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Use of animation to facilitate students in acquiring problem-solving: From Theory to Practice

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Use of animation to facilitate students in acquiring problem-solving: From Theory to Practice

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Abstract: In this article the use of animations is explored to facilitate students acquiring of problem-solving. The goal is to spur interest in educators for further research on the use of animated videos, which combine contextualised stories, animated worked examples and practice questions on an interactive platform to teach learners mathematics concepts and problem solving skills.

Keywords: Animation; Problem solving; Mathematics Education

1 INTRODUCTION

The difficulties with learning mathematics among students, especially the low attaining students, can be classified under broad categories: (1) cognitive and (2) affective reason (Toh and Lui, 2014). Under cognitive reason, many students fail to understand the problem (Gunbas, 2015), or are unable to devise a plan to solve the problem (Rahman & Ahmar, 2016), not to mention the actual solving of the problem itself, and looking back at the whole process of solving the problem. In other words, all the four stages of problem solving of Polya (1945) pose learning difficulties to many students. Furthermore, many students have difficulty visualising the mathematics problem. Under affective factor, the context of the typical mathematics problems used in school textbooks fails to arouse the interest of learners (Walkington, Sherman & Petrosino, 2012).

Under affective reasons, many students found mathematics boring and fail to see the relevance of the subject in the real world. As a result, they are not interested or unwilling to put in much effort in learning the subject.

Research has also shown that learners are generally drawn to learning from animated videos because of their cosmetic appeal (for example, Phan, 2011) and their ability to facilitate learners visualise mathematics concepts (Scheiter, Gerjets & Schuh, 2010).

This paper discusses the use of animated videos in helping students learn mathematical problem-solving. We will do this through discussing the theoretical foundation for this seemingly "radical" approach, and demonstrating our development of one animated video targeted to teach one specific lower secondary mathematics concept (percentage). The detail of the animated video can be located in the URL found in Annex A.

Our animated video (Annex A) is targeted to help students contextualize mathematical problems through stories, and, building on this understanding, facilitate students learn problem solving through clearly explained worked examples. Finally, the animated video

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reinforces these newly formed schema through similar practice questions, which students will be encouraged to practice with minimal scaffolding. In short, the goal of this animated video is to entice learners to mathematics problem solving, develop problem-solving skills and to use "specific context to teach transfer skills to novel situations" (Kapa, 2007). We believe that students will develop an interest and will be eased in learning mathematics problem solving. In short, the animated video aims to address both the cognitive and affective aspects of learners in mathematics problem solving.

2 LITERATURE REVIEW

2.1 COMPUTER ASSISTED INSTRUCTION (CAI)

Animated videos created for learners to learn concepts or skills are a form of Computer-Assisted Instruction (CAI). CAI is a medium of instruction where instructional materials are presented using an information-technology device like a computer. CAI is useful in teaching learners, especially those who learn at a relatively slower pace. It helps reduce the cognitive load (Gunbas, 2015) of learning a new concept or skill by allowing learners to solve the problem one step at a time (Chang, Sun & Lin, 2006). Furthermore, CAI allows learners to learn at their own pace without pressure from their peers and other people (Arslan, 2003, cited in Gunbas, 2015).

CAI has been shown to be more effective than traditional instruction (Camnalbur & Erdogan, 2008; Yesilyurt, 2010). For instance, in a study conducted by Soliman & Hilal (2016), they found that CAI increased learners' mathematics comprehension and application skills. Moreover, learners in that study also developed a positive attitude towards the learning of mathematics. Another study conducted by Chang, Lin and Sung (2006) (cited by Huang, Liu, Chang, 2012) demonstrated that CAI helps learners visualise abstract mathematical ideas via representations, scaffolding in terms of questions to guide learner thinking, helping learners assess their own solutions, and other forms of help while learners attempt to solve the problem, thus improving problem-solving abilities of lower attaining learners.

2.2 CONTEXTUALISATION, WORKED EXAMPLE AND PRACTICE

In existing education literature, the use of animated videos that combine stories, worked examples, and extension practice questions have hardly been mentioned in the teaching of mathematics problem solving.

