Incorporating the use of comics in the secondary mathematics teaching of the order of operations

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Abstract. This study explored the use of comics in teaching secondary mathematics students the topic of ‘Order of Operations’. The focus was to improve students’ achievement with the use of comics as a tool to enhance the learning process and at the same time develop students’ interest in learning mathematics. A total of 33 Year 7 students from one of the secondary schools in Brunei Darussalam were involved in this study. Using an action research as the design research approach, two sets of comics relating to the concept of Order of Operations were used to teach students during the intervention lessons. A pre-test was given prior to the lessons, and then a post-test after the intervention lessons were completed. The results between the scores of the students’ pre- and post-tests showed improvements in their performance, indicating that the use of comics does help students in a way in learning the topic of the Order of Operations. Throughout the intervention sessions where comics were incorporated, students’ reactions to comics were taken into account through classroom observations as part of the analysing process. A few selected students were interviewed to give their feedbacks and their thoughts on using comics during lessons. While most had positive views towards comics in general with the majority stating that using comics made the lessons fun and interesting, there were also those who found comics not suitable to be used in the educational setting. The overall findings suggested that using comics have the potential to be used as a tool for teachers to facilitate their students’ learning.

Keywords: Secondary Mathematics; Action Research; Comics; Order of Operations.

1. Introduction
Mathematics is one of the core subjects not only in Brunei Darussalam but also in curriculum worldwide. The importance of mathematics is greatly emphasized, as it is one of the most challenging subjects in school for many students. They tend to get discouraged and have difficulties catching up with the subject as students still struggle to understand the connection of the mathematical theories in the real-world situations. Students could not relate mathematics to the real world and because of that they could not apply these mathematical concepts into another context [1-4]. Many are not interested in mathematics as they have the initial belief that mathematics is one of the hardest subjects to score, hence will change their perspective of the subject very early on and will demotivate them easily [5-8].

The basic knowledge of operations goes back to the primary level of education, as students should be able to evaluate numbers with different operations independently [9]. In the lower secondary level, students will learn how to evaluate mixed operations with the use of BODMAS rule. BODMAS is the acronym used commonly in mathematics lessons in Brunei. It stands for Bracket, Order, Division,
Multiplication, Addition and Subtraction. Meanwhile, PEMDAS is commonly used in the United States of America.

According to Bautista [10], in order to evaluate numerical expression, students will have to ‘operate’ numbers in order. Because of this, the use of BODMAS is usually emphasized in class as a way for them to remember the order. It is important for students to know how to evaluate numbers since it is the foundation of mathematics that is used to further solve complex arithmetic in the advanced level.

2. Literature review

Many efforts had been made through the years in order to improve students’ performances in mathematics all around the world [11]. The study conducted by Sa’ad et al. [11] investigated the reasons of secondary school students’ poor mathematics performance in the Azare Metropolis of Bauchi State, Nigeria. In their study, it was discovered that the negative attitude towards mathematics caused by several factors, and one of the factors to be highlighted in relation to the study by the authors is the inadequate use of appropriate materials in the lesson. In order for the students who are struggling in mathematics to succeed, different teaching methods and practical learning styles with different teaching strategies should be emphasized [8, 12-16]. Hence, encouraging students to develop positive attitudes towards mathematics.

When it comes to order of operations, students will commonly associate it with BODMAS or PEMDAS. BODMAS is the acronym used generally in the classrooms in Brunei, and according to Lee et al. [17] it acts as a device to help students remember the order in solving problems. Many students have no difficulty remembering the acronym when using it to solve expressions but the application of the rule itself still needs refining as they do not correctly operate numbers from left to right. The common misconception is that when it comes to having multiplication and division in the same expression students will inevitably solve the division first because the D of Division goes first before Multiplication in BODMAS. Same mistake goes to having subtraction and addition in the same expression.

