TEACHERS' EXPLORATION USING GRAPHIC ORGANIZER FOR PROBLEM SOLVING IN PRIMARY MATHEMATICS

Nor Azura Abdullah and Nor'Arifahwati Haji Abbas
Universiti Brunei Darussalam

Abstract

This study is an exploratory study of primary school teachers conducting in utilizing Graphic Organizer as a tool to teach problem solving in a professional development setting. The importance of problem solving among children has been highlighted in the Brunei educational reform, particularly in mathematics. One of the inhibiting factors in teaching problem solving is the low level of comprehension and transformation skills needed to solve mathematics word problems. Graphic Organizer is an instructional strategy used to help students to compartmentalize the necessary information to solve word problems. A group of mathematics teachers was introduced to embedding Graphic Organizer as a tool to address issues in problem solving in a professional development workshop. They implemented the strategy in their respective classes and found ways to apply and assess students' problem-solving strategies. Their reflections on the challenges and affordances Graphic Organizer posed in teaching problem solving are also discussed.

Keywords: Graphic Organizer, problems solving, Mathematics, professional development

INTRODUCTION

Brunei's education system, known as SPN 21(Ministry of Education (MoE), 2009), has put a greater emphasis on teaching and learning that covers the 21st century skills encompassing communication skills, collaborating skills, critical thinking skills and problem-solving skills as stated in the National numeracy and literacy standards. Problem solving has been identified as one of the basic skills in the 21st century (e.g., Trilling & Fadel, 2012). It should be incorporated in the mathematics instruction in teaching and learning as it is regarded as the cornerstone of mathematical learning (National Council of Teachers of Mathematics, 2000; Common core state standards, 2010). In general, Problem solving is a difficult skill to master but must be taught in Mathematics (Myers et al, 2022). Problem solving however has long been in existence in our life. It permeates in every aspect of our life in various forms including those that are of mathematical based problem. Exposing students early to this skill is essential to prepare them to be future-ready. Through early exposure to problem-solving skills, students will experience learning the processes of when and how as well as justifying their actions while applying the skill (Root, Browder, Saunders, & Lo, 2017).

Despite the introduction of various innovations for assisting children to see the relationship between texts and mathematical concepts, word problems remain difficult for children (Simamora et al., 2017) and

Corresponding author: Nor Azura Abdullah

studies have shown that students generally possess low problem-solving ability (NAEP, 2008; Wulandari et al., 2015). Over the years teachers have continuously witnessed children struggling to solve word problems. In this study, a schematic diagram tool known as Graphic Organizer, originally used to improve reading comprehension, was introduced to mathematics teachers. Replacing mathematics symbols, expressions and equations into text makes Graphic Organizer applicable in mathematics education. Graphic organizer enables students to understand concepts and see relationships encompassing mathematical symbols, expressions, and equations, and express them in a graphical manner (Ives & Hoy, 2003).

PROBLEM SOLVING IN MATHEMATICS EDUCATION.

Problem solving does not only require students to perform mathematical computation, but it also requires them to understand the underlying reason for applying the mathematical skills whenever necessary (Browder et al., 2018). This is because problem solving often comes in the form of text embedded in mathematical concepts and problems to be solved. The issue of students struggling to perform well in solving mathematical problems is not new. It is challenging for students to solve mathematics problems (Browder et al., 2018), and in particular, word problems. Many aspects contribute to the difficulty include the absence or lack of familiarity with the context of the problem and the lack of ability to comprehend what is being read. Problem solving often requires the comprehension of textual, graphical numerical and symbols, and this adds to the complexity of the problem (Braselton & Decker, 1994). This situation could be more problematic for children whose language of instruction is not their mother tongue.

