Toward Pervasive Knowledge Building – Mobile Devices for Creating Meaningful Math around Our Everyday Lives

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Abstract: The proposed research will examine Knowledge Building pedagogy for students' construction of knowledge around meaningful mathematics in their everyday lives. Students will be encouraged to contribute personally relevant and meaningful mathematics rooted in recognizing math in the world around them and their authentic wonderings about the world. Knowledge Building will be extended by mobile devices for learning which pervades across locations, contexts, and globally distributed communities and enables diverse forms of knowledge representation and expression. Design-Based Research (DBR) will be utilized to co-design the technology and practices with students, educators, and engineers. We aim to achieve a sustainable practice for students to create new mathematical knowledge in and beyond their classroom, contextualized within their culture, community, and personal lives for a personally relevant and meaningful educational experience.

Introduction

Improvement of mathematical literacy represents an educational priority in elementary schools across Ontario (Zegarac, 2016). According to the EQAO Office (2016), standardized math scores in Ontario for grades 3 and 6 have been steadily declining over the last five years. In response, Ontario's Ministry of Education has put into action a Renewed Math Strategy that supports teachers' development of mathematical knowledge and promotes students' deep understanding, development of skills, and appreciation of how mathematics is used in students' everyday lives (Zegarac, 2016).

Toward continuing development of innovative practices and supporting technology, this research looks at ways to rethink mathematics, driven by the pursuit of a knowledge-creating culture and a practice which extends beyond the classroom and across networked communities. This research will include students, teachers, and engineers in co-designing the practices and technology for students' sustained inquiry in authentic contexts.

Authentic Contexts for Mathematics

Contextualizing mathematics in meaningful and relevant ways can have a powerful impact on students' abilities to understand and apply mathematical knowledge (Boaler, 1993). When math is disconnected from the world, it becomes disconnected from its meaningfulness. Personally meaningful mathematics is derived from students recognizing their own cultural values in relation to mathematics. D'Ambrosio (1985) used the term *ethnomathematics* to contrast *academic* mathematics, where ethnomathematics refers to the math that is used by cultural groups or individuals beyond the classroom. When students realize the utility of mathematics in their personal and cultural contexts, they are better able to use mathematics to analyze, understand, and apply mathematics in their lives (Boaler, 1993). Caine and Caine (1991) explain that the brain is designed to be immersed in complex, rich contexts in which interconnected and meaningful learning promotes deeper understanding.

In making connections between math and students' lives, we can create more meaningful contexts for learning. Personal meaning can be attributed to these math contexts when students are genuinely free to direct their learning based on their perceptions of a problem to attain their personal goals (Boaler, 1993). Providing students with opportunities to engage in mathematical practices of value beyond the classroom is shown to develop more flexible forms of knowledge which can be applied in a range of situations and recognized by students as a relevant part of their lives (Boaler, 2001). Finding ways to support students in creating a localized context, articulating and developing meaning, and interconnecting ideas appear to be promising steps toward meaningful learning and deep understanding in mathematics education (Boaler, 1993; Carpenter & Lehrer, 1999; Maier, 1991; Small, 2013).

Knowledge Building

There is a strong belief in the mathematics education community that students learn best when actively engaged in constructing their own understandings (Small, 2013). Knowledge Building is a constructivist approach which aims to bridge the gap between in- and out-of-school learning (Scardamalia, in press), where students are co-directors of authentic, open-inquiry and co-creators of community knowledge. This approach led to the emergence of what has become known as a *Knowledge Building culture* – a culture in which peers gain a sense of belonging through their sustained commitment to solving knowledge problems (Scardamalia & Bereiter, 2010). Thus, "Knowledge Building is the creation and improvement of knowledge of value to one's community" (Scardamalia & Bereiter, 2010, p. 8).

Knowledge Building is a deeply innovative approach to education which moves beyond prescribed learning paths and allows students to actively explore their own paths and ideas. The goal of Knowledge Building theory, pedagogy, and technology is to recreate schools as knowledge-creating organizations (Scardamalia & Bereiter, 2016).

