How using comics can assist in determining the students’ learning of distance-time graphs

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Abstract. The art of teaching mathematics at all levels requires a lot of creativity and innovation from a teacher for the students to effectively grasp what they are taught. Teachers tend to devise various means always ensure that they understand the attention of a learner in mathematics lessons bearing in mind that some learners easily switch off in mathematics lessons. In this study, we explored how a teacher can effectively use comics while teaching upper secondary students the topic of Distance-Time Graphs. The research entails that problems exist among the mathematics areas where the students face a challenge in grasping the concepts they are taught and even lose concentration more quickly while the teacher is teaching thereby falsely conceptualising that mathematics is a difficult subject. The concepts involved in this paper are in concurrent to the existing literature that the use of comics is one of the ways to draw the attention of students while teaching them. An action research approach was adopted to determine whether students’ understanding of mathematics concepts in Brunei schools could be improved using comics. The problems that 38 Year 10 students encountered while learning Distance-Time Graphs have also been elaborated in this paper, and the methodology through which comics can be incorporated into the teaching and learning process in this area has also be shown for practical application in the Brunei secondary school. There is also an elaboration on how the research concerning the use of comics in teaching was conducted and how the hypothesis was analyzed and evaluated to have a positive outcome in the teaching and learning process.

Keywords: Use of Comics; Distance-Time Graphs; Secondary Students; Concepts

1. Introduction

Learning mathematics is challenging and problematic for most students at all levels of learning. Numerous complaints from students in learning institutions about mathematics only indicate the level of difficulty of science and mathematics. Most students dislike learning mathematics due to the struggles they encounter in grasping different mathematical concepts. Mathematics is challenging and continues to be more difficult as the student progresses to higher classes or grades. According to most students in government schools in Brunei Darussalam, Mathematics is considered a difficult subject as compared to the other subjects. To solve mathematical problems, critical thinking and reasoning must be present. This is because there is a high probability of making errors when an individual is not attentive. According to Nelson et al. [1], they argue that most children who experience difficulties in learning Mathematics also find sciences such as Physics challenging. A large number of those students who fail to understand mathematical concepts also find it difficult to interpret simple scientific explanations [2-5].
Due to the difference in the learning capabilities of students, it is evident that there are also faster learners who face little or no difficulty in learning Mathematics. They can read concepts and interpret them utilizing theoretical methods and strategies. However, the group of individuals who do not understand mathematics theoretically requires visual aids, which could help them to be more successful and astute learners. Contemporary modern society in Brunei requires the introduction of new techniques of learning that are inclusive of all the different categories of students. Both the faster and slower learners as well as those students who cannot learn without the assistance of visual aids should be considered in the various school curricula [6].

Concerning this issue, it is evident that there is a need to introduce comics in the learning of mathematical concepts in Bruneian schools. The plotting of Distance-Time Graphs is one of the most intellectually tasking mathematical concepts for young students aged below 16 years to comprehend. To ensure they have a better visual understanding of the situation, it is fundamental to introduce comics in the classroom and at home as part of contemporary cutting-edge teaching techniques.

For most of the results presented by learning institutions in Brunei, there are downward curves on the progress of students in interpreting mathematical concepts [7-13]. Most of them score below the average mark in mathematics compared to other subjects. This is a problem that has been contributed to by the failure of students to constantly practice mathematics, thereby immersing himself or herself in the subject. Most of them spend their time doing other activities such as playing video games instead of practicing mathematics. When they are faced with tests and examinations, they find it difficult to remember mathematical formulas required for them to answer particular questions.

The general goal of this present study encompasses introducing comics in the teaching of mathematical and scientific concepts to secondary school students. Most students are considered to be dependent on visual elements to help them in understanding various mathematical concepts. By introducing comics as a learning method or tool to help students in learning mathematics, many of these very students may have an advantage in understanding the mathematical and scientific concepts they need to master at their level of study. Additionally, the study aims at helping students and instructors to understand the visual techniques that can be used to introduce comics in the classroom. Also, it will include an analysis of the methodologies that can be effective in the introduction of comics in the study of Distance-Time Graphs. Students will understand how to interpret comics to learn different mathematical concepts specifically for a Distance-Time Graph.

2. Literature review

Novel approaches proposed for the teaching of mathematics are premised on the need for adequate preparation of students for the rapidly changing world. In part, these approaches include a shift of teaching models to a more transformative style designed to meet the 21st Century demands [14]. Novel styles allow for the premising of the perceptions of learning around it being a process that uses prior interpretations to construe either revised or new interpretations of the meaning of one's experiences, which can then help guide their actions in the future. Transformative approaches place more weight on addressing the challenges surrounding the delivery of skills and content in a productive manner so that it improves the learning outcomes of students [15, 16]. One of these transformative approaches is the use of comics. The application of the medium of the comics creates an extension of the facts provided by textbooks, thereby facilitating the student to understand the concepts in question more easily [17].