Employing meaningful contexts to help learners in problem solving has been shown to positively influence learners' problem-solving process (Goldstone & Son, 2005). The use of contextualization in problem-solving serves as a source of motivation for learners engaged in the problem-solving process. It also increases a learner's ability to transfer their skills to novel situations (Gunbas, 2015). As such, studies have suggested using stories that learners can identify with, to help them learn problem-solving skills. For instance, Gunbas's (2015) study advocated the use of stories to aid learners in the comprehension of problems because stories have the power to make the context of problems more meaningful to learners. This facilitates the activation of real-world knowledge, which helps learners devise the correct solution (Inoue, 2008). Other studies also showed that learners' comprehension of problems improved when computer-based stories included elements like narration and animation (Grimshaw, Dungworth, McKnight & Morris 2007; Pearman, 2008).

Besides stories, worked examples have also been shown to contribute positively to learners' problem-solving abilities. Worked examples present learners with full worked solutions and explanations. Hence, they are considered a highly guided form of instruction (McLaren, Gog, Ganoe, Karabinos & Yaron, 2016). Learning problem-solving skills through worked examples is more effective than practicing questions without any assistance (Rourke & Sweller, 2009). By the *Worked-example Effect* (Sweller, 1988), it has been shown that learning from worked examples reduces cognitive load by focusing learner attention on analysing the right way of solving the problem. This facilitates the learners in building of meaningful cognitive schema, which can be transferred to novel problems (McLaren, Gog, Ganoe, Karabinos & Yaron, 2016).

To further reinforce this cognitive schema, studies advocate that learners practice similar problems without any guidance (for example, Lin & Singh, 2013). This extra practice enriches the schema and helps learners integrate the newly learned information within the existing information, thereby further reinforcing learning, resulting in greater transfer learning (Wouters, Paas & Merriënboer, 2008).

3 DEVELOPING AN ANIMATED MOVIE FOR A LOWER SECONDARY TOPIC: THEORETICAL PRINCIPLES AND THEORY TO DESIGN

We produced an animated video for teaching one important concept of a lower secondary mathematics topic Percentage – that of combining two percentages. This concept on the combination of two percentages is generally counter-intuitive to many students, especially the low attaining students. Two key features about our animated video and their rationale are discussed in the two subsections below.

3.1 KEY FEATURES OF THE ANIMATED VIDEO

This section discusses the key features that we took into consideration in developing our animated video. To begin with, we used a story to serve as a form of conceptual instruction. Conceptual instruction refers to the instruction of principles focused on a domain (Hiebert & Lefevre, 1986). Conceptual instruction is known to help learners be familiar with the concepts that need to be applied in the problem, to help them reduce the difficulty of problem-solving. It is thus reasonable that we placed story before the worked example segment of the animated video. We also believe that it is disadvantageous to proceed directly to procedural instructions without contextualizing the mathematics or setting the scene for the mathematics, because this would encourage rote learning of the solution steps and could even kill the students' interest in the topic. The placement of the story before worked examples and procedural instruction facilitates the acquisition of transfer skills. Studies have also shown that this approach will lead to learners generating more accurate solution steps in their subsequent solving of the problems. (Fyfe, DeCaro & Rittle-Johnson, 2014).

In addition, the story that we constructed involves a real world scenario to contextualize the abstract mathematical problem into the situation that teenage students can easily associate (we used the setting of a boy "buying roses during Valentine's Day"). We use this setting as a bridge between real life and the learning points brought across in the story, so that students can engage in *Elaborative Rehearsal* (Craik & Lockhart, 1972) and process the information at a deeper level by associating them with real life scenarios (Goldstein, 2011).

A common misconception students encounter in combining two percentages is the addition of two percentages without considering the change of the base, and perform procedurally the addition of the two percentages (Lee, 2006). The story that we crafted builds on this misconception. In developing this animated video for learning, we provided a seamless scaffold to guide students from specific to general in handling mathematical problem situations. In the first part of the video, we provided actual numerical values for all quantities to facilitate students to develop their understanding. In a gradual stage, the scaffolds are reduced; eventually we invite the students to solve the related mathematics problems after watching the hilarious video clip. At this stage, no numerical values are given. This made the problem more challenging as compared to a typical mathematics problem with given numerical values (Kibbe & Feigenson, 2017). The story and its setting in the animated video serve to address this potential difficulty faced by students in “mathematical problems” discussing generic principle but without given numerical values.

