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Title	Principles in using comics for mathematics classroom instruction
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## **Principles in Using Comics for Mathematics Classroom Instruction**

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### **Abstract.**

Mathematics has always been a difficult subject for many students. Consequently, many students fear the subject and refuse to engage in this subject. There are many educational theories which attempt to address students' motivational and cognitive issues in learning mathematics. In this lecture, I attempt to propose an alternative approach of teaching mathematics through the use of comics based on my experience of infusing comics into the teaching of mathematics for the low progress learners. I further present a framework of infusing comics for mathematics instructions, and take reference from not only educational theories but also from the perspective of communication theory. In designing lessons using comics, I make reference to how the various elements of the communication model are taken into consideration in the design process. I illustrate the application of this framework with the use of exemplars, making reference from both primary and secondary levels. With the advent of Generative Artificial Intelligence, what appears to be a rather expensive process of developing comics package could potentially become relatively inexpensive, so that educators and designers could invest more time in conceptualizing the content of the comics package. Thus, the theoretical framework for the design process deserves greater attention to researchers and educators.

### **Keywords.**

Comics for mathematics instruction; problem solving; communication theory.

### **Introduction**

The use of comics for mathematics classroom instruction (more generally, classroom instruction for any subject) has not received much attention only until decades ago. In fact, researchers have commented that comics were seen as “enemies” of schools most frequently (Cleaver, 2008; Toh et al., 2017). However, there are some educators who appeared to be convinced of the power of comics in education. For example, some researchers asserted that comics can improve academic literacy among students (Tilley, 2008) and also heighten students' interest and foster their

engagement in mathematics (Cho, 2012). There appears to exist several comics books which teach the entire undergraduate mathematics courses such as Differential Equations and Engineering Mathematics in Korean language. There also appears to have numerous research articles in Japanese language on the impact of comics on student learning. In the years 2008 and 2014, I have also been engaged in writing a series of mathematics textbooks for the low progress learners by infusing comics into the school textbooks. All these perhaps point to the shift in belief on the role of comics in school education.

The visuals and the invariant use of humor in comics are likely to be the two main features of comics that could have attributed to their usefulness for classroom instruction (Kaplan & Pascoe, 1977; McVicker, 2007). The students are likely to be attracted to the cartoons and hence to the text associated with the comics, hence leading them to have a deeper understanding of the content conveyed by the comics (e.g., Toh, 2009). Further, empirical studies have shown that the use of humor could improve students' information processing (e.g., Kaplan & Pascoe, 1977).

### **Comics for Mathematics Instruction**

A survey was conducted on a group of mathematics teachers in Singapore who taught the low progress learners (Toh & Lui, 2014). The survey result showed that the teachers of the low progress learners, in addition to using the standard mathematics manipulative to engage their learners, had started to develop their own comics for their mathematics lessons. However, there appeared to be a lack of concerted effort among the teachers in developing comics for their classroom instruction. Perhaps more importantly, they lacked a theoretical framework for their comics design and a large part on the use of comics appeared to be rather serendipitous. This in fact motivated me to begin a research project to design and study the impact of comics on student learning.

#### **Designing comics package**

Selected topics from the mathematics syllabuses from the lower secondary were used for our intervention using comics for classroom instruction. The first selected topic was Percentage from the secondary one topic. The comics instructional package was meant as an alternative teaching package to replace the existing curriculum material. This meant that the comics package would need to be complete with all the curriculum content, the essential learning experience and the practice questions, such that students would not need the usual instructional material for learning the topic on Percentage. This is our design to study the efficacy of comics on students' learning of mathematics.

The design of the package also took into account of active participation by the schools. In addition to the typical practice questions, much effort was also used in the design to reinforce student learning (Figure 1). Despite our intention for the low progress learners, it turned out that the creative thinking questions belong to the realm of higher order thinking skills.

Figure 1.

Sample of higher order thinking questions and their use.