Since gaining independence in 1984, Brunei has adopted a bilingual education policy whereby the medium of instruction in schools is in English and in Bahasa Melayu (*Malay language*). All subjects except Malay were taught in English starting from Year 4 primary schools. Since 2008, with the education reform of *Sistem Pendidikan Negara ke-21 (SPN21)* translated as the National Education System for the 21st century, the medium of instruction for Mathematics subjects at lower primary starting Year 1 to Year 3 has changed to English (MoE, 2009). There are challenges and difficulties for teachers to teach mathematics in a language that the students have yet to master. Kirkpatrick (2012) recommended to delay the use of English as medium of instruction until later years of primary schooling or at secondary level. This is because there are no advantages for younger children in Southeast Asia specifically to learn academic subjects in a language other than their first language. Abedi and Lord (2001) supported this claim, where children who are not proficient in English have a disadvantage in mathematical performance, especially word problems. They found that English language learners scored significantly lower in mathematics tests than their peers who have good command in English. In addition, they found in their study that the students with low problem-solving skills would have difficulties with text heavy problems.

In Brunei primary classroom, Mahdan (2020) found that primary school children who are exposed to keyword approaches to solve word problems are unable to correctly comprehend mathematics word problems. Mahdan taught her students; one group using English only and the other group using English and Malay to solve word problems. There were no significant differences other than both groups of students have errors in their understanding of the problems. This is similar to study done by Yusof and Malone (2003), who observed upper primary students can read mathematical word problems, but error increased in terms of comprehending, transforming and processing the word problem. Thus, word problems and problem-solving questions that are heavy in text are among the most problematic topics to teach and learn. Rasidah (1997) found that students performed poorly in solving word problems irrespective of the language used, English or Malay in this case. She encouraged educators to develop students' language skills especially comprehension skills and their problem-solving skills. Thus, students' difficulty with word problems could be due to the complexity of the text in word problem as found in Abedi and Lord (2012).

In the Brunei primary mathematics curriculum, the mathematics skills are interweaved with the mathematics processes and values as depicted in Figure 1. Since the reform in 2009, the mathematics syllabus has placed emphasis on students' mathematical processes such as mathematics computational skills, mathematical thinking, estimation and mental computation, communication, and attitudes and values. Thus, this has gradually changed the mathematics instructions to a more learner centered developing these skills while maintaining the development of the mathematics contents.

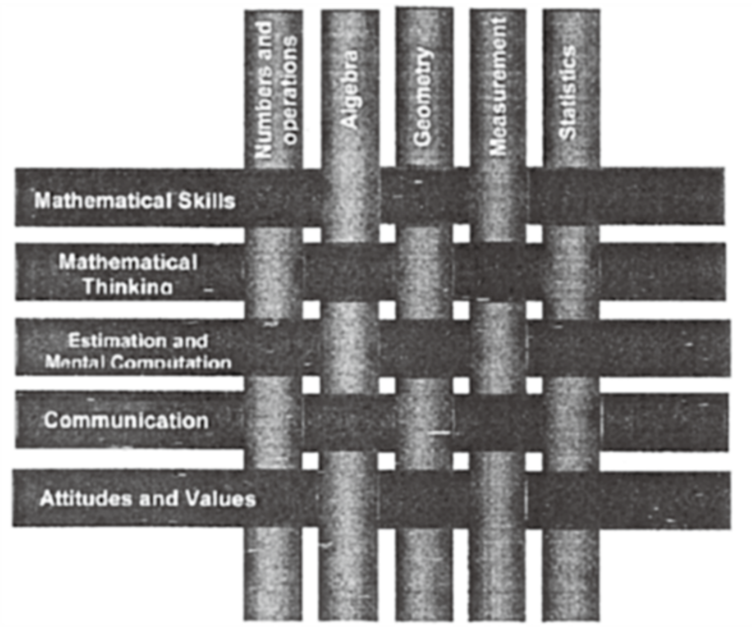


Figure 1. Brunei Mathematics Curriculum Conceptual Framework

Madihah (2006) reported that teachers have difficulties in implementing problem solving and honing mathematical thinking skills to students due to exam-oriented culture that exhorted teachers to take more traditional approaches in teaching to prepare their students for written examination skills. She reported that teachers are also committed to complete the content-heavy syllabus to make sure students are equipped with the knowledge to be tested at the end of the academic year. However, a slow shift in emphasis has emerged; for example, a case study of primary mathematics teachers (Haji Abdullah, 2021) was reported to plan their learner centred lessons focusing on communication and mathematical thinking. However, during the implementation, the instructions shifted to a more teacher-centred approach as the students and the classroom learning environment proved to be an obstacle and hindered the intended planned lesson to be carried out.