The animated video begins with the scene of a boy buying roses during Valentine’s Day. The underlying problem involves the concept of combining two percentages (two consecutive discounts). To begin with, all numerical values of the price of roses and the discounts are given (Figure 1).

Figure 1. *The first setting of the animated video (with all numerical quantities given)*

We used colloquial language (or Singlish, in the Singapore context) in designing the entire animated video. An example of a screenshot on the use of Singlish (characterized by the absence of subject or object, and the use of “lah” as examples) is shown in Figure 2. We did this in order to make the story relatable to the students because it is easier for them to identify with such narratives. Moreover, the use of colloquial language triggers students to pay more attention to the dialogues because a character that speaks in their jargon has more value as a social cue (Clark & Mayer, 2011).

Figure 2. *A screen shot of the animated video in which colloquial English is used*

In developing the animated video, we used humour to increase its entertainment factor (Figure 3). Studies have shown that incorporating humour in a lesson that is taught using an Information Communications Technology (ICT) tool has a positive impact on learners' attitude towards the lesson. This is because the use of humour provides a cognitive break for learners to absorb the information presented (Garner, 2006). In this way, learners are more likely to be motivated to learn (Panaoura, 2012).

Figure 3. *Use of humour as seen in the comment made by one of the characters*

4 WORKED EXAMPLE WITH THE AID OF ANIMATION

We created a smooth transition between the story and the problem to be discussed by (1) lifting the mathematical concept from the context of the previous story (combining of two percentages in a discount situation) in the animated video; and (2) posing another related mathematical concept that is similar to the context of the story (combining of two percentages in two-step increase situation). This enables the students to tap on the conceptual knowledge delivered via the story to guide them in the problem solving (Figure 4).

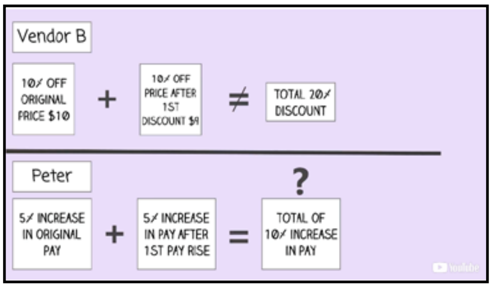

Figure 4. *Elicitinc … iew problem*

Learners are presented with the worked solution immediately instead of allowing them to attempt the problem first without any guidance. Van Gog, Kester & Paas (2011) explained that presenting learners first with worked solution would reduce intrinsic cognitive load on learners, thereby reducing the working memory load. Working memory, which is responsible for capturing information to be processed, has limited capacity (Miller, 1956).

The worked example is explained using animation (Figures 5 and 6). Animations can depict changes in information in the animated video (Lowe, 2003, cited by Wouters, Paas & Merrienboer, 2008). Therefore, animation is a form of dynamic visualisation that can break down the solution steps into more understandable pieces, so learners can visualise the changes in each successive step, acquiring a more robust understanding of the worked solution (Wouters, Paas & Merrienboer, 2008).

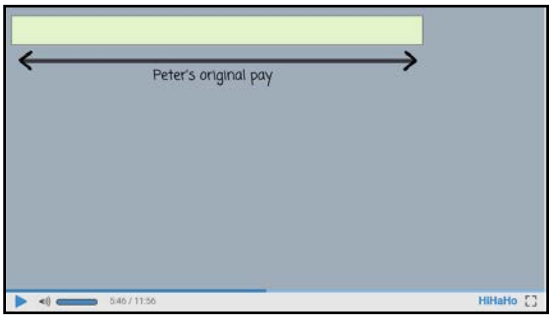

Figure 5. *This screen shows only the original pay using a model*

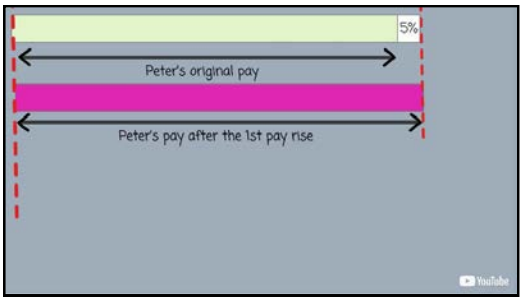

Figure 6. *This screen follows immediately after that in Figure 5, showing the change in the model after the first pay rise via animation*

This animation is accompanied by narration so that two types of internal representation - verbal and pictorial – are used to enhance learning (Scheiter, Gerjets & Schuh, 2010).