Ameis [18] used the concept of hierarchal approach in order to avoid this common misconception. With the use of visual representation that shows the hierarchy-of-operators triangle it helps students to see the priority of operations. Division and Multiplication falls on the same level in the triangle as well as Subtraction and Addition in the same category to show the same priority when operating numbers. From the study of Ali Rahman et al. [9], the results showed great improvements when using this approach and the students preferred to use the triangle than the normal acronym of BODMAS. This shows that the visual also plays an important part in helping students to remember the concept better than the traditional way the textbooks usually emphasized. With the help of this approach students are seen to make less mistakes in solving problems of the order of operations.

Comics had been used as early as 1949 as an instructional tool for special needs and lower ability students [19]. They stated that teaching using comics that follows a storyline would create a sense of adventure that will make learning more motivating for the students. Children in today’s society would normally prefer visuals over heavy text, especially when in the era where Internet has been widely used at homes and the way messages are conveyed online is appealing to them [20].

2.1. Comics in education

Comics are one of the many examples of visual representation that can be integrated in mathematical lessons. Though commonly deemed as non-educational or an unsuitable material in schools, teachers nowadays are starting to see its appeal for the students to enhance their learning when these comics are constructed appropriately [21]. However, there was still a lack attempt of using comics in classroom, and according to Toh and Lui [21], it is one of the reasons he wanted to explore the idea of developing comics as a teaching approach in mathematic lessons.

Toh and colleagues [22] mentioned that the use of comics would increase students’ engagement in the classroom. The two key features that are present in comics are visual arts and also humor, which are imperative in attracting students’ interest. Visual does not only enhance learning but also extend students’ knowledge so that they are able to create their own understanding of the concepts that are
present in the comics [23]. Meanwhile, the use of humor in comics will help student remember content for a long time.

From the study conducted by Krishnan and Othman [24], the use of comics as a teaching tool has been effective in enhancing the learning process. It assisted the students with anxiety in learning mathematics to not feel intimidated and demotivated. The use of comics has also helped encourage students to see mathematics in a different perception. This learning environment will create a positive attitude for the students and when they become positive their achievements will improve [24].

2.2. Comics extension

One of the many concerns of teachers in education is to get students to connect concept into the real-world situations [25]. Piaget’s theory on children’s cognitive development as cited by McLeod [25] has influenced educators and teachers in developing constructivism of learning. His theory of constructivism becomes a focal point in education, as it is one of the most important aspects in enhancing students’ learning. Piaget suggested that the role of a teacher is to facilitate students and adapt discovery learning in order to increase their understanding. It is believed that through the use of comics teachers are able to facilitate and extend students’ learning. Since comics can be used to deliver concepts, it gives students opportunities to process information, develop thinking and construct knowledge [26].

According to Wiegerová and Navrátilová [27], the use of conceptual comics in school brings different approaches in learning to support constructivism. It produces a positive learning environment that creates discussion among students as they get to analyze images and problems produced by the comics. Students are also given the opportunities to share and extend their own ideas, which aligned with Piaget’s theory that suggested students should be allowed to learn in an active environment where they have more engagement than passive learning [28]. It is hoped that teachers consider comics as an alternative pedagogical tool to help students enhance their learning as it does not only allow them to construct knowledge, but it also gives them the opportunity to grow by developing critical thinking and enriching their understanding, so that they are able to apply knowledge to a real-life context [26].

3. The study

The use of visual representation is prevalent in the classroom setting as it is one of the strategies teachers use to engage students. The use of comics has also been one of the tools that some teachers began to appreciate in education nowadays as it does help develop students’ interest [29]. With this comes a positive attitude in mathematics and students will tend to remember concepts more with the help of these tools. However, in Brunei, comics are still not commonly used in the classroom and due to this limitation, the researcher intended to explore the use of comics as a teaching tool in improving students’ performances in education. And through this research it is hoped that the use of comics in the classroom for the mathematics lessons will be considered as a teaching tool among teachers in Brunei. Thus, the aim of the study is to explore the use of comics in the lesson in improving lower secondary students’ performance on the order of operations and to examine the students’ perception of using comics as a tool of learning in the classroom.