Numerous efforts have been initiated to assist students in coping with their difficulty with word problems. Among the initiatives done by scholars and educators includes the use of Graphic Organizers (GO) as a tool to support reading of mathematics problems (Barton & Heidema; 2002) and mathematical problem solving (Khoo et al., 2016; Zollman, 2009). In terms of reading mathematics text, Barton and Heidema (2002) suggested that GO is a useful tool to break down the information presented in the text into smaller parts where students can make connections of these information with their prior knowledge. Furthermore, students can organize and comprehend these pieces of information which is meaningful to them. With improvement in their reading and comprehension skills, students are able to make connections the mathematical concepts in order to solve word problems. This can be found in the study done by Zollman (2009) where middle school children improved in their problem-solving skills specifically where GO aided the students to "coordinate their mathematical ideas, methods, thinking and writing" (p. 8). Similar results were found in local studies done by Khoo et al. (2016) and Sai et al. (2018), whose students showed improvement in their problem-solving skills and, furthermore, with the aid of GO, students' attitudes, and confidence towards problem-solving also improved. GOs do not only help students' language skills but are also used to get a clearer picture for learners to communicate their mathematics thinking in solving non-routine word problems. Khoo et al. and Sai et al. agree that with the use of a graphic organizer, students can communicate their mathematical thinking during problem solving.

GRAPHIC ORGANIZER (GO)

The use of GO originated from an initiative to improve reading comprehension in language classes. Later, mathematics educators 'borrowed' this instructional tool to assist students in understanding the concepts and facilitate their attempt in connecting the relationships between the mathematical symbols, expressions and equations. All these can be expressed graphically in the GO worksheet (Ives & Hoy, 2003). In other words, GO provides scaffolding strategies for learners to unfold the questions asked into digestible information.

Despite having an array of GO formats to choose from, the common feature among the different types of GO is that all these formats aim to depict the thinking process by reorganizing the information into a graphical or pictorial format (Ellis, 2004). The GO is designed visually in such a way that the students or solvers need to write down the known information based on the texts and only then find or propose the solution. Essentially, GO is a visual representation showing the relationship among the key concepts in a topic with the purpose to improve students' learning outcomes by going through the process of comprehending and arranging information before trying to solve the questions. In short, it is a tool that represents the text concepts. In the authentic mathematics classroom, GO serves as an instant tool to check students' learning progress. Teachers can quickly identify from the GO the student's progress or confusion in solving the problem given to them.

In this study, we used Zollman's (2009) adaptation of GO that originated from literacy teaching tools. The adapted GO is a tool that helps students to solve word problems by organizing the processes, information, and possible solutions in no exact order. The *four corners and a diamond* graphic organizer consist of five areas that asked students to 1) think what they needed to find, 2) list what they already know, 3) plan the possible solutions, 4) try out their solutions and 5) explain what they have learned in solving the problem.