2.1. Use of comics in teaching

Many scholars support the use of visual representations since it develops mathematical problem-solving skills in students. Furthermore, mathematical tasks require appropriate problem-solving skills that enhance the formation of logical solutions. Arguably, the use of comics in teaching mathematics is ideal for improving problem-solving skills and more so to secondary students in the 21st century. It is crucial to prepare the future generation for technological advancements, which means that developing critical mathematics thinking skills among today’s students is vital to ensure that future challenges can be adequately handled [18]. Therefore, the application of comics in classrooms is one
way through which students can be prepared for future challenges. Visual images can be used to convey specific essential messages since they encourage the learners to understand the concept in their own ways. Furthermore, instilling critical mathematical ideas in the learners requires them to remain attentive throughout the learning period and the only way to ensure this would be presenting them with comics that relate to the mathematical ideas being taught [19]. Notably, retaining mathematical skills requires more than just introducing the figurative concepts.

Various approaches can be used to visualise knowledge, which includes animations, maps, diagrams, sketches, and visual metaphors [20]. These approaches can be used to present knowledge in such a way that the students know the what, why, how, who, and where of the problem being solved. Furthermore, visualisation can help students see and grasp concepts that are difficult to explain [21]. Visual explanations help learners to grasp concepts faster than words and figures. Visual images communicate in a rather direct manner as opposed to verbal language. It provides the learners with a detailed reference, which means that they can be able to infer the behavior, causality and understand how the system works.

2.2. Problems faced by students when dealing with distance-time graphs
Cleveland and McGill [22] noted that while line graphs are the most difficult to interpret among school-going children, two-dimensional graphs and circular graphs are easily interpreted. These results are echoed in Peterson and Schramm’s [23] research that found line graphs being highly inaccurately read, with a 0.55 participant correlation between numerical reasoning and the ability to interpret graphs.

The TOGS (Test of Graphing in Science) test of Padilla et al. [24] developed for the measurement of graphing skills in math and science (more so the construction and interpretation of graphs) realised that student in grades 7-12 had incrementally higher graphing skills. The continued teacher understanding of student logical reasoning processes of Distance-Time Graphs is crucial in comprehending the reasons for faulty graph construction and misinterpretation allowing for the development of practical approaches to help their students better grasp the graphical concepts. The use of comics in the teaching of mathematical concepts is an area worth exploring as studies elsewhere (such as Singapore) have proved its usefulness in increasing motivation and engagement among school going children [25].

2.3. The role of colors in teaching mathematics
Colors have been used in learning as a visual aid in mathematics for a long period of time. The general observation is that colors do enhance the brain process, and students who are instructed or taught using colors, understand faster and information is reinforced for a longer duration, thus enabling them to perform well in exams [26].

Mathematics is a discipline that requires the use of abstract and concrete relationships and thus simultaneous brain processing is necessary [27]. Using colors has been found to incorporate the left and right sides of the brain, thus facilitating effective learning of mathematics for students in high school. Furner and Worrell [28] carried a research on the role of colors on high school learning, and found that colors enhance the processing of information in the brain. Steps towards achieving holistic learning of mathematics in high school students should involve teachers incorporating color to stimulate both the left and right sides of the brain.

Distance Time Graph is a good example of mathematical concepts, which require the use of color or comics to teach. A high school instructor needs to use different colors to explain the changes in time and distance [28]. It is not advisable to use the same colors throughout the graph. Different colors will create visual appeal and interests among the students who will thereby understand the concept more easily. The concept will be easily reinforced because it can make a quick connection with the colors, which were used in the graph. More so, when different colors are used, it is easy to follow throughout the graph and read the interception points between two cyclists in the same graph [27]. A graph may be plotted to show different displacement and speed; for instance, blue can be used for a
fast, steady speed, red for the stationary phase and green to show an increase in speed. Such multiple colors will make it easy for the students to recognize a distinction as opposed to when a similar color is applied throughout for all functions.

The reason as to why colors are effective in classroom teaching of mathematics is due to the close association children have with colors. Children like bright colors, and thus when these bright colors are presented in classroom learning, students’ interest in whatever is being taught, will increase. Adding colors in the classroom environment will make students aggressive and they will thus grasp the concept of mathematical models [26]. Thus, when teaching high-level mathematics, it is advisable to use contrasting and bright colors for effective reinforcement of memory.