4. Methodology

4.1. Research design

The design for this study implemented the action research approach. Accordingly, action research involved the process of planning, instruction and evaluation that can assist teachers to explore the idea of creating lessons in helping students in their learning process and accomplish the desired outcomes [30]. In order for the study to be carried out, a thorough planning must be made in designing the lesson. Designing a pre-test was the first step on the research study and following it the items of the test must be checked first for its validity and reliability. Two different classes of the same school were given the pre-test before the intervention lessons and the post-test would follow shortly after completing the lessons. Classroom observation was also part of the analysis to investigate any important information
during the intervention lessons. Selected students underwent interviews and the results from the tests and the interviews were collected for further analysis. The study of this research is of mixed qualitative and quantitative methods.

4.2. Sample
The participants involved on the study were from two Year 7 classes in one of the secondary schools in the Brunei-Muara district. A total of 33 students participated in the study where 27 students were of the higher ability and 6 were from the lower ability class. The participating students were in the age range of 12 to 13 years old. A few selected students were chosen to do interviews based on their post-test results as well as individual survey to identify their perceptions on the intervention, their views on the topic itself and also the comics.

4.3. Data collection and instruments used
Students were given the pre-test without informing them in advance to identify the students’ errors and misconceptions prior to the intervention lessons on the topic. The results of the test were recorded for quantitative analysis. The test was given immediately after the intervention lessons have completed. The items of the test were similar to that of the pre-test and the score recorded for analysis and compared to the results of the pre-test.

All participating students took part on the survey after they completed the post-test and each individual student was to give brief thoughts on the questions provided. These were used as part of the qualitative data. Based on their responses in the survey, a few students were then selected and interviewed for further evaluations. A few selected students were interviewed after the survey was given and analyzed. Students were interviewed using semi-structured interview questions on their perceptions of comics integrated in the classroom, their thoughts on the topic itself and their opinions of the intervention. These interview sessions with the students were recorded for future analysis as part of the qualitative data.

Figure 1. Samples of comics used during the intervention lessons.

The two sets of comics were created as a tool for the intervention lessons (see Figure 1). Characterizations and dialogues of the comic were also considered to ensure that the story was made academically suitable to be used in the classroom and in line with the context of mathematical concept. Each comic had provided sample of problems on Order of Operations to be solved by the students during each intervention lesson.

The comics used during the intervention lesson focused on scaffolding and collaboration between students. They were first introduced to the topic of the Order of Operations with a comic that follows the story in a classroom setting where the teacher is seen to be teaching students the concept of the Order of Operations. Its content involved solving equations on the Order of Operations. Sufficient examples
were provided in the comics as part of the exercises. The second comic was a short comic that requires students to work in pairs in solving a longer equation with the emphasis of left to right rule and Ameis’ hierarchy-of-operators triangle, which was also highlighted in the comics.

5. Results and discussions

5.1. Descriptive statistics results

The results of the statistical data were presented in terms of the descriptive statistics using the Statistical Package for Social Sciences (SPSS) in order to analyze the data. Furthermore, the charts will be included to see the differences in the students’ performances. The results and findings from the students’ responses were presented according to main themes.

Table 1. Descriptive statistics of students’ results from the pre- and post-tests for the two classes.

|        | N  | M    | SD  | Min | Max |
|--------|----|------|-----|-----|-----|
| Pre-test | 33 | 10.76| 2.72| 4   | 15  |
| Post-test | 33 | 15.03| 2.02| 11  | 18  |

The results show that the mean score for the overall post-test (M=15.03) is higher than the overall pre-test (M=10.76), which has a difference in overall mean score of 4.27. A paired sample t-test was further used to analyze and determine whether there is an improvement between the results of the pre-test and the post-test. From the results of the t-test, there is a statistically significant difference between the overall mean scores of the pre-test (M=10.76, SD=2.72) and the post-test (M=15.03, SD=2.02; t(32)=12.861, p =.000). These results indicated that both Year 7 classes on average had shown improvement in the test.

Figure 2. The number of students according to the marks of the pre- and post-tests.