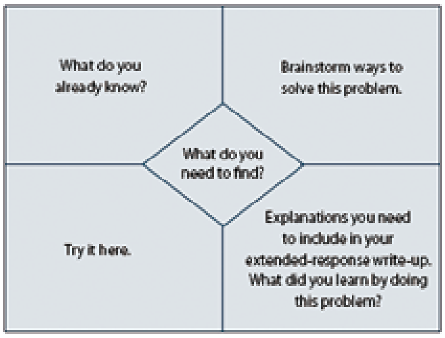


Figure 2. Zollman's (2009) four corner and a diamond graphic organizer

CONCEPTUAL FRAMEWORK

The objective of Zollman's GO is similar to Polya's (1945) approach of solving a mathematics problem. Polya's approach consists of four steps in sequence i) understand the problem ii) devise a plan iii) carry out the plan and iv) check and extend. It is in a linear order where students are required to execute the problem in ordered steps. Although the GO has the same purpose as Polya's (1945) strategies in solving mathematics problems, the solving process is differnt (Zollman, 2009). The GO's spatial model helps students in terms of visualising their strategies and in a non-linear schema diagram approach. The similarity of the sequential steps between Polya's approach and Zollman's GO model is depicted in Figure 3 for clarification.

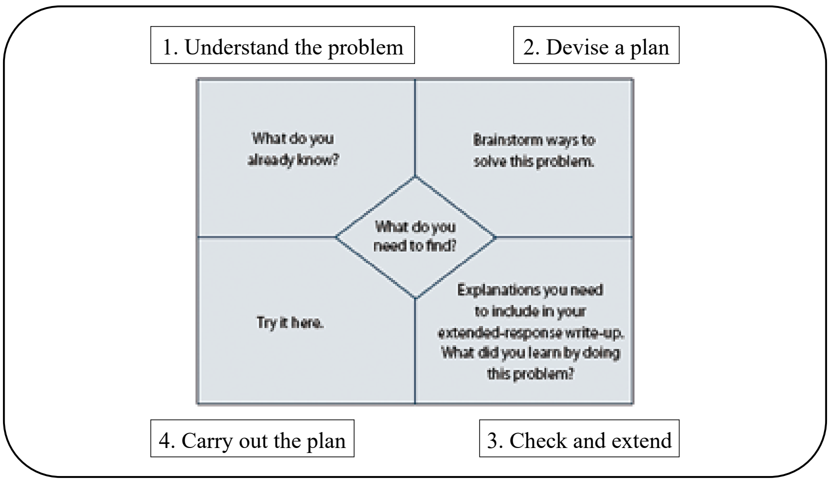


Figure 3. The combination of Polya's (1945) steps of solving mathematical problems onto Zollman's (2009) graphic organizer.

The GO as shown in Figure 3 does not have sequential order to process a word problem. Students can read a mathematics word problem and write the information at no specified order. For instance, upon reading a problem, if students identify a mathematical operation as possible solution, they can fill in the information on the top right corner of the GO. The information then can be stored on the GO while students process other information to solve the problem.

RESEARCH DESIGN

The purpose of our study is to investigate the use of GO in the teaching and learning of problem-solving skills in mathematics lessons in a bilingual education setting. The research aim of the study presented here was to explore the use of GO in primary mathematics classrooms from teachers' perspectives in order to answer the research question "How do teachers reflect on the use of Graphic Organizer for problem solving in primary mathematics lessons?" We explored the experience of teachers in using GO as a tool to aid students in solving non-routine problems based on their written reflections.

The research design of this study is based on a qualitative inquiry to evaluate the use of GO as an aid in problem solving. Patton (2002) termed this as evaluation research in qualitative inquiry where the "qualitative findings in evaluation" is used "to deepen understanding" (p. 10). The grounded theory is used as the foundation of this research design as the methodological approach that is best suited for this study (Lambert, 2019). Inductive analysis was done on the documents consisting of teachers' written reflections.

A total of 30 certified primary mathematics teachers from various government schools enrolled in a professional development workshop on problem solving. They were selected by the Ministry of Education from various schools across the four districts in Brunei Darussalam and were of various academic backgrounds.

METHOD AND PROCEDURES OF THE STUDY

In the workshop, the teachers were introduced to the use of GO as an innovative tool to cater to students' difficulties in comprehending and transforming mathematics word problems. The version of GO introduced by Zollman (2009) was adapted to suit mathematics word problems. The GO consists of four corners space and a diamond space as depicted in Figure 1. There are five questions asked in the graphic organizer, that is, on what to find, on what is known, brainstorming of how to solve the problem, space to try out and space to provide explanation and reflection.

