*Running Head: Framing Issues – Improve Students’ Learning through Well-Designed LEs*

Framing Issues:

Improve Students’ Learning through Well-Designed LEs

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The Issue

The issue I have selected is the potential of electronic learning environments (LEs) in teaching mathematics to improve student understanding of complex abstract concepts, and in turn, improve overall student learning in the subject. Math was a focus for several in the e-ography discussion. While Sabrina and Stephanie had fond memories of Math Munchers, Stephanie noted that it did not help her much with learning math. Andrea, Bill and Janet discussed the merits of using Khan Academy, but Andrea and Stephanie wonder if it puts enough emphasis on problem solving and higher order thinking and understanding of math concepts. In our exploration of misconceptions in STEM subjects, it was noted that “making mistakes and addressing assumptions may help students to be open to attacking their own learning from an objective perspective” (Rebecca). It is possible for students to have misconceptions due to their previous learning or lack of necessary prior knowledge (Jhodi), and a process of remediation is needed (Driver et al., 1985) to assimilate or accommodate new information (Posner, Strike, Hewson, & Gertzog, 1982). Misconceptions are a natural and unavoidable part of learning (Gonen, 2008). STEM learning necessarily involves a process of identifying and addressing student misconceptions, and digital LEs have the potential to dispel them and result in lasting understanding.

Our “Unpacking Assumptions” discussion focused on effective technology use in STEM subjects. There was some consensus that it should be self-directed and self-paced (Keith & Janet) so the individual has control over the learning, for example, I mentioned a hands-on approach as opposed to on-screen demonstration and stop animation. As well, students who have a good understanding of how to use the technology will have more success in learning with it (Keith). Overall, however, our best use descriptions are focused on computational process understanding when discussing effective technology, so I continue to advocate that there must be better uses of which we are not aware. Several, including myself, noted the use of technology to support current teaching methods, in particular teacher-directed transmission teaching, as it is difficult to break the pattern of using technology to sustain non-student centered methods. Finally, my interviewee primarily uses computing activities for practice and reinforcement, but I suspect that LEs have the potential to produce a lasting understanding of mathematics.

Selection of Studies

The articles I selected focus on computer-based math instruction in a blended context in elementary and high school settings to improve students’ understanding of mathematical concepts. At the outset, I randomly perused the ETEC533 research folders on CiteULike and bookmarked articles of interest related to my teaching context and research interest which is using interactive digital learning environments or objects for teaching mathematics. Initially I selected two articles (Bruce & Ross, 2009; \*Michael, 2001[[1]](#footnote-1) (Appendix A)) which focused on the use of such environments to improve student learning. Then I completed a preliminary search in Academic Search Complete using the following keyword combinations: math computers, computer-based math, technology-based math, and interactive online learning objects. Here I found an article about a cognitive tutor program developed at Carnegie Mellon University and tested in a neighbouring high school (Hubbart, 2000). There was also two general articles on the case for technology in math and science education (\*Koblitz, 1996; Sinn, 1995), but I felt they were somewhat dated and was hoping for more current research. A study of student motivation in a mobile age (\*Ciampa, 2014) was briefly listed as possibly connecting to my focus, but it was eliminated later as too general for my purpose. Another article I discovered about teaching hybrid post-secondary course effectively contained a college algebra case study (\*Westover & Westover, 2014); although it has merit, its focus is on post-secondary students who are motivated within their chosen program, so I eventually eliminated it to focus on middle to high school learners. There were also two articles on computer gaming for math learning that seemed like they might connect because the game-based environments were online digital learning environments (\*Fengfeng, 2008; \*Looi, Duta, Huber, Nuerk & Kadosh, 2013). The Fengfeng article was a solid contender for selection until near the end of my searching, but the Looi et al. article was much too brief in detail providing summary results with limited discussion. Since I was not yet satisfied with my collection of findings, I completed a general UBC search using these search terms combinations: interactive online learning math, and interactive online learning math high school. I found another general article about who education should go digital, but it was general in focus (\*Edwards & Wirt, 2012), while another supposedly about interactive multimedia in online education was about including images and video in elearning content areas and not interactive learning objects (\*Cheng, Basu & Goebel, 2009). I found a meaningful research article about an online learning system in Australia called HOTmaths that was implemented and tested in a blended learning format in high school math classes, and it closely connects with our Module A discussions (Cavanagh & Mitchelmore, 2011); they studied three teacher with different technology comfort and experience as they implemented the use of this resource in their classes. After getting feedback on my selected resources and rationale and closely reading my selected articles, I realized the computer simulation article (\*Michael, 2001) was off topic, so I completed another UBC Library search and found a more complimentary article on pedagogical, mathematical, and cognitive fidelity of math related websites which often contain digital learning objects (Bos, 2009). Although this article is general in focus, it has an excellent perspective on judging and choosing websites (digital learning environments or objects) with pedagogical, mathematical and cognitive fidelity.