Figure 2 shows the number of students based on their marks of the pre-test and the post-test. It shows that the number of students is distributed more towards the higher scores for the post-test than the pre-test. There was an overall increase in the number of students between the pre-test and post-test’s scores. Hence, the overall results show there was an increase in the students’ performances after the intervention lessons.

5.2. Classroom observations
A checklist of classroom observation was used during the intervention lesson to record any valuable information on the students while using comics. This helped to observe and take notes of important aspects that may be significant to the research during the analysing process.

- **Students’ reactions to comics.** When the comics were distributed to the students in both classes, some showed interest and enthusiasm towards the comics. Students were seen focused and they took their time to read the materials. Their gestures and postures indicated excitement and throughout the lesson students paid attention to the class when the teacher gave explanations, which indicates that the comics did help them to be more focused on the lessons. Not all students, however, gave the same responses to the comics. Some of the students gave no reactions to them and were only neutral about the prospect, especially those of the higher ability students.

- **Students’ engagement with comics.** Students were able to solve the problems in the comics with little guidance from the teacher. The comics itself had helped them in solving the problems. Students felt comfortable during the lesson and were not afraid to ask questions whether it was on the topic itself or the comics. Seen from the observation was students’ engagement with each other and they were able to solve the problems together through discussions. The overall classroom environment was positive and the focus on the social constructions gave students the opportunities to learn confidently and engage comfortably with peers and teacher.

- **Students’ perceptions of comics.** Students generally stated that they were happy about the lesson, knew what was expected of them and understood the lesson criteria. Their thoughts and perceptions of comics were also analyzed after the selected students were interviewed. However, there were some instances during the intervention lesson where the students were more interested in the comics rather than the educational content it conveyed. One student was seen making comments on the characters and was not paying attention to the lesson.

5.3. **Students interviews analysis**

The semi-structured interviews were done to investigate students’ thoughts on the use of comics in the lesson and their general views of the topic of the Order of Operations and the comics given to them during the lessons. Based on the students’ interviews their perceptions of comics can be divided into three main themes as follows:

- **Comics are fun and interesting.** The six students who were interviewed stated that using comics during the lesson was fun and interesting. Three students found that pictures were what caught their attention and the comics were fun to read. Previously, they found mathematics boring and with comics they came to learn that there was a way to make it fun. All six interviewees agreed that using comics were new to them and some of them had never read comics before or had read comics before but not frequently.

- **Comics help understand the lesson better.** Some students found that comics do help them during the lesson. When it comes to the topic of the Order of Operations students that were interviewed stated that the topic was not at all difficult but they still found it hard to remember the hierarchy of the operations but with comics they remember how to use the order better. In their general views of the comics used in the lesson, one student mentioned that he remembered bits and pieces of the situation where the character said ‘Always start from left to right’ and used that bit of information while doing the test. It helped him to remember the order as well while solving the operations. Another student felt that comics will help students concentrate and understand better so she preferred to use comics rather than the typical textbook and notes.

- **Comics are not suitable in educational setting.** Three students out of six that were interviewed preferred to use comics during the lesson while the other three did not. Those who did not thought that comics are not suitable to be used in the class. These students had different ways of viewing them. While they thought comics were fun and interesting in the context of education, they felt it was not appropriate to use comics. One preferred the conventional notes to comics and another
student stated that comic was a distraction and using it would make students lose their focus. The student further elaborated that it was something that had never been done before in class and thus it was something she was not used to.

5.4. General discussions
From analysing the students’ answers of the pre-test and post-test, students had difficulties solving longer equations with multiple operations involved. The common misconception while solving these equations is that students tend to solve according to the BODMAS rule without understanding its hierarchy. There was an improvement in their result after the intervention lessons and a few of the students were seen using the Triangle Rule to solve the equations on their pre-test.

Comics also help students remember facts and concepts [24], and this can be seen from student’s answer scripts as well as from their interviews. The Triangle Rule was incorporated in the comic itself and shown in some of the students’ answers, they were using this concept to help them solve the problems on the pre-test. This shows that these students were paying attention to what was conveyed in the comics. From the interview session, one student who chose to use the concept of BODMAS stated that what he remembered from the comic was how the character emphasized on operating the equation from left to right and the hierarchy of which operator to solve first.