Scardamalia (2002), defines 12 Knowledge Building principles which define and guide Knowledge Building practices. These principles include:

- *Real Ideas, Authentic Problems* - students are driven by a desire to understand the world and solve authentic problems
- *Knowledge Building Discourse* - discursive practices of sharing, refining, and transforming knowledge move the community toward the goal of advancing their knowledge
- *Democratizing Knowledge* - all students actively contribute their knowledge for the advancement of community knowledge
- *Pervasive Knowledge Building* - work with knowledge pervades across school subjects, time of day, and geographical location

Knowledge Forum

Knowledge Building continues to be supported by Knowledge Forum, a research-driven online platform for promoting networked communities' work with ideas and creation of knowledge (Scardamalia & Bereiter, 2010). Knowledge Forum is a platform which gives ideas a voice, to host the collective knowledge of peers, teachers, parents, or even globally distributed communities. These ideas are not just shared, they become part of the communities' knowledge where ideas are meant to grow. Use of Knowledge Forum in education continues to represent a revolutionary change in educational practice, from classrooms focusing on tasks and activities to continual improvement of ideas (Scardamalia, 2004).

Knowledge Building in Math

Successful work has already been done to establish Knowledge Building as a promising means of studying mathematics (e.g. Daher, 2010; Hurme & Jarvela, 2005; Moss & Beatty, 2006; 2010; Costa, 2017). Knowledge Building and Knowledge Forum have been utilized together in most of these research studies (e.g. Hurme & Jarvela, 2005; Moss & Beatty, 2006; 2010; Costa, 2017) with many positive outcomes. According to Moss & Beatty (2010), grade 4 students at both high- and low-levels of achievement can solve algebra problems of recognized difficulty and illustrate Knowledge Building culture and the principle of democratizing knowledge. Another recent study has shown that students as early as Grade 2 can productively use Knowledge Building in both face-to-face and online contexts using Knowledge Forum (Costa, 2017). Some research has even begun to explore the use of Knowledge Building with mobile devices for cross-context pervasive learning.

Pervasive Knowledge Building

Knowledge Building communities are now beginning to utilize mobile devices (smartphones or tablets) to support seamless Knowledge Building processes across formal and informal settings, enhanced by contextualized, location-based mobile scenarios (e.g. So, Seow & Looi, 2009; So, Tan, & Tay, 2012). These studies used learning trails to explore the physical contexts corresponding to geographically and historically significant locations and events. Daher (2010) applied Knowledge Building for mathematical modelling of phenomenon outside of the classroom. However, these studies have yet to use Knowledge Forum for facilitating pervasive Knowledge Building experiences.

Previous versions of Knowledge Forum were a limiting factor in promoting pervasive Knowledge Building due to restriction of the platform to desktop computers (e.g., So, Tan, & Tay, 2012). Knowledge Forum has since undergone a transformation for improved compatibility on a variety of mobile devices. A recent study in mathematics (Costa, 2017) used iPads as the primary device for accessing Knowledge Forum.

According to So et al. (2009), benefits of seamless Knowledge Building with mobile devices include increased access to technology across time and physical spaces, contextualized learning *in situ* which includes real-time data gathering and analysis which promote connections between ideas and observations, and the use of multimedia to create or modify digital artifacts captured in context. "[W]ith the tight coupling of mobile and Web 2.0 technologies from pedagogical perspectives, young learners can be engaged in participatory knowledge building processes linking formal and informal learning experiences" (So et al., 2009, p. 380).

Mobile Devices in Mathematics

Mobile devices are becoming increasingly powerful, cheap, and accessible to students. Utilizing these prevalent devices and students' existing competencies and affinity for technology may provide a transformative context for mathematics education.

People's existing practices with mobile devices typically fall into the four basic practices (White, Booker, Martin & Ching, 2012): (1) capturing and collecting multimedia information and experiences across a variety of settings, (2) communicating and collaborating with others, (3) consuming and critiquing media, and (4) constructing and creating personal forms of representations and expressions through edited multimedia (i.e. films, slideshows, sketches, podcasts, or written reflections).