**Activity 1.**

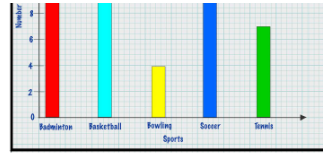
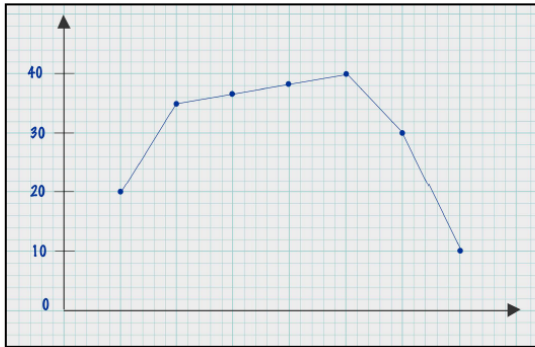
- 1) Conduct a survey on average number of hours of sleep of your classmates.
- 2) Chart your data on a pictogram.
- 3) Write two questions you can answer from your pictogram.

**Activity 2.**

- 1) Find out the number of rainy days in 4 weeks
- 2) Chart your data on a pictogram.
- 3) Write two questions you can answer from your pictogram.

**Question 4 Part B.**

Now tell a story based on the following line graph. Remember to label the horizontal axis and the vertical axis.



(D) Which is the least popular sport?

Answer: \_\_\_\_\_

(E) What percentage of the employees play soccer? Correct your answer to 1 decimal place.

Answer: \_\_\_\_\_

(F) \_\_\_\_\_ more employees play badminton than tennis.

(G) \_\_\_\_\_

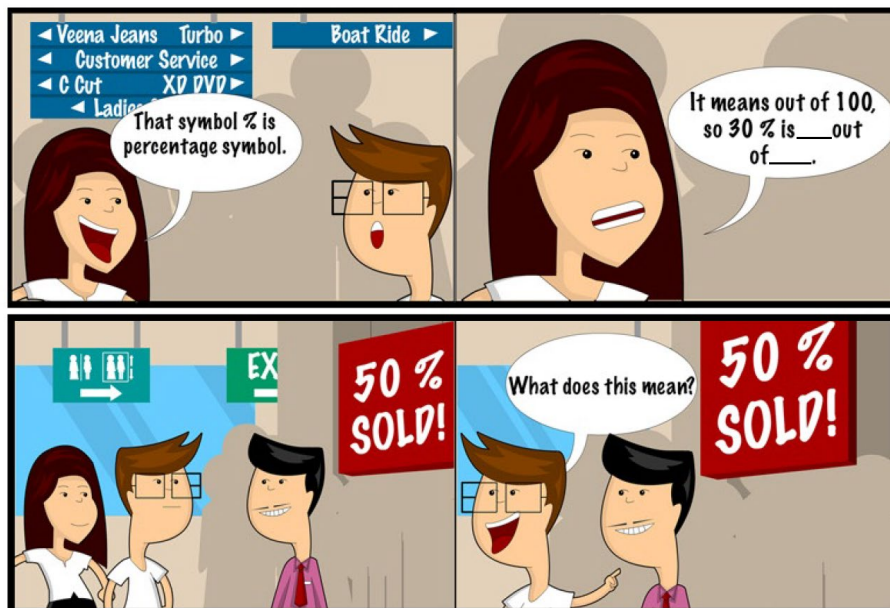
Answer: Basketball

In designing the comics package on Percentage, we selected the context of a shopping spree to elicit all the related concepts related to percentage. This was to align to the bestselling novel at that time *Shopaholics* which broke the movie record office then (Toh et al., 2019). Through a shopping experience of two fictitious characters, all the concepts on Percentage are brought forward for discussion. A sample of the comic strip is shown in Figure 2.

The process of contextualizing mathematics is important for learning the subject. This is especially so for the low progress learners and younger children. This facilitates the learners to link the new mathematical content knowledge to their real-life learning experience (Tinajero et al., 2019). Such an approach indeed has a long history found in the use of children’s literature.

As mentioned earlier, we not only focus on the content of coverage in our design of the package; we also took into account students’ learning experiences by providing them an opportunity to engage in non-traditional assessment-type of items, e.g., classroom hands-on activity (Figure 2).

Figure 2. Sample of a comic strip discussing the meaning of the percentage symbol



In our study of enacting lessons using our comics teaching package, it was found to our pleasant surprise that teachers do not merely use the package passively. Indeed, teachers creatively adapted our comics teaching package and incorporated various activities such as role-play, storytelling and data collection activities among the students (Toh et al., 2018). Indeed, the context of the comics package inspired the teachers to go beyond the mathematics curriculum by inviting students in developing their 21<sup>st</sup> century competency skills (Toh et al., 2017).