6. Conclusions and implications
Based on the statistical data analysis, the overall mean score of the post-test for this study is higher than the overall mean score of the pre-test, thus showing improvement in the students’ results after the intervention lessons. Students had a positive view towards comics in general and majority of them agreed that using comics made the lessons fun and interesting. Through the classroom observations, students gave a positive reaction to the comics and the classroom environment throughout the lessons was overall positive. There were engagements among the students during the pair discussions, and social constructions between the students and teacher during the lesson were also present. A few of the students who did not prefer comics still had difficulties getting used to the idea of using comics during the lessons only because it had never been done before and the idea was completely new to them. According to these students, comics are not suitable to be used in the education setting because they viewed comics as non-educational.

Additionally, the students who preferred to use comics during the lessons revealed that comics helped them remember the concept better and thus helped improve the result of their post-test. Majority of the students enjoyed comics because of the colors and the characters that attract them, and had interest in mathematics when the comics were introduced to them during this study.

The implication of using comics in the classroom is that it helped in improving the quality of students’ performances both during the lessons and also the test. Comics helped improve students’ interest in learning as well as students’ engagement. Apart from being a new teaching tool in the classroom, comics covered several theories that are imperative in enhancing students’ learning in the classroom [26]. The findings of this study suggested that comics have a potential in the education settings and can be used as a tool in order for teachers to facilitate students’ learning. Students were seen paying attention and were confident in answering questions during the discussions.

7. Limitations and recommendations
The use of comics in classroom is still uncommon in the educational settings, especially in Brunei. Through the research and findings of this study, there was a positive insight of what comics could offer to education and it also provided a promising approach in students’ learning. However, not all students prefer comics. The rare availability of educational comics may be one of the reasons students were still cautious of its use in the lessons. A few of the students from this study felt that comics are not suitable in lessons. However, we cannot generalize based on this study alone. Therefore more researches should be done to identify further on the students’ thoughts of using comics in the class. Comics covered several theories that are important in enhancing students’ learning. In this present study, social constructions
and constructivism were present. However, in order for these theories to have its fullest impact, future researchers should focus on the content of the comics that require higher order thinking skills. Take into consideration the Bloom’s Taxonomy while incorporating stories and mathematical concepts in the comics. Time constraint is also one of the limitations while conducting this study. Hence, in order to improve the research and to fully investigate the effectiveness of using comics, future study needs to be done in a longer time frame and a larger sample size.

