Strategic Use of Content-Specific and Content-Neutral Technologies to Cater Learning Diversity in Mathematics

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Abstract: We used a 2 (prior knowledge: less vs stronger) x 2 (order: content-specific -learning object- first vs content-neutral -mind map- first) between subjects factorial design to investigate how the two factors affects classroom discussions. The results showed that the advanced students benefited from learning with mind map first while the novice preferred the learning object first. We suggest taking prior knowledge and content-level dependency into account when designing technology enhanced mathematics curriculum.

Keywords: Expertise Reversal effect, learner expertise, technology, motivation, mathematics

Introduction

Literature suggests that technology is essential in teaching and learning mathematics (Chiu, 2017; Chiu & Churchill, 2015; Chiu & Mok, 2017, NCTM, 2015); it influences mathematics curriculum (NCTM, 2015). School curriculum leaders in our community have experienced difficulty in designing technology enhanced teaching to cater the diverse learning needs of students in Mathematics lessons. Students with different prior knowledge levels respond differently to a technology, (see individual difference principle in Mayer, 2009 and Kalyugas' Expertise Reversal Effect, 2007), particularly in content-level dependency (Chiu & Churchill, 2015; Chiu & Mok, 2017; NTCM, 2015). Hence, this study aims to investigate how learner prior knowledge levels and the order of using content-specific (e.g. Geogebra, learning objects, and modeling application) and content-neutral (e.g. mind map and discussion forum) technologies affect classroom discussions in Mathematics lessons.

Literature review

Literature shows that individual difference includes learner expertise affects mathematics learning with technology (Chiu & Mok, 2017; Kalyuga et al., 2012; Ng & Chiu, 2017). This idea was supported by one of the popular cognitive learning theories on learner expertise – Expertise Reversal Effect (Kalyuga, 2007). This effect suggests instructional designs that were beneficial for novice learners may be useless or harmful for advanced learner during learning. This theory was supported by many empirical studies have showed that technologies for mathematics teaching which benefits less knowledgeable learners will complicate more knowledgeable learners to develop problem solving skills (Chiu & Mok, 2017; Rey & Fischer, 2013; Spanjers et al., 2011). It could be due to heavier cognitive load when developing problem solving skills. Therefore, learner expertise could determine the effectiveness of technology, particularly how much content was included or presented, on mathematics learning. Literature further suggests using content-specific and content-neutral approaches to technology integration in teaching content-based curricula in schools (NCTM, 2015). Content-specific technology technologies promote prompting and meaningful subject knowledge and content-neutral technologies, that include communication and collaboration tools and Web-based digital media, are more open-ended and promote inquiry environment (NCTM, 2015). In final, how learner expertise and content-level dependency affect mathematics learning remains unclear or understudied, which echoes the needs of our curriculum leaders and indicates the high significance level of this study.

This study

The present study aims to investigate how to strategically use technologies: content-specific and content-neutral: to support classroom discussions in Mathematics. To achieve this research goal, we used an experimental study, a 2 x 2 between subjects factorial design with the factor's learner expertise (prior knowledge: less and higher) and the order of using technologies (content-specific first vs. content-neutral first), to understand how the treatment affects classroom discussions for learning linear equations. The content-specific and content-neutral technologies were a learning object that allows students to manipulate variables for their own learning, and a mind map application respectively. The participants were 122 Grade 10 students, (15-16 years old, around 55% is boy).

Results

For Mathematics learning, univariate ANOVAs showed that there were no significant effects of learner expertise, $F(1, 118)=1.23$, $p=0.27$, partial $\eta^2=0.01$, and of the order, $F(1, 118)=2.02$, $p=0.158$, partial $\eta^2=0.02$. A significant interaction effect was found, $F(1, 119)=5.52$, $p=0.020$, partial $\eta^2=0.04$. A significant simple effect was found for the more knowledgeable group who learned better with the discussion forum first, $F(1, 58)=19.99$, $p=<0.001$, partial $\eta^2=0.26$. The other effects are not significant. For intrinsic motivation and invested mental effort, simple effects were found for the less knowledgeable group who invested less mental effort and had higher motivation level with the learning object first, all p values<0.001. Simple effects were found for the more knowledgeable group who invested less mental effort and had higher motivation level with the mind map first, all p values<0.001.

Discussion, conclusion and limitations

The two empirical implications are (i)the more knowledgeable group had more constructive classroom discussion when learning with the mind map first, indicating the content-neutral technology provided them with learning opportunities to think and to reflect before discussion; and (ii)the less knowledgeable group who learned the learning object developed better problem solving skill, which implicates the content-specific technology refreshed or strengthened their prior knowledge before classroom discussion.

Moreover, this study affords two practical suggestions. Mathematics that is well structured subject concerns fact, rules and theories; therefore, holding relevant prior knowledge is very important for discussion. In other words, the students who are able to hold a conversation are those who have a more complete subject knowledge (Kalyuga, 2007). To prepare the novice for classroom discussions, we suggest using content-specific technologies to consolidate their knowledge. The second suggestion concerns the technology used for the advanced student in post-discussion activities. We suggest using content-neutral technologies such as mind map and digital portfolio applications as reflective technologies for the learning activities after discussions. These content-neutral technologies provide learners with more open learning opportunities to connect fact, rules and theories for building/rebuilding their own understanding (Rey & Fischer, 2013).

For the limitation, this study did not use the qualitative method such as interviews and portfolio to triangulate the quantitative results. Accordingly, in the future research, more relevant studies with mixed research method should be done in other mathematics topics to expand the findings.

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