3. Methodology

The primary research design plan that was used for this study is action research. Accordingly, when conducting research, it is fundamental first to identify the problem to be solved, and then come up with viable solutions, which can be used to solve the problem in the long run [29]. This study adopted a multi-pronged method of research, which included both qualitative and quantitative analyses in an attempt to investigate the effects of introducing the comics learning techniques in learning graphs of distance-time.

3.1. Sample

One mixed-gender or co-educational Bruneian government secondary school was chosen for the main study. The sample for the intervention was Year 10 students studying the International General Certificate of Secondary Education (IGCSE) Mathematics (0580) Core Syllabus under the three-year program in a secondary school in Brunei. There were 38 students, aged from 15 to 17, involved in this intervention. Students had to be present during the pre-test, the lesson intervention and post-test in order for them to be included in the sample and data analysis. Throughout the study, 11 students (from the overall 49 students) were absent collectively and their results were not included in the analysis.

3.2. Data collection instruments

The instruments used in this study are as follows:

- **Pre-test and Post-test.**
  - The first author designed the pre- and post-test questions, which consisted of four questions. The questions used for the post-test were the same as those used for the pre-test. The pre and post-test questions were taken from the recent IGCSE Mathematics (0580) Core syllabus past examination papers which can be obtained from the Cambridge Assessment International Examination (CAIE) website.
  - The questions used in the pre-test and post-test were organized into four categories. Table 1 below shows the categories used in the test papers.

| No | Categories                                      |
|----|------------------------------------------------|
| 1  | Finding information by reading the Distance-Time Graph |
| 2  | Making calculations based on a Distance-Time Graph  |
| 3  |Completing the Distance-Time Graph                |
| 4  |Interpreting the line graph                       |

- **Student Interviews.** To obtain the data required, selected participants for the study were interviewed. The participants were required to answer the questions asked of them, which were recorded using a recording device. The participants were chosen based on the increase from their pre to post-test marks. The interview questions were brief and the research probed the interview
questions based on the students’ responses but at the same time maintaining the content of the interview questions. The interview questions adapted from Perales-Palacios and Vilchez-Gonzales [30]. The interview questions are as follows, and not limited to:

1. Can you tell me whether or not you liked the idea of using comics for learning Distance-Time Graphs, whether you like to read comics and whether you enjoy reading them?
2. Do you believe that by using comics, you can learn better than the traditional way of learning?
3. Do you think comics can improve the way you think?

The ‘What do you remember about Distance-Time Graph?’ question was also directed to the sample. This was to check whether or not the students remembered anything about Distance-Time Graphs when using visual, in this case, comics in teaching.

- **Comics.** Comics were used to teach the students, as this is the intervention method used in this study. A freelance artist was hired to create the comics intended for the research. The storyline in the comics was conceived from discussions between the first author and the freelancer, but the mathematical content came from the first author himself. Refer to Figure 1 for the sampled comic strips. Before conducting the lesson using these comics, four experienced teachers were requested to proofread the content, language and images used in order to ascertain the appropriateness of the content used for students in the upper secondary classes.

![Figure 1. Samples of comic strips used during the intervention lesson.](image)

4. **Results and discussions**

This study aimed to identify whether the use of comics helped the students in terms of their learning of the Distance-Time Graph. Thus, it is based on the data that was collected from the questionnaires and interviews, as well as pre-test and post-test results that marked the students’ perceptions before and after the intervention lesson.

4.1. **The effects of using comics on the students’ performance**

Table 2 shows the pre- and post-tests data that were collected. It revealed that the performance of the pre-test has the mean score of 4. The total score for the test is 20 marks and the passing mark for this test is 10 marks. This shows that the students that participated in this research are in a low ability group for this particular topic. After the intervention, there is an increase of the mean from the pre-test to the post-test, which is an increase from 4 to 10.50. The data shows that this intervention might be effective with lower ability students since the mean for both classes is not that far.
Table 2. Pre-test and post-test marks.

| Class      | Mean | Std. Deviation | Minimum | Maximum |
|------------|------|----------------|---------|---------|
| Pre-test   | 4.00 | 2.181          | 0       | 10      |
| Post-test  | 10.50| 2.658          | 5       | 16      |

By comparing the 2-line graphs in Figure 2, there’s a shift on the post-test line graph to the right compared to the pre-test line graph. This means that the students showed improvements in their post-test score.

![Figure 2](image)

Figure 2. Overall pre- and post-tests for both classes.

