (taken from Zollman, 2011; 2009a; 2009b)

This graphic organizer (Figure 1) allows students to begin their work in whichever way they want (pictorial orientation), unlike the traditional sequential procedure in Polya's model (Zollman, 2011). Teachers can pinpoint to each student, the areas of difficulty they face in i.e. the ability to read

and comprehend word problem, what strategy to apply in solving and ability to be able to answer correctly (Schwanebeck, 2008). Moreover, Ellis (2012) described that the visual and graphic representation in this graphic organizer portray spatially the relationships between statements, terms, concepts and ideas within a learning task.

Following the assumption that Brunei students are too reliant on rules rather than understanding, the main goal and objective of implementing the *four-corners-and-a-diamond mathematics graphic organizer* in this present study is to improve students' performance in three main areas: Mathematics knowledge, strategies knowledge and Mathematical explanation through their write up in the graphic organizer.

METHOD

The participants of this study were from a Year 9 (average age of 14 and 15) class in a government secondary school in the Brunei-Muara district. The participants consisted of 10 male and 14 female students. This action research study (Parsons & Brown, 2002) consisted of three cycles; pre-test, intervention cycle and a post-test followed by an open-ended questionnaire. There were three intervention lessons on using graphic organizer in solving Mathematics word problems, one intervention lesson on word problems that involved linear equation, one lesson that involved simultaneous equations and lastly one lesson that involved quadratic equations.

This study employed a mixed research method that comprised of quantitative and qualitative data collection tools. The instruments used were the Mathematics results from the Students' Progress Assessment (SPA), pre-test and post-test, an open-ended questionnaire, and a daily journal.

The participants' previous year SPA Mathematics results were analyzed in order to enrich the data on their Mathematics' backgrounds. The pre and post-tests consisted of word problems assessed on the syllabus relating to Year 9 Algebra. A four-point scoring rubric was adapted from Zollman (2011) to analyze the students' workings, rather than just assessing their final answers. The rubric aided in assessing students' performance in terms of students' Mathematical knowledge, strategic knowledge and Mathematical explanations.

Moreover, open-ended questionnaire consisted of three open-ended questions that were adapted from Schwanebeck (2008). The survey was analyzed to investigate students' opinions towards the utilization of graphic organizer in the classroom. Students' perspectives and views on the new instructional strategy were coded (Creswell, 2014) correspondent to their responses on the questionnaire. Furthermore, the daily journal act as a reflection piece of work by the teacher during the intervention period to gather teacher's perspectives on the application of graphic organizer in the lessons i.e. the changes of students' attitudes during the intervention lessons, difficulties students faced during the intervention lesson and etc.

RESULTS AND DISCUSSION

The SPA results gathered from students' previous year showed that the participants scored an average of 60% in their Mathematics subject, with a highest score of 74% and a lowest score of 47%. Thus the sample is made up of a class of students with different levels of Mathematical ability.

The Effectiveness of Implementing the Four-Corners-and-a-Diamond Graphic Organizer

As shown in Table 1 that the total mean score of the post-test decreased by 10% from the pre-test. It is important to note that the test scores were assessed based on the students' final answers only. This meant that the workings or strategies employed by students were not assessed i.e. even though a student showed an improper working or no working was presented, he/she would also be awarded a mark for a correct answer.

Table 1. Mean Score and Standard Deviation for the Pre and Post-Tests

Test	Question 1		Question 2		Question 3		Total	
	M	SD	M	SD	M	SD	M	SD
Pre-test	0.25	0.61	0.75	0.99	0.67	0.96	1.67	1.31
Post-test	0.46	0.72	0.63	0.92	0.42	0.78	1.50	2.00

Note. Question 1 (linear equation); Question 2 (quadratic equation); and Question 3 (simultaneous equation)

Further analysis of the qualitative data identified that there were some explanations for the lower total mean score in the post-test as follows:

1. Use of calculators were not allowed in both tests

   Since the study placed more focus on the performance of students in using graphic organizer, thus the numbers in the question were set to be small to avoid students' difficulty in calculation. However, this had become an issue. Since the numbers were small, findings from the pre-test showed that there were more than half of the students (63%) obtained their answers from doing the trial and error strategy or from inspection.

2. No final answer despite showing desired workings

   Analysis from the post-test revealed that students were presenting proper workings but failed to derive the final answer. Hence, an assessment based on only the students' final correct answer shows that students obtained a higher overall mean score in the pre-tests than in the post-test.