GO was introduced and the teachers had the opportunity to experience how to use the GO in groups during the workshop. They were given time to solve a set of problems. The whole group sharing their application of GO was discussed. In this study, the teachers learnt from the learners' perspective in solving problems with the help of GO by trying out a variety of problem-solving questions and write their answers and thoughts on GO like shown in Figure 1.

In the workshop, the teachers familiarized themselves with eight strategies of problem solving (Hatfield, Edwards, Bitter and Morrow, 2008). The eight strategies that the teachers were exposed to were 1) estimation and check, 2) developing formulas and writing equations, 3) drawing pictures, graphs, and tables, 4) modeling, 5) working backwards, 6) flowcharting 7) acting out the problem and 8) looking for patterns. To communicate their mathematical processes, GO was used to show the strategies used.

In the workshop, teachers developed a set of rubrics they agreed on in assessing students' problem-solving skills. They agreed to look at four categories of students' learning process in solving non-routine word problems. The four categories were 1) understanding, 2) knowledge and process, 3) strategy and 4) explanation. Each learning process had five levels of descriptors with scores ranging from 0 to 4, with 0 indicating no planning shown in the 'strategy' category to 4 indicating students got everything planned with relevant strategy and using clear representations. The detailed rubric is shown in Table 1. In addition, teachers learned and adapted the use of a student scoring guide to solving a problem based on Hatfield et al.'s (2008) assessment on mathematical proficiency.

Table 1

Problem solving rubric

Learning process	Descriptors				
	4	3	2	1	0
Understanding	They understand the whole concepts	They understand almost everything	They understand some of it	They understand a little bit	They did not understand the problems
Knowledge and process	They gave the correct answer and shown clear correct workings	They gave the correct answer and provided appropriate workings	They provided answer with some correct workings shown	Little working was shown, or they provided answer only or they have a little misconception	They did not try at all, or No working was shown at all
Strategy	They got everything planned with relevant, strategy and using clear representations	They got almost everything planned and/or using other appropriate representations	They got some of it planned and/or using diagrams	They got a little of it planned or planned with some misconceptions	They did not try to plan at all
Explanation	They explained why they did everything using mathematical terms and steps	They explained most of why they did things and/or using keywords and steps	They explained some of why they did things and/or with some keywords	They explained a little of why they did things and/or showed some steps	They did not try to explain at all

Groundwork was conducted before the teacher implemented their action research in their own classrooms. Upon discussion, upper and lower primary teachers confirmed one similar written problem and another problem of their choice. In total, there were two problems to be solved by their students. The teachers encouraged their students to utilize GO in solving the problems. They were given more than 4 weeks to conduct the action research before writing a report to the facilitators. It was agreed to have the minimum of three lessons: introduction of GO, students applying the GO in solving at least 2 problems; each in a lesson.

Research evidence is based on the reports done by the teachers at the end of the workshop series in which they were required to share their findings with all the workshop participants via group presentation. This explorative study involves collecting multiple forms of evidence encompassing students' work using GO, students' rubric, data of students' achievements and teachers' reflections. These data were then analysed qualitatively. First, the authors read the written reports multiple times especially the reflections part of the reports and took notes by highlighting information of teachers' experience in implementing GO in their lessons. In an open coding phase, this highlighted information was categorised into two categories namely challenges and opportunities. In these categories, several subcategories were found to support the categories. The students' works were collected as evidence to corroborate the claims of the teachers. The authors compared notes, analysed and synthesised the findings separately and then collaboratively to validate our analysis through researcher's lens (Creswell & Poth, 2018).

However, it is a limitation of the study where participants' validation was not available. This is largely due to logistical constraints. With participants' lens on the findings, it could provide further credibility to the findings of this study (Creswell & Poth, 2018). Furthermore, this is a study involving a small sample of teachers in Brunei and may not be generalised to the population.