The aim of conducting the paired sample t-test was to make a comparison of the mean scores obtained from the pre-test and post-test, this time for the combined two classes (refer to Table 3). Consequently, the null hypothesis was rejected because the p-value was below 0.005. \(p<0.005\). The results, therefore, indicated that using comics to teach Distance-Time Graphs helped improve the performance of students. This conclusion is attributed to the significant differences observed between the scores in the pre-test and post-test.

Table 3. The paired sample test.

| Paired Differences | t   | df | Sig. (2-tailed) |
|--------------------|-----|----|----------------|
| Pre-test – Post-test| -6.632 | 37 | .000 |

4.2. Students’ perceptions on using comics

This study aimed to determine if using comics in the teaching of mathematics is an effective way of ensuring students understand the concepts taught. On average, more students fail in Mathematics than any other subjects that mainly involved calculation, for example Physics. Helping these students understand Mathematics will be beneficial for them in achieving successful grades at school and in
their future educational endeavors. Comics contain images that are colored and this makes Mathematics lessons attractive and interesting, capturing the attention of prospective students. Interviews were used in this present study as the primary source of data that was conducted by the teacher of the class who taught Mathematics through the medium of comics.

Taking into consideration the interviews conducted, the study has led to the conclusion that the use of comics in teaching Mathematics is crucial due mainly to the fact that it makes studying fun and enjoyable. When students are taught using a method, which makes them feel relaxed, enjoyable and entertained, they tend to remember the information. Comics have colors, which affect the emotions of students; hence when comics are used in teaching, they trigger positive emotions that help students learn more effectively. The use of comics and colors made the lesson of Distance-Time Graph more understandable and memorable. It is also vital for teachers to understand the capabilities of their students before choosing teaching techniques. Even if a teacher is teaching the whole class using one teaching technique, he or she should help the students individually. Teachers of Mathematics should also use their discretion when choosing to use comics as a teaching resource or tool, since some lessons do not lend themselves to this medium.

5. Conclusions
According to the paired sample t-test results, considerably significant results were obtained (p=0.000). There is an improvement on the students’ overall post-test marks compared to the pre-test marks, where the line graphs have shown a shift to the right for the post-test marks. For the analyses, the questions and the sub questions for the pre-test and the post-test were classified into four main categories: Finding information by reading the graph (C1), Making calculations based on a Distance-Time Graph (C2), Completing the Distance-Time Graph (C3) and Interpreting the line graph (C4). Upon further comparisons on the questions found in the afore-mentioned categories, results obtained showed that students scored marks from questions in the C1 category. There is also a marked increase in results obtained from questions in the C2 category where most students were able to explain and interpret a given graph.

6. Implications and recommendations
The use of digital comics may prove useful because in this study each page of the comics had to be printed in addition to physically distributing the comics to all the students. This proved to be both tedious and time-consuming, especially in relation to human and physical resources. With this in mind, future researchers could email electronic copies of the comics to the students in advance, for them to read at their leisure at home before moving on to the lesson (by incorporating the flipped classroom [31-34]) or having the students go to the school’s ICT lab.

It is recommended that the class observations be video recorded. The rationale for this is that a researcher cannot entertain and observe every student in the class due to time constraints. Furthermore, some verbal interactions between students during the course of the lesson may help the researcher in terms of supporting the data collected. Hence, the students’ immediate feedback was required, because giving feedback is considered vital in facilitating students to be independent learners in evaluating, monitoring and regulating their own learning [35, 36]. Using video recording, a researcher could also review at leisure on what transpired during the lessons.

This study is aimed more towards the lower ability students in a class of 38 students. It is also recommended that a larger and random sample could be used in order to produce a much wider-reaching comparison encompassing the effects of using comics as a means to interpreting Distance-Time Graphs. Concerning future studies, it is also recommended that further explorations of other topics in Mathematics be conducted, not just focusing on the IGCSE Syllabus. Indeed, it could prove useful to broaden the study to Mathematics Syllabus D and Additional Mathematics subjects.

References
[1] Nelson T, Burton L and Bennett A 2010 Mathematics for Elementary Teachers: A Conceptual
Approach (New York: McGraw-Hill)

[2] Sarwadi H R H and Shahrill M 2014 Understanding students’ mathematical errors and misconceptions: The case of year 11 repeating students Mathematics Education Trends and Research 2014 1

[3] Kani N H A and Shahrill M 2015 Applying the thinking aloud pair problem solving strategy in mathematics lessons Asian Journal of Management Sciences and Education 4 20

[4] 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

[5] Chua G L L, Shahrill M and Tan A 2016 Common misconceptions of algebraic problems: Identifying trends and proposing possible remedial measures Advanced Science Letters 22 1547