*Keywords: online, digital, interactive, learning environment, learning object, blended-learning, middle school, high school*

Review of Selected Articles

Hubbart, L. (2000). Technology-Based Math Curriculums. *T H E Journal, 28*(3). Retrieved January 23, 2014, from UBC Library Academic Search Complete: <http://search.ebscohost.com.ezproxy.library.ubc.ca/login.aspx?direct=true&db=a9h&AN=3795123&site=ehost-live&scope=site>.

Researchers at Carnegie Mellon University (CMU) developed a Cognitive Tutor (CT) program to be used to teach math which was tested at Langley High School (LHS). The program is motivating and engaging as it presents students with “real world problems” and puts the math equation in context with specific, practical information to make it less abstract. It detects “flaws in reasoning” and helps the student “rethink the problem.” There’s an active process of individual thinking for every student in the class, and since the CT assists the students, the teacher has time for one-on-one teaching and assistance for those struggling. This teaching model is student-centered and hands on as every student is engaging with the CT to solve what could be real problems. They spend around 40% of their learning with the CT and the rest with a textbook. An atmosphere of collaboration developed as students sought the help of their peers, and their analysis of their errors and working together on solutions demonstrates the development of a community of practice. The results of the study are impressive as the students taught with the CT “significantly outperformed similar students in traditional courses.” In particular, their achievement in problem-solving increased by 100% which is of great significance with the concern of students’ inability to transfer their computational knowledge to solving problems. These students were also more likely to complete higher level math. This thinking tool has been refined over 15 years of research at the point of publishing and is currently available online to be incorporated into math curriculum.

Bruce, C. D. & Ross, J. (2009). Conditions for Effective Use of Interactive On-line Learning Objects: The case of a fractions computer-based learning sequence. *Electronic Journal of Mathematics and Technology* [online serial], *3*(1). Retrieved January 23, 2014, from CiteULike (10293579): <https://php.radford.edu/~ejmt/>.

 The Critical Learning Instructional Paths Supports (CLIPS) online LO was created to be delivered in a blended format in Ontario grade three math classes to address the difficulty of students to retain fractions concepts and, thus, dispel misconceptions that carry into adulthood. Misconceptions stem from their not being used regularly in everyday life, the complicated written notation, the difficulty of ordering them on a number line, and the complex nature of their rules. They were concerned with scaffolding the content in a learning sequence with clear instructions, so students could self-navigate and control the pace of learning. Teachers are short of time and expertise for designing and programming their own LOs, so a well-designed and field-tested LO can assist teachers in delivering an excellent learning sequence. A few more issues are addressed through the design of this LO: (1) making real-life connections to make an abstract concept concrete, (2) consideration of learning styles by using “varied visual representations,” and getting “immediate and helpful feedback” to address misconceptions. These researchers found that the introductory activity of the teacher was important to student learning; the students experienced greater learning success when there was an obvious, direct connection with the CLIPS experience that followed. The data sources were several and varied organized observational methods (classroom observations, field notes of student interaction on CLIPS, informal student questioning during interaction with CLIPS, and transcripts of student interviews), and it was analysed systematically; however, the data is not represented in the article. They concluded that pacing, sequencing, the introductory off-line task, and the “technological facility of the user” all matter, but these conclusions are stated without mention of the data to support it.

Cavanagh, M., & Mitchelmore, M. (2011). Learning to teach secondary mathematics using an online learning system. *Mathematics Education Research Journal, 23*(4), pp. 417-435. Retrieved January 24, 2014, from UBC Library: [http://link.springer.com.ezproxy.library.ubc.ca/article/10.1007%2Fs13394-011-0024-1](http://link.springer.com.ezproxy.library.ubc.ca/article/10.1007/s13394-011-0024-1). DOI: 10.1007/s13394-011-0024-1.

 Three secondary math teachers without prior experience teaching with technology were studied as they began to use an online learning system (OLS) in their lessons, Cambridge HOTmaths (http://ww.hotmaths.com.au); the researchers at Macquarie University in Sydney, Australia observed and documented changes in the teachers’ “Pedagogical Technology Knowledge” (PTK) (pg. 417). It was noted that technology is often used in a peripheral manner, and studies were cited to support the idea that teachers need professional development and training to “move beyond simply enhancing teachers’ technical skills… to influence teachers’ beliefs about what constitutes good teaching…” with technology (p. 418). In particular, they wanted to explore whether a well-designed OLS would address some of the professional development issues and lead to more effective pedagogical usage of the technology. The teachers’ PTK developed as they used the OLS in their classes. They all started as technology bystanders who allow students to try the program on their own; then they progressed to by technology adopters who use the system in conjunction with their own teaching practices. Success, however, was found to be more dependent on the already established pedagogical skills of the teacher. Finally, one teacher moved to technology adaptation as she became more comfortable with the OLS and creative in incorporating it into her lessons. The technology was integrated into her teaching instead of an add-on to the lesson. All experienced a gradual transition to “greater degrees of integration” (pg. 431), and the hope of further transforming learning into student-centered learning was suggested. The conclusions of the study were completely drawn from observations of the teaching and interviews with the teachers. It does not seem as though students were asked any questions formally or informally, so I wonder what their perspective would offer to the discussion. As well, the paper neatly describes four types of technology users, and the first three neatly describes the three teachers; it seems contrived without some quantitative data to support the observations. There is an unrealistic leap from technology adopter to adaptor, suggesting that this next step will be realized, but it would be a significant shift in teaching. The technology adopter is still using a fairly teacher-directed format, so the change is not a simple next step.