RESULTS AND DISCUSSION

The authors analyzed all the reports and evidence provided by the teachers. The first section describes the implementation of GO in solving non-routine problems and the reflections from the teachers on their experiences implementing GO in their lessons. The second section is to extend from the teachers' experiences on the possibilities of using GO as an aid in solving non-routine problems, as an aid in problem-solving skills, as a mediator for communication skills and as an assessment tool in problem-solving.

Teachers' experiences and reflections

All the participating teachers implemented the non-routine problems in the lessons and used GO as an instructional and learning tool. They reported their students on mixed-ability students. In the teachers' reflections report, teachers shared and described their experiences of using GO for non-routine problem solving. These reflections are further categorised into opportunities and challenges as shown in Table 2 and elaborated in next sections.

Table 2

Main coded themes of teachers' reflections on using GO

Teacher Group	Opportunities	Challenges
TG1	Expressed ideas in own language It encourages the pupils to express their ideas Helps pupils to plan how to solve the problem Help pupils to get marks even if they don't answer correctly Helps pupils to think and communicate their process	Language barrier Problem in mathematical terms
TG2	Excellent tool for visual learners who struggle with information that is presented in written form Gives every student starting point for problem-solving process	Limited time frame High achiever dominant Difficulty in whole sentences explanation (language barrier)
TG3	Graphic organizer helps express students' thinking Group work is better than individual task	Difficulty in brainstorming session and explanation corners Allocate more time to explain and familiarise students on how to use GO
TG4	Graphic Organizer a tool to organising information and relationship As a strategy that may assist pupils (who are) identified as having difficulties with problem-solving. Increase pupil's willingness to attempt the problem. Mitigating hesitancy and resistance. Allow pupils a strategy to organise the information before answering, hence may increase the confidence to answer.	Need extra support for pupils with learning difficulties Continuously use graphic organizer for familiarisation
TG5		There are too many ways to answer the question. The writing of the question should be very clear and unambiguous.
TG6	Clearly shows their planning and derived their answers By using the graphic organizer the process of solving a problem is taken into account and pupils may score marks in the process regardless of final answer Low achievers at least are able to score marks Rubric help to identify the strength of each pupil	Took a lot of time to familiarize with GO but once students figured it out less help from the teacher

OPPORTUNITIES

The teachers reported the opportunities that the use of GO had presented to them in their teaching. They reported that GO is a good tool for representing students' knowledge, help to express students' thinking, and enable students to express their ideas in their own language styles. These affordances supported the benefits of GO as recommended by Zollman (2009). A sample of the student's work using a graphic organizer is shown in Figure 3.

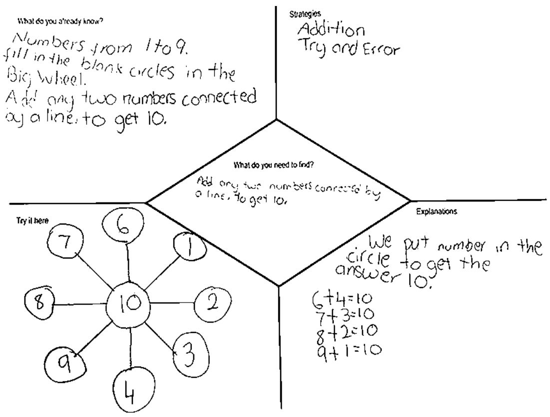


Figure 3. Sample of student's work using graphic organizer

The teachers reported that, through the use of GO, their students were able to explicitly express their knowledge and thought processes on the spaces provided in GO. With the students' written work on the GO, the teachers were able to collect evidence and discern the type of strategies used by their students. The schematic diagram of the GO breaks down the steps into non-linear sections that enable students to write down their thinking and their solving strategies to find the solution. For students to be able to articulate their thinking processes. As with any higher order thinking, for students to be able to articulate their thinking processes, it is not an easy feat as reported by the teachers, who asserted that it is an added value but disrupts their normal routine. To change a habit, a new technology as a disruptor may be useful. Maybe graphic organizers are a possible disruptor in this context.