3. Time

   It was identified in the daily journal that the limitation caused by time constraint in teaching and learning of the intervention lesson was another possible cause to the lower mean score in post-test. This inhibits students from fully equipping the application of a new instructional tool (graphic organizer) in solving word problems. Moreover, students were eager to fill up all the empty boxes in the graphic organizer. They were reluctant to give up easily on one question and proceed to the next question unless they filled up all the boxes. Hence, in the post-test, students were taking up too much time in the first question and had fewer time to solve the remaining questions. This resulted in students performing less desirably in the last two questions as shown in Table 1.

Students' Performance after the Utilization of Graphic Organizer

Students' workings, i.e. no workings or improper workings in the pre-test, showed that students had a weak Mathematical skill in presenting their workings. Table 2 represents the results gathered by employing the four-point scoring approach (Zollman, 2011) to assess students' workings. It shows that there was an increase of the students' overall mean score in their Mathematical knowledge, Mathematical strategy and Mathematical explanation.

Table 2. Mean and Standard Deviations of the Pre and Post-Tests

Types of	Question 1		Question 2		Question 3		Total	
Mathematical Performances	M	SD	M	SD	M	SD	M	SD
Mathematical Knowledge								
Pre-test	0.79	1.06	0.63	0.82	0.88	1.12	2.29	1.96
Post-test	2.42	1.14	1.63	1.35	1.29	1.33	5.33	3.21
Mathematical Strategy								
Pre-test	0.92	1.06	1.21	1.06	1.25	1.36	3.38	2.26
Post-test	2.54	0.83	2.25	1.11	2.25	1.54	7.04	2.91
Mathematical Explanation								
Pre-test	0.46	0.59	0.79	0.66	0.83	1.27	2.08	1.73
Post-test	1.75	1.22	1.88	1.08	1.29	1.27	4.92	3.01

Note. Question 1 (linear equation); Question 2 (quadratic equation); and Question 3 (simultaneous equation)

Referring to the students' Mathematical knowledge in Table 2, the total mean scores of their post-test increased drastically by 57%. Moreover, the mean score of the first question rose the most (67%) from 0.79 to 2.42. Further analyzing the post-test revealed that students showed a more organized work and had a better understanding in their Mathematical knowledge. They presented proper Mathematical notation such as Mathematical signs and variables in their workings rather than giving in their answer with improper workings i.e. in the pre-test.

Moreover, it can be seen that the mean score of the students in terms of the Mathematical strategy increased by 52%. In the post-test, students performed better in their planning i.e. the use of models and diagrams. This is concurrent to the research done by Ulat (2006) that reported the use of planning i.e. model drawing helps students to improve understanding.

Furthermore, students had improved by 58% in the total mean score of their Mathematical explanations. Not all students were able to show completed workings in the post-test but compared to the pre-test, the overall improvement in the post-test was significant (from 2.08 to 4.92). Students have also learned to check if their solutions were reasonable, and try to understand the logic behind their answers. This has helped to overcome students' weaknesses in communication and comprehension abilities in solving word problems. Figure 2 shows the sample work of a student who started to gain some understanding of his/her workings by double-checking the reasonableness of his/her answers.