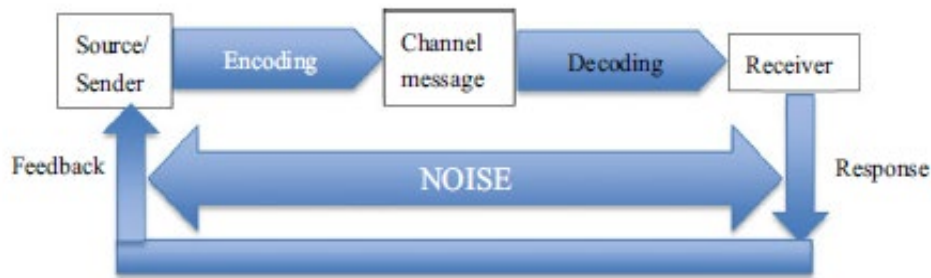
### Contextualization of mathematics

The stress to contextualize mathematics could likely be traced back to as early as 1982 in the Cockcroft Report on the rising worry that adults might not be able to apply the mathematics they had learned at school in real-world contexts (Boaler, 1993). Thus, it is not surprising that eventually, educators advocated the importance of contextualizing mathematics. Naturally, the affordance of comics as an avenue to contextualize mathematics is utilized for educational objectives. The advantage of contextualizing mathematics is not so much as to explicitly emphasizing the relevance of mathematics in the real world, but is an indirect way of highlighting mathematics in the real world, usually through a more lighthearted way of demonstrating rather than hard-selling.

## Comics for Mathematics Instruction – Using the Lens of the Communication Theory

In this section I propose a set of principles for designing comics-based mathematics lessons using the perspective of a communication model. We first present a model of (mass) communication.

Figure 3. *A Communication Model*



We can see an analogy between mathematics instruction and communication. The message that is to be communicated could be likened to the mathematics content that teachers are teaching in their classrooms.

- **Source / Sender.** Drawing an analogy with the communication model, the source/sender could be likened to the teacher and the content in the syllabus that is to be delivered to the students.
- **Encoding.** The teacher in the classroom attempts to present the “message” in a form that is relatable to the students. This involves much skilful means of the teachers in designing the content for lesson delivery, based on their knowledge of the content and their students, in short, their pedagogical content knowledge. In particular, contextualizing mathematics using real-world situation is perhaps one approach used in comics instruction in the mathematics classrooms.
- **Channel message.** Mathematics content typically is presented in the format of “Definition → Theorem → Worked Example” in an accepted mathematics discourse. This might not be an approach that the general student population could accept. Educators are considering other approaches, such as using humors or real-world context to introduce a concept. As an illustration, a local textbook starts the topic on probability by using a thinking question based on a short comic strip (Figure 4). This not only brings out the relevance of probability as a concept in real world, but provides an opportunity for students to re-think the definition of probability in relation to equally likely event, using their real world experience.

Figure 4. *A Comic strip on an Event at a Casino Illustrating an Abuse of Probability Concept*



- Decoding.** This is the process that students make sense of the “message” that is conveyed through the content of the message. In the case of using comics for mathematics instruction, it is instructional that teachers ensure that the “message” that is to be conveyed is the mathematics content and the comics is the vehicle of delivering the content, that is, the channel of communication. To facilitate students to make sense of the content delivered, teachers could provide the essential scaffolding.
- Response.** The receiver should not only have understood the message conveyed, but also responds to the message. This in turn provides feedback to the sender. In the classroom instructional setting, this refers to the students understanding the message conveyed, develop positive emotion towards the message and take further actions. In the context of problem solving, this would mean that the students generalizing what they have learnt, creating new knowledge based on what they have acquired, with teachers making judgement how further to enhance students’ learning.
- Noise.** In this entire process of “communication”, the reduction of “noise” is equally important to ensure the success of the entire process. Noise in this case prevents the intended message from reaching the receiver in the correct form. The reduction of noise would also mean that the learners are directed to the content of the message rather than the channel that conveys the message, i.e., on the mathematics rather than on the vehicle conveying the mathematics content. As discussed above, the environment about which learning takes place could itself be an obstacle for students acquiring the knowledge.