Based on the results we have learned from the teachers' actual use of GO in their mathematics lessons involving problem solving, we would like to recommend a few strategies that might help in the learning for problem solving.

GO AS AN AID IN PROBLEM SOLVING SKILLS

Despite language barriers, the students were able to hone their problem-solving skills specifically in the mathematical learning process of understanding, knowledge and process, strategy, and explanation. This is in agreement with Khoo et al. 's (2016) study of using GO with secondary students in solving word problems. The student participants in their study showed an increase in mathematics performance particularly Mathematical knowledge, Mathematical strategy, and Mathematical explanation.

GO AS A MEDIATOR FOR COMMUNICATION

The GO can not only help students as a reading strategy, as GO was used in learning English language, but it has also further aided the students to communicate their mathematical knowledge and mathematical thinking skills. This could be seen from the following statement made by teacher TG1A (pseudonym).

TG1A: The pupils that used Malay languages in their writing were able to tell what they were asked to do. In other words, they know what to do; it's just that they have a language barrier.

Despite teacher TG1A's students using Malay language to explain their solutions, they had understood the question. This is different from studies done by Yusof and Malone (2003) and Mahdan (2020) where their students were unable to understand problem solving involving word problems, irrespective of the medium of language used, which is Malay and English. This interesting incident might be due to the use of GO that compartmentalizes on finding out the pre-concept ideas that the students have on the problem. This statement supports findings by Sai et al. (2018) where their student participants were able to make progress in word problems by breaking down the information using GO into smaller sections. These findings correspond to the advantage of using GO as Zollman (2009) recommended "helps students reduce and organise information, concepts, and relationship" (p. 5).

TG1A: It can reduce information processing demands as it doesn't need to process as much semantic information to understand the question given.

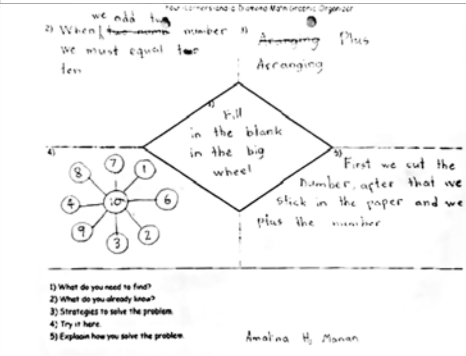
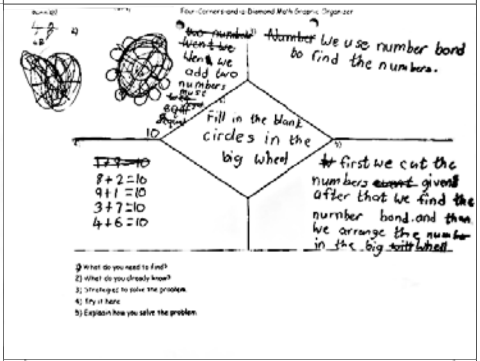
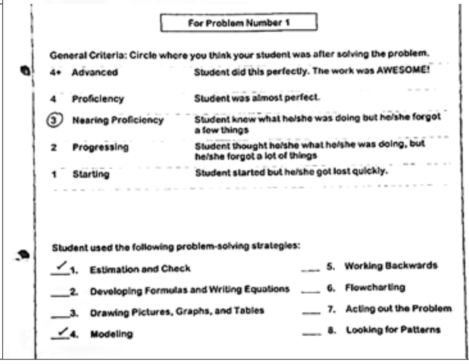
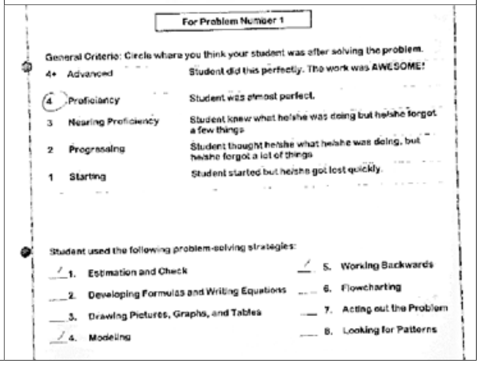
GO AS ASSESSMENT TOOL FOR PROBLEM SOLVING