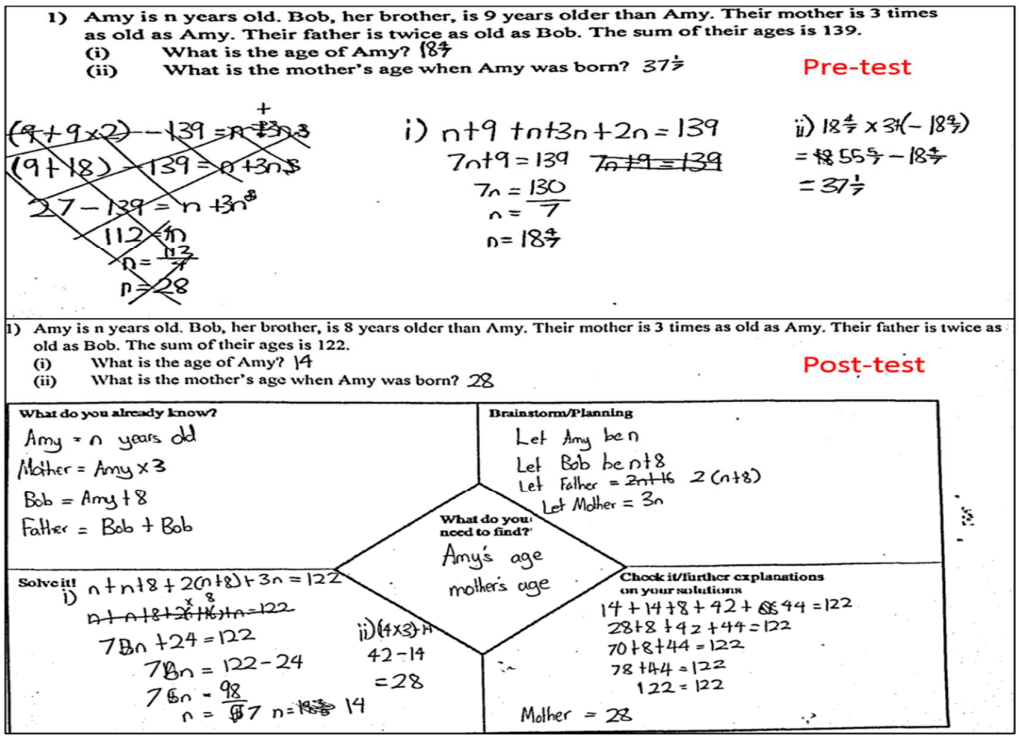

Figure 2. Student double-checking his/her workings in the check it box

Students' Perspectives after using the New Instructional Strategy

Findings from the open-ended questionnaire were analyzed to investigate the students' perspectives on using the new instructional tool (graphic organizer) in three different ways, as follows:

1. Students' feedback on using graphic organizer

   Students (45%) expressed that the questions are less confusing as the graphic organizer helped break down the word problems and arranged the given data in an organized manner. 20% of the students expressed that the use of graphic organizers gives a better representation of their data or workings and they appreciate this tool. Another 20% of the students experienced difficulties in applying graphic organizer in solving word problems although they considered graphic organizer as useful. Many students commented that it is time-consuming to fill up all the five boxes in the graphic organizer.

2. Willingness in applying steps in graphic organizer

   Majority of the students (43%) preferred not to do all the steps in the graphic organizer. Time factor was identified as the main issue. Another 33% of students were willing to draw and fill up all the empty boxes in the graphic organizer. Further analysis on this response revealed various reasons that drive students in agreeing to do all the steps in graphic organizer such as better clarity, saves time and useful application of graphic organizer. A remaining 24% of students were undecided because they considered the effective application of graphic organizer but also the drawback it brings i.e. time-consuming.

3. Students' attitude and confidence level

   After the introduction of graphic organizer, students' attitude and confidence level has boosted up to 86%. Most students (42%) stated that the graphic organizer makes problem solving easier. They expressed that

their work are more organized and this made word problem solving easier. Moreover, 21% of the positive response explained that the application of graphic organizer assisted them in solving i.e. they fill all the boxes in the graphic organizer which eventually lead them to solve the word problem. Furthermore, 14% of the responses commented that graphic organizer helped them to understand the question better. From this response, it is believed that graphic organizer allows students to break question into parts and brainstorm the Mathematical ideas in an organized manner (Zollman, 2011).

Changes Observed by the Teacher over the Intervention Periods

Findings in the daily journal reflected that students feel lost and they have never been introduced to any standard guideline in solving word problems. Moreover, when they came across word problems on simultaneous equations, students were confused by the overloaded information given in the question. Students did not know how to get started and were discouraged by the abundance of information. Wordy word problem is a common problem faced by most of the students especially in Brunei where English language is not their first language (Pungut & Shahrill, 2014).

During and after the introduction of graphic organizer, it can be seen that most of the problems students had before had been resolved. Teacher observed that students now has a guideline on how to begin their work and they can begin in whichever way they want i.e. pictorial orientation in solving word problem. Furthermore, teacher observed that students has less confusion in understanding wordy word as problem can be broken into parts and filled into the appropriate boxes in the graphic organizer.

CONCLUSION

With the use of graphic organizer in the learning and teaching of solving word problems in the class, students had shown a great improvement in their overall performances in terms of their Mathematical strategy, Mathematical knowledge and Mathematical explanation. From the intervention lesson, it can be seen that the use of graphic organizer breaks problem into parts and organize their data. Thus, this may help mitigate students' confusion in understanding a wordy question. Additionally, from the study, the use of graphic organizers allows teachers to specifically identify the areas of difficulty students faced.

As a result, this finding is believed to be able to help overcome the weaknesses of students in Brunei on their communication and comprehension abilities in solving word problems (Ulat, 2006; Pungut & Shahrill, 2014). Moreover, the study showed that students at present were having a positive attitude and higher confidence level towards solving word problems. This is a positive stance as most students in the past were having negative impressions of solving word problems and this discouraged them to try.

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