These four basic practices are typically directed toward out-of-school activities but may be guided toward mathematics, science, or engineering as they overlap with practices embodied in STEM (science, technology, engineering, mathematics) education (White & Martin, 2014). Additionally, the practice of creating multiple forms of representations and expressions overlaps with 2 principles of Universal Design for Learning (CAST, 2011), (1) multiple means of representation (for equity of knowledge access), and (2) multiple means of action and expression (for equity of knowledge expression). The integration of mobile devices responds to the call to bridge the gap between in-school and out-of-school experiences and understandings (e.g., Bonotto, 2004; Civil, 2002) and the development of mathematical competencies that are useful in students' everyday lives (e.g., Boaler, 2001; Zegarac, 2016). The mobile revolution has led to the prevalence of mobile devices in the workplace and as an integral part of people's lives (White & Martin, 2012). Now, it is important for educators to decide what this revolution looks like within education, in- and beyond-the-classroom.

Design-Based Research

Since its conception, Knowledge Building has been co-designed alongside technology for supporting the collaborative construction of community knowledge (Scardamalia & Bereiter, 2010). Design-Based Research (DBR) is much like innovation in manufacturing. DBR evolves through creation of prototypes, testing in authentic practice, evaluation, and iterative refinement over multiple iterations (Anderson & Shattuck, 2012). DBR produces findings that feed back into the cycles of innovative design (Bereiter, 2002).

Interest in DBR continues to grow as a valid means to bridge the gap between research and practice in formal education (Anderson & Shattuck, 2012). DBR seeks to trace the evolution of learning in complex, messy school contexts to test and build theories of learning and instructional tools that survive the challenges of everyday practice (Shavelson, Phillips, Towne, & Feuer, 2003, p. 25).

Pragmatic characteristics of DBR include the aim of refining theory and practice and appraising the emergent theories in terms of how well they work to improve practice (Wang & Hannafin, 2005). Central to DBR is the applied aspect and its ability to create lasting value for a community. Research which advances theory but fails to exemplify value for a community has not justified the value of that research (Anderson & Shattuck, 2012). Similarly, research which lasts only as long as the researcher stays, but disappears as soon as the researcher leaves, misses the point of DBR as sustained improvement to the local community. "What defines design research is its purpose: sustained innovative development" (Bereiter, 2002, p. 326).

Proposed Study

The purpose of this study is to explore pervasive Knowledge Building and the Knowledge Forum online environment as effective means of accessing authentic contexts and building deep mathematical knowledge with grades 5/6 students in Ontario.

This research will utilize DBR to improve the practice and technology through multiple design iterations. Each iteration allows students to engage in the Knowledge Building practices. At the end of each iteration, co-design meetings will be held to allow educators, researchers, and engineers to reflect on the previous iteration, assess online Knowledge Building discourse, then co-design new practices and technological improvements to incorporate into the future iterations.

Daily practices may include students generating theories and wonderings about math, then searching for those concepts in the world to test their theories and build locally contextualized mathematical knowledge. Knowledge Forum may be used for capturing mathematical information and experiences using a variety of multimedia (notes, pictures, video, audio, drawings) for multiple forms of knowledge representation and expression. These digital artifacts may be worked on locally or shared beyond the class to collaborate on unsolved problems or advance improvable ideas.

Rooting math discourse in students' own lives aims to promote authentic Knowledge Building. This practice will be extended by mobile devices for seamless Knowledge Building across contexts (in-class, on the playground, at-home) and a Knowledge Building culture which pervades students' lives across physical locations, formal and informal contexts, and geographically distributed communities.

Expectations

We expect that students will develop a deeper connection with mathematics and contextualize their learning within their own cultures, communities, and everyday lives. Students may be more engaged in mathematics with students feeling more compelled to contribute and learn. As this research is pragmatic in responding to the needs of the students and communities, we hope that this work will not just help students address problems in mathematical achievement, but lead to improvement in their lives and their communities. It is more than learning about math in the world, it is about students' lives and wonderings being the canvas on which math is explored and around which new knowledge is created. With Knowledge Building, students can go beyond the school context to generate knowledge and theories around their real world and authentic ideas. This research continues to support that endeavor.

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