## **From the communication model to designing comics-infused lesson**

Several studies have independently evolved on the use of comics for mathematics classroom instruction within the Singapore mathematics education setting (Cher & Toh, 2022; Chu & Toh, 2020; Han & Toh, 2019). Through conducting a systematic literature review and collective classroom experience of the authors, principles of designing comics lessons were articulated. These principles also align to the models of communication presented above. We provide the list of principles below.

Rather than teaching through the formal approach of definitions followed by worked examples, storytelling provides a less rigid approach to convey the same mathematical “message” across to students. This is similar to the use of children’s literature to teach mathematics, which has shown to have positive impact on children’s cognitive and affective growth (e.g., Caparo & Caparo, 2006; Edelman et al., 2019). Comics provides the affordance of storytelling as a channel of communication. Using this channel, the designers of comics generally will take note of the context of the comics to ensure its relevance to the students (Goldstone & Son, 2005; Han & Toh, 2019). The comics must be relatable to the students.

**Context is age dependent.** Generally, students want to feel empowered, and this appears to be the reason that younger children are attracted to superheroes (Sousa & Schneiderman, 1986). On the other hand, older students are generally more attracted to real world context that is relevant to their day-to-day life. Thus, the choice of the context of comics is an important factor for one to take into consideration in designing comics-based mathematics lessons. Thus, in Toh et al. (2019), we use the entire episode of a shopping spree to bring out the mathematics concepts of percentage for secondary school students (age 13 to 14); but in Cheng et al. (2020), the story background involving superheroes was used to teach fractions to primary school students (age 10 to 12).

**Texts and languages used in the comics.** The choice of texts and languages used in comics is important to ensure the success of communication. One reason that children prefer reading comics over textbooks is that comic books do not contain lengthy sentences and paragraphs. In fact, texts used in comics are usually succinct and usually in the form of dialogues between the characters of the comics (Keogh & Naylor, 1999). Interpreted in this way, a typical exposition in mathematics comics book should contain mainly dialogues between the fictitious characters and, in this way, all mathematical concepts are explicated.

If necessary, we suggest that the use of colloquial language could be an approach in designing the dialogues of the comics package, although this idea might be frowned upon by some researchers and educators. It should be noted that the use of colloquial language could lead the learners to pay more attention to the dialogues (hence the exposition) since discussion using the learners’ own jargons is likely to have greater values as a social cue (Clark & Mayer, 2011).

Building on the use of comics, bringing out “visual disagreements” reflecting students’ misconceptions to create cognitive conflict is one important strategy in developing comics instructional package (Naylor & Keogh, 2013). The students, being attracted to the comics, are likely to attempt to resolve this cognitive conflict.

**Graphics of the comics.** Researchers have shown that appropriate use of colors has the ability to improve memory retention (e.g., Pan, 2010; Spence, et al., 2006). The designed comics should be reasonably colorful. It appears that students are more motivated to learn in lessons with colored comics (Shahrill, et al., 2022).

However, Shahrill et al. (2022) also cautioned that the use of colors should not be excessive, as this could become the “noise” in the communication process and serve as a distraction from the main message instead. As a general rule of thumb, Faiola and DeBloois (1988) suggested that the total number of distinct colors should not exceed six, as the eyes can generally keep track of not more than six colors at one glance.

**Interaction.** The comics instructional package should also not only include the comics for reading; it could further include opportunities for students to engage in the comics. In a communication process, not only the sender successfully conveys the message to the receiver, the latter also has an opportunity to respond to the comics, which in turn becomes the feedback for the sender (Figure 3). This feedback in particular is crucial in the education context. In response to this, Toh et al. (2018) proposes that the dialogues in the comics could also serve as a cloze passage for students to complete the mathematical content (See Figure 2 for an example). The comics should also suggest further activities to engage the students with activities with the similar theme as the comics (Figure 1). It was observed by Toh et al. (2018) that in using comics for classroom instruction, teachers are actively engaging their students with activities related to the themes of the comics. Thus, such opportunities should also be proposed by the comics designer.

## Conclusion

We have discussed the potential of the use of comics for mathematics classroom instruction, and provided some principles of designing comics-based mathematics lessons using the perspective of mass communication. In our last note, I would like to mention that this paper only provides the tip of an iceberg; the full potential of comics for classroom instruction has not been fully covered. With school-going children generally attracted by comics, it is not an over-statement that comics can be used to address questions of the futures in the schools – issues such as sustainability of the earth’s resource (Toh et al., 2023). More of discussion on the power of comics will appear sometime in the future.

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