[6] Sharma H 2013 Effectiveness of video instructional material in educational psychology for B. Ed. students of Madhya Pradesh Doctoral Dissertation (India: Devi Ahilya Vishwavidhyalaya University)

[7] 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

[8] Abdullah N, Shahrill M, Tan A and Yusof J 2017 Comparing students’ level of conceptual understanding and procedural skills when solving non-routine problems INFORMATION-An International Interdisciplinary Journal 20 7117

[9] Chong M S F et al 2018 Teaching problem solving using non-routine tasks AIP Conference Proceedings 1952 020020

[10] 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

[11] Shahrill M, Putri R I I, Zulkardi and Prahmana R C I 2018 Processes involved in solving mathematical problems. AIP Conference Proceedings 1952 020019

[12] Simpol N S H, Shahrill M, Li H-C and Prahmana R C I 2018 Implementing thinking aloud pair and Pólya problem solving strategies in fractions Journal of Physics: Conference Series 943 012013

[13] Halim N L A, Li H-C, Shahrill M and Prahmana R C I 2018 Teaching strategies in the learning of highest common factor and lowest common multiple Journal of Physics: Conference Series 943 012041

[14] Bell D V 2016 Twenty-first century education: Transformative education for sustainability and responsible citizenship Journal of Teacher Education for Sustainability 18 48

[15] Rotherham A and Willingham D 2010 “21st-Century” skills: Not new, but a worthy challenge American Educator 34 17

[16] Silva E 2009 Measuring skills for 21st-century learning Phi Delta Kappan 90 630

[17] McVicker C J 2007 Comic strips as a text structure for learning to read The Reading Teacher 61 85

[18] Matussin H S H H, Abdullah N A and Shahrill M 2015 Integrating ICT and learning study in teaching conversion of travel graphs International Journal of Innovation in Science and Mathematics Education 23 25

[19] van Garderen D, Scheurmann A, Poch A and Murray M M 2018 Visual representation in mathematics: Special Education teachers’ knowledge and emphasis for instruction Teacher Education and Special Education 41 7

[20] Yusoff Z, Katmon S A, Ahmad M N and Miswan S H M 2013 Visual representation: Enhancing students’ learning engagement through knowledge visualization Paper presented at the International Conference on Informatics and Creative Multimedia

[21] Bobek E and Tversky B 2016 Creating visual explanations improves learning Cognitive Research: Principles and Implications 1 27

[22] Cleveland W S and McGill R 1985 Graphical perception and graphical methods for analyzing
scientific data Science 229 828

[23] Peterson L V and Schramm W 1954 How accurately are different kinds of graphs read? Educational Technology Research and Development 2 178

[24] Padilla M J, McKenzie D L and Shaw E L 1986 An examination of the line graphing ability of students in grades seven through twelve School Science and Mathematics 86 20

[25] 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 1

[26] Riegle-Crumb C and Humphries M 2012 Exploring bias in math teachers’ perceptions of students’ ability by gender and race/ethnicity Gender & Society 26 290

[27] Battey D 2013 “Good” mathematics teaching for students of color and those in poverty: The importance of relational interactions within instruction Educational Studies in Mathematics 82 125

[28] Furner J M and Worrell N L 2017 The importance of using manipulatives in teaching math today Transformations 3 2

[29] Lobato J, Hohensee C and Rh odehamel B 2013 Students’ mathematical noticing Journal for Research in Mathematics Education 44 809

[30] Perales- Palacios F J and Vílchez- González J M 2002 Teaching physics by means of cartoons: A qualitative study in secondary education International Journal of Science Education 27 1647

[31] Nawi N et al 2015 To flip or not to flip: The challenges and benefits of using flipped classroom in geography lessons in Brunei Darussalam Review of European Studies 7 133

[32] Manjanai S N N P and Shahrill M 2016 Introducing the flipped classroom strategy in the learning of year nine factorization International Journal of Interdisciplinary Educational Studies 11 35

[33] Latif S W A et al 2017 Implementing the flipped classroom model in the teaching of history Journal of Education and Learning 11 373

[34] Toh T S et al 2017 The Flipped Classroom Strategy: The Effects of Implementation at the Elementary School Level Mathematics Lessons ed S De Silva Proceedings of the 3rd International Conference on Education (Sri Lanka: The International Institute of Knowledge Management) pp 186-97

[35] Ferguson P 2011 Student perceptions of quality feedback in teacher education Assessment & Evaluation in Higher Education 36 51

[36] Al-Bashir M, Kabir R and Rahman I 2016 The value and effectiveness of feedback in improving students’ learning and professionalizing teaching in higher education Journal of Education and Practice 7 38