Madihah (2006) reported that teachers may not be equipped to teach mathematical thinking then. In the action research performed by the teachers, none of them showed their unreadiness in teaching problem solving skills. In the implementations, none of the teachers reported on the difficulties of using the rubrics to assess students' problem-solving strategies (Table 2). This could mean that with the use of rubrics, it helps teachers to assess students' mathematical processes more efficiently and systematically.

The teachers also reported that they were able to identify the problem-solving strategies their students had used on the GO as well as their proficiency in solving problems. Sample of students' work and assessment from teacher TG1B are shown in Table 3 below. The pictures show how the teachers focused on the proficiency of students' problem-solving skills as well as the problem-solving strategies based on the information written on their GO.

Table 3.

Students' GO and Problem-solving rubric

Student	TG1BSA	TG1BSD
Graphic Organizer		
Problem solving proficiency and strategies		

With these practices as evident in Table 3, the assessments of mathematics problem solving were seen to be *shifting* towards a more process-oriented assessment. This could be the first step to mitigate the norm in Brunei mathematics teachers where Abdullah and Leung (2019) study, the Brunei mathematics teachers normally focused on product-oriented lessons. Although the 2019 study was not specifically on problem solving, mathematics teachers in this study shared their struggle to implement different approaches in the classroom when the norms or *cultural scripts* of mathematics lessons are strong. These cultural scripts include Brunei teachers to rely on product-oriented lessons preparing for examinations. Due to this norm, low-ability students were mostly left behind. However, with GO, these low ability students were found to be motivated in attempting solving the problems and they were still able to score marks based on their processes rather than the final answer. This sentiment was highlighted by the teacher participant:

TG1B: The pupils get some marks even if they don't get the answers correct.

CHALLENGES

The challenges reported included time constraints in using a GO because students would take a long time to be familiarised with it, too much class discussion surrounding the use of GO, and assessing the GO was time-consuming. Although the teachers felt that the use of GO was time consuming, they also saw the benefits and suggested for GO to be used in the early years of primary schooling, more frequently and beyond problem-solving lessons.

TG1C: The use of graphic organizers in solving any problems for the primary pupils should be implemented as early as in Lower Primary Year 1 since it can improve the pupils' thinking skills to solve mathematics problem questions.

TG1A: It is hoped that the graphic organizer can be used in the classroom more often especially when it comes to problem solving.

TG3: We should use the graphic organizers in the routines Mathematics questions to make them understand well on the purpose of this method.

TG3: We also found out that pupils also work better than doing it individually.

However, we believe as suggested by some of the teachers, that when students have become accustomed to using a graphic organizer, time limitation will no longer be an issue. To address this, the authors recommended that graphic organizers be used in other subjects as well. Originally, GO are used in English language teaching, thus adhering to Brunei's Whole-of-Nation approach, we can also use graphic organizers in other subjects and let students become accustomed with the tool in their learning.

CONCLUSION

As with any other novel tools employed in the classroom, challenges are inevitable, and opportunities are forthcoming. In this study, graphic organizers do help with the communication skills of the students in terms of expressing their mathematical thinking. Furthermore, it could be a useful tool to assess students' mathematical performance in the process stage and less focus on the final product of problem solving. The authors believe that with effective instructions, graphic organizers can be a powerful tool that can help develop students' problem-solving skills as well as promote high quality communication of their mathematical thinking as aspired by the Brunei education reform of SPN21.

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Nor Azura Abdullah
Universiti Brunei Darussalam
Email: azura.abdullah@ubd.edu.bn
https://orcid.org/0000-0001-7259-5224

Nor'Arifahwati Haji Abbas
Universiti Brunei Darussalam
Email: norarifahwati.abbas@ubd.edu.bn