The animated video also employs the use of fading and intuitive reasoning to guide learners in the understanding of the worked solution. When the problem is first explained, learners are given an intuitive reasoning as to how to solve the problem (Figure 7). This facilitates the development of intuitive and informal reasoning in the students, as it is well-known fact that informal reasoning is more relatable than the formal reasoning, and thus easier for learners to understand. The worked example that we created capitalizes on this informal reasoning and develops a more formal reasoning. This helps generate a deeper understanding of the formal solution procedure (Hodges, Johnson, & Roy, 2017).

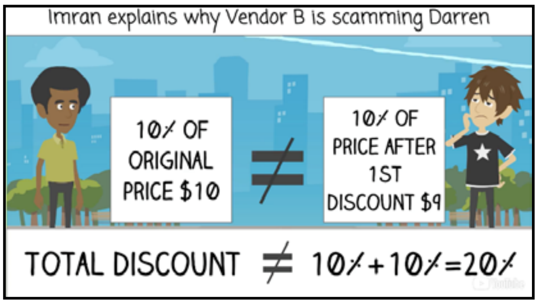

Figure 7. *Develop the intuition in learners that because the base prices are different, one cannot simply add up the discounts*

In order to develop formal reasoning, we make the problem (see Annex B) less abstract by giving Peter's starting salary an actual numerical figure. We further demonstrate how the problem should be solved via a worked example. This worked example builds on the intuitive reasoning earlier developed in learners to demonstrate a formal reasoning and hence presentation of the solution of the altered problem. Another reason for employing fading is that learners also exhibit greater transfer skills when concrete examples are explained before abstract examples (McNeil & Fyfe, 2012). Subsequently, we proceed to the actual problem where Peter's concrete starting salary is an unknown. Here, because learners already have knowledge of how to present the solution when the starting salary is a concrete figure, we will replace the salary given by an actual numerical value with an unknown "X", and then demonstrate the relevant calculations to obtain the final answer.

One way to increase self-regulation is for learners to ask themselves a series of questions while solving a problem. Before attempting the problem, learners can ask themselves what prior concepts are needed to devise a plan (Panaoura, 2012).

As we are targeting low attaining students in mathematics, who usually have a low level of prior knowledge regarding the problem and the solution procedures, the video provides questions with answers to the series of self-regulating questions described above. This helps guide learners to understand the solution procedure in the worked example. Furthermore, research shows that when learners are left to understand a worked example alone, they engage in very superficial self-explanation of the solution (see for example, Atkinson & Renkl, 2007). Hence, these comments force learners to think about the solution steps, encouraging deeper processing of the content, thus increasing germane cognitive load (Figure 8).

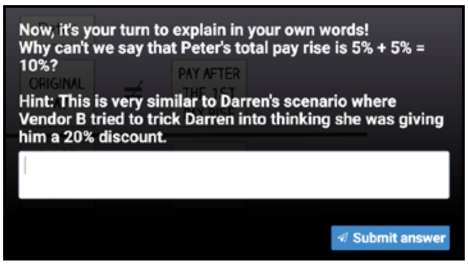

Figure 8. Questions that encourage deeper level of processing in learners

5 EXTENSION QUESTIONS

Besides facilitating the transfer of knowledge to novel situations as mentioned in the literature review, practice questions after the worked example is also beneficial in several ways. Merely studying a worked example in itself is a form of passive learning. Although learners are given pop-up comments on the rationale of each step to force them to process the information in a more in-depth manner, worked examples lack the hands-on activity to practice what they have just learnt (Wouters, Paas & Merriënboer, 2010). Thus we included two extension questions.