References
[1] Khalid M 2006 Mathematical thinking in Brunei curriculum: Implementation issues and challenges (Japan) Paper presented at the meeting of the APEC-Tsukuba International Conferences
[2] Chong M S F and Shahrill M 2016 The use of an emerging framework to explore students’ cognitive competency Indian Journal of Science and Technology 9 1-12
[3] Chong M S F, Putri R I I and Zulkardi 2018 Teaching problem solving using non-routine tasks AIP Conference Proceedings 1952 020020 2018
[4] Chong M S F, Shahrill M and Li H-C 2019 The integration of a problem solving framework for Brunei high school mathematics curriculum in increasing student’s affective competency Journal on Mathematics Education 10 215
[5] Hamid M H S et al 2013 Barriers to mathematics achievement in Brunei secondary school students: Insights into the roles of mathematics anxiety, self-esteem, proactive coping, and test stress International Education Studies 6 1
[6] Jameel H T, Ali H H and Phil M 2016 Causes of poor performance in mathematics from teachers, parents and student’s perspective American Scientific Research Journal for Engineering, Technology, and Sciences 15 122
[7] Othman R et al 2016 Investigating the relationship of student’s ability and learning preferences: Evidence from year 7 mathematics’ students New Educational Review 44 125
[8] Abdullah N A, Shahrill M, Yusof J and Prahana R C I 2018 Identifying the factors affecting students’ performances in primary school mathematics Journal of Physics: Conference Series 1097 012137
[9] Ali Rahman E S, Shahrill M, Abbas N A and Tan A 2017 Developing student’s mathematical skills involving order of operations International Journal of Research in Education and Science 3 373
[10] Bautitsta G 2012 PEMDAS and the Common Errors in the Order of Operations Math and Multimedia
[11] Sa’ad T U, Adamu A and Sadiq A M 2014 The causes of poor performance in mathematics among public senior secondary school students in Azare Metropolis of Bauchi State, Nigeria IOSR Journal of Research & Method in Education Ver. III 4 2320
[12] Shahrill M et al 2013 A comparison of learning styles and study strategies used by low and high math achieving Brunei secondary school students: Implications for teaching International Education Studies 6 39
[13] Matzin R et al 2013 A comparison of learning styles and study strategies scores of Brunei secondary school students by test anxiety, success attributions, and failure attributions: Implications for teaching at-risk and vulnerable students Review of European Studies 5 119
[14] Khoo J S et al 2016 Graphic organizer in action: Solving secondary mathematics problems. Journal on Mathematics Education 7 83
[15] Tapa H et al 2017 Determining the relationship and influencing factors of high school students’ performances and achievements in mathematics Turkish Online Journal of Educational Technology Special Issue for INTE 2017 10 792
[16] Mundia L and Metussin H 2019 Exploring factors that improve mathematics achievement in Brunei. Studies in Educational Evaluation 60 214
[17] Lee J K, Lickwinko S and Taylor-Buckner N 2013 Exploring mathematical reasoning of the order
of operations: Rearranging the procedural component PEMDAS. *Journal of Mathematics Education at Teachers College* **4** 73

[18] Ameis J A 2011 The truth about PEDMAS. *Mathematics Teaching in the Middle School* **16** 414

[19] Affeldt F, Meinhart D and Eilks I 2018 The use of comics in experimental instructions in a non-formal chemistry learning context. *International Journal of Education in Mathematics, Science and Technology* **6** 93

[20] Phoon H–Y et al 2018 *Featuring the comic ‘Nym the Leaf Fairy’ in teaching about plant systems at elementary school science* (Indonesia) Paper presented at the International Conference on Mathematics and Science

[21] Toh T L and Lui H W E 2014 Helping normal technical students with learning mathematics – A preliminary survey *Learning Science and Mathematics Online Journal* **10** 1-10

[22] Toh T L, Cheng L P, Ho S Y, Jiang H and Lim K M 2017 Use of comics to enhance students’ learning for the development of the twenty-first century competencies in the mathematics classroom *Asia Pacific Journal of Education* **37** 437-52

[23] Toh T L, Cheng L P, Jiang H and Lim K M 2016 *Use of comics and storytelling in teaching mathematics* ed P C Toh and B Kaur (Singapore: World Scientific) Developing 21st century competencies in the Mathematics classroom 241-59

[24] Krishnan S and Othman K 2016 The effectiveness of using comic to increase pupils’ achievements and higher order thinking skills in science *International Journal of English and Education* **5** 281

[25] Mcleod S 2018 Jean Piaget's Theory of Cognitive Development: Simply Psychology *Study Guides for Psychology Students - Simply Psychology*

[26] Bolton-Gary C 2012 Connecting through comics: Expanding opportunities for teaching and learning *US-China Education Review* **2** 389

[27] Wiegerová A and Navrátilová H 2017 Let’s not be scared of comics (Researching possibilities of using conceptual comics in teaching nature study in kindergarten) *Procedia - Social and Behavioral Sciences* **237** 1576

[28] Murphy S 2019 How to Apply Piaget's Theory in the Classroom *The Classroom | Empowering Students in Their College Journey*

[29] Cleaver S 2008 Comics & graphic novels *Instructor* **117** 28

[30] Stringer E T, Christensen L M F and Baldwin S C 2010 *Integrating Teaching, Learning, and Action Research: Enhancing Instruction in the K-12 Classroom* (California: Sage)