Bos, B. (2008). Virtual math objects with pedagogical, mathematical, and cognitive fidelity. *Computers in Human Behaviour, 25*, pp. 521-528. Retrieved January 31, 2014, from UBC Library: <http://www.sciencedirect.com.ezproxy.library.ubc.ca/science/article/pii/S0747563208002070>.

 In 2003, the National Council of Teachers of Mathematics (NCTM) was charged with reshaping mathematics teaching through the use of technology; however, there have been many challenges and obstacles, such as the quality of the software or equipment or the teacher’s ability to choose and use it in their classroom. As a result, technology designers were encouraged to develop well designed math objects that were pedagogically sound and would support cognitive understanding “to deepen mathematical understanding and encourage…students to work at higher levels of generalization or abstraction” (pg. 521). Bos (2008) describes effective design for web-based interactive math objects that offer “manipulations, multiple representations, multiple entry points, and provides opportunity to test, revisit, revise, and apply mathematical patterns” (pg. 522). Pedagogical fidelity refers to the students’ ability to do the math without distraction due to poor design or the limited technical features. Mathematical fidelity is the mathematical accuracy of the objects within a program or environment as it is manipulated and represented in different forms. Finally, cognitive fidelity refers to the question of “whether a concept is better understood when the object is acted on” (pg. 522), so that abstract ideas become more concrete for learners. She believes the main focus should be on helping students engage in higher order thinking to come to an understanding of mathematical concepts. Interactivity and novelty are not good reasons for incorporating technology, according to Bos (2008). As well, drill and practice does not lead to concept development or problem-solving and reasoning which are more important than ever before. Bos has developed a rating system to determine a web-based math program’s fidelity that is described in five stages: static state, kinesthetic/aesthetic, static computational, discrete dynamic, and continuous dynamic. Static content is the least supportive to cognitive development while the dynamic stage describes the learning objects within such an environment as having fluid interactions where information is exchanged between formats so that patterns and relationships can be observed and understood. Her study focused on teaching quadratic functions to low-achieving high school students using interactive Texas Instruments (TI) InterActive lessons; they were tested using a state mandated Test of Knowledge and Skills (TAKS) Mathematics Test. It was found that the students who experienced the interactive lessons that were high in fidelity (pedagogical, mathematical, and cognitive) performed significantly higher than the control group on the standardized test. She conjectures, “If math is seen as problem solving and thoughtfully teamed with technology, deep conceptual learning can be a reality” (pg. 527). This research could be further supported with qualitative research as well to also benefit from students’ attitudes.

Conclusion

 These four studies have a common thread in regards to improving teaching with technology in math classes. Choosing well-designed LOs or LEs is critical to effective technology use that will result in deep learning whether a focused fractions LO or a more comprehensive website like HOTmaths. Although there is merit in teachers delving in and trying technologies, the environments are not all quality as defined by high pedagogical, mathematical, and cognitive fidelity. While all the studies focused on trying a particular LO or LE, only the interactive TI objects demonstrated solid improvement in the struggling learners through a standardized test. The fractions (Bruce & Ross, 2009) and the Hotmaths (Cavanagh & Mitchelmore, 2011) studies reported gains in learning, but they were not quantifiably measurable. There would be some benefit from seeking students’ opinions about the experience in using various LOs and LEs. Bos (2008) describes an excellent system for choosing well-designed materials which can be applied to any web-based LO or LE. The Cognitive Tutor, although different in nature as a program that assists your thinking, it is also focused on problem-solving and deep, critical thinking to develop an understanding of mathematics. I would use Bos’ system for rating LOs and LEs because it is criteria/descriptor-based. I would seek out well-designed environments so that I could focus on the lesson planning and development to integrate the technology into the teaching. Ideally, if I had the opportunity, I would be most interested in incorporating the Cognitive Tutor program because the students use the program in a variety of groupings (self, pair or group) to solve problems. The problem-based focus in the design is a shift away from teacher-centered instruction to student-centered learning that is active and engaging. These LO and LE developments were the developments of universities and the testing was in collaboration with elementary and high schools. We need more such partnerships to create meaningful technology that can be shared with other educational institutions, so teachers can continue to develop their pedagogy and deliver these materials with effectiveness.

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Appendix A: Articles Not Selected

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1. any reference with an asterisk (\*) is located in Appendix A which is a list of articles that were eliminated from selection for the review [↑](#footnote-ref-1)