We provide self-explanation prompts as a form of hints to help scaffold the solution procedure (Figure 9). These hints are a guide to lead learners to actively think about the knowledge they have acquired to help them overcome the mental blockage (Panaoura, 2012).

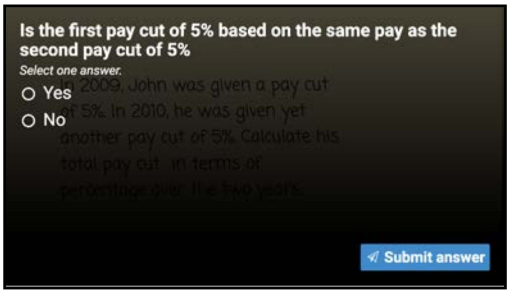

Figure 9. *Self-expl* *ld the solution procedure*

In order to boost students' confidence, the first practice question is contextually and structurally similar to the worked example to ensure learners are able to attempt the question successfully. This could further motivate students to have a genuine interest in mathematical problem solving. In order to ensure that the first question achieves this effect, we incorporate a passive pause with a motivational pop up after the question has been attempted (Figure 10).

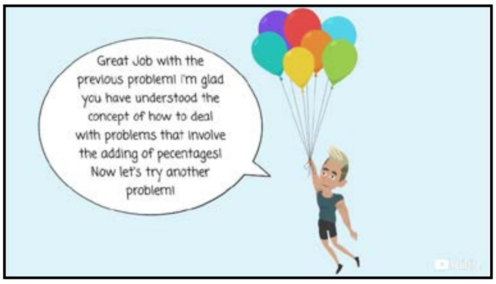

Figure 10. *Example of a passive pause with specific encouragements*

The second practice question is of a different context from the worked example in the previous segment. This helps learners think more deeply into the concepts learnt, thus enhancing the skill to transfer the mathematical skills to a different context.

It is also important to pitch this question at a suitable difficulty level because a question that is too challenging will cause learners to lose their confidence in mathematics problem solving, attributing failure to their supposed lack of ability (Weiner, 1985). A different context for the mathematics problem would likely be more challenging for the students. Thus, more self-explanation prompts are given to learners to provide greater scaffolding and guidance to learners so they are able to solve the problem.

Finally, to end the animated video, a summary of the concepts learnt in the animated video is presented in the form of a mind map (Figure 11). Mind maps are a form of graphic organizers that transform words into a series of graphics, giving learners a good visual and mental consolidation of what they have learnt (Merchie & Keer, 2016). With a more in-depth understanding, and a more comprehensive mental representation of the knowledge gained, learners are more able to transfer this knowledge to solve novel problems (Safar, Jafer & Alqadiri, 2014).

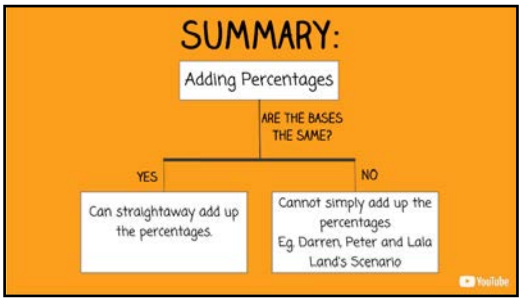

Figure 11. *Mind map to summarise the concepts learnt*

6 CONCLUSION

This paper describes the development of an animated video package to teach lower attaining students acquire problem-solving skills using the context of percentage. At the time that this paper is written, we have yet to evaluate learners' response towards the video and the video's impact on students' learning. The authors will pilot this animated video in Singapore schools.

We hope that this paper could spur interest in educators for further research on the use of animated videos, which combine contextualised stories, animated worked examples and practice questions on an interactive platform to teach learners mathematics concepts and problem solving skills.

APPENDIX

Annex A: https://goo.gl/aRV53Z
Annex B: In 2009, Peter was given a pay rise of 5% and in 2010, he was also given a pay rise of 5%. Is his total pay rise 10% over the two years? Justify your answer." (adapted from http://math.nie.edu.sg/mprose)

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