Integrating Technology into Mathematics Teachers' Design and Use of Authentic Assessments

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ABSTRACT

This paper reports on the preliminary findings of an action research that aimed to build mathematics teachers' capacity in designing and using reliable and valid authentic assessments and assessment for learning that *meaningfully* incorporate the use of technology to capture students' learning of mathematics and development of competencies such as critical thinking, complex problem solving, communication, and self-directed learning. Five teachers who taught Grade 6 mathematics participated in a school-based professional learning community over a six-month period. They employed the criteria for authentic intellectual quality, the patchwork text assessment strategy, and the Structure of the Observed Learning Outcome taxonomy to design authentic assessment tasks. To further achieve the goals of enhancing student learning, the teachers have adopted the Substitution Augmentation Modification Redefinition (SAMR) Model to infuse digital learning into the authentic assessment tasks. The data sources included teacher focus group interviews, analyses of the mathematics authentic assessment tasks and students' work, and one-on-one interviews with the teachers and a selected sample of students.

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Introduction

In an era of competency-based curriculum and outcome-based reporting, building teachers' capacity in designing and using authentic assessments to support students' learning and development of the 21st century competencies is deemed to be a central priority in teacher education and professional development programs. A further layer of developing students' competencies in the 21st century classrooms also calls for teachers to effectively and meaningfully leverage technology into their assessments to create authentic learning environments for students. This necessitates a paradigm shift from conventional paper-and-pencil assessments measuring knowledge reproduction and low-order cognitive skills to authentic assessment tasks that compel students to exhibit higher-order thinking skills and authentic intellectual capacities (Koh & Luke, 2009).

Teachers require competence in selecting, adapting and designing learning experiences that engage learners in Assessment for Learning (AfL). Embedded in daily teaching and learning, AfL strategies are instrumental in supporting and promoting student learning, while encouraging dispositions such as self-regulated learning, inquiry, habits of mind, and lifelong learning (Stiggins, 2002; Wiliam, Lee, Harrison & Black, 2004). Further, teachers must be equipped with the assessment literacy necessary to develop authentic assessment tasks that are well aligned with the curriculum, mirroring the real-world tasks and standards of performance experts or professionals face in the field (Wiggins, 1989).

The ubiquitous nature of technology merits its inclusion in the design of robust, authentic assessment, if students are to acquire the skills necessary to thrive in a complex, highly technological knowledge-based economy. Meta-analytic studies of the literature detail the profound positive effects of technology-supported learning and assessment in mathematics on overall student achievement (Li & Ma, 2010; Roschelle, Pea, Hoadley, Gordin, & Means, 2000; Schacter, 1999a; Kaput & Thompson, 1994). When nested in a constructivist learning environment, technology can serve as an instrument for approaching instruction and assessment in mathematics differently (Arcavi, 2003; Jonassen, 1996). Even the most commonplace digital tools can support the design and implementation of authentic assessment tasks in order to deepen mathematical conceptual understanding and develop key competencies such as creative and innovative problem solving, communication, analytic thinking, collaboration and self-directed learning (Roschelle et al., 2000).

Teachers' professional learning and reflections surrounding their classroom assessment practices and technology use improve markedly when they are collectively undertaken with colleagues in a collegial, non-threatening setting and are framed by actual evidence of student learning (Black & Wiliam, 2009). Likewise, Koehler and Mishra (2008) assert that isolated technology-focused workshops held out of context do little to build teacher capacity in technology integration; whereas, teachers engage more fully in solving authentic problems surrounding technology integration and develop stronger knowledge of technology application when working collaboratively in design teams.

This paper reports on the preliminary findings of a research project that aimed to build teachers' capacity in designing and implementing authentic assessment and AfL, supported by technology, through a grass-roots school-based professional learning community (PLC). The criteria for authentic intellectual quality, the patchwork text assessment strategy, and the Structure of the Observed Learning Outcome taxonomy were employed to design authentic assessment tasks. To support and enhance student learning, the Substitution Augmentation Modification Redefinition (SAMR) Model was employed to inform the integration of digital tools and learning into the authentic assessment tasks (Puentedura, 2006).

Literature

Shifting Paradigms: Towards Authentic Assessments in Mathematics

Conventional assessment is widely critiqued for providing an incomplete picture of student achievement (Wiggins 1989; Newmann et al. 1996). Similarly, technology-supported mathematics assessments are largely computerized tests similar to the conventional written ones (Bennett, 1998). These 'snapshot' assessments do not provide valid measurements of higher order intellectual ability, nor do they inspire the capacities needed to perform real-world tasks (Wiggins, 1989; Resnick, 1987). Loveless (2008) maintains that, "[i]f current conventional assessment practices in mathematics prevail, with assessment remaining wed to what is easy to measure and what has traditionally been taught, reform in school mathematics is not likely to succeed." (p.14). The new forms of assessment needed to prepare 21st century learners call for new kinds of expertise among those who develop the tasks. Teachers are required to improve their assessment literacy as defined by Stiggins (1991) in order to deepen their understanding of the principles of authentic assessment design and of the authentic intellectual work this demands (Newmann et al., 1996). Research has shown that teacher improvements in assessment practice has a strong effect on student achievements and that when teachers design more intellectually rigorous learning and assessment tasks, student work reflects more complex and authentic intellectual capacities (Black & Wiliam, 1998a, 1998b; Bryk, Nagaoka & Newmann, 2000; Koh, 2011; Newmann, et al., 1996).

In mathematics, two basic elements in designing better-quality assessments are: the task and the format. Tasks must be mathematically meaningful, intellectually demanding and rooted in a real-world authentic context to impact student learning outcomes. Additionally, the assessment format has a profound impact on the nature of tasks that can be offered and quality of student response. Assessment formats that leverage Information and Communication Technology (ICT) affords unique opportunities enhancing quality of assessment and teaching and learning (Van den Heuvel-Panhuizen, 2007).

Authentic Assessment and Technology in Mathematics

Technology has significantly influence both the content and pedagogy in schools, driving a shift towards active, student-centered, and inquiry-based education that encourages deeper conceptual understanding and thinking skills (Glaser, Chudowsky, Pellegrino, Eds., 2001). Becoming *assessment literate* in 21st century classrooms involves developing teacher fluency in technology use and integration. Meta-analytic studies pertaining to technology-supported learning and assessment in mathematics fundamentally agree that technology holds immense potential for improving student performance provided it is used effectively (Kaput & Thompson, 1994; Li & Ma, 2010; Roschelle, Pea, Hoadley, Gordin, & Means, 2000; Schacter, 1999a;).

Digital tools enrich student learning by supporting the four fundamental characteristics needed for effective learning: (1) active engagement, (2) participation in groups, (3) frequent interaction and feedback, and (4) connections to real-world contexts (Roschelle et al., 2000). In learner-directed classrooms, the collaborative nature of technology incites sharing in the social space of the classroom where students learn from 'more able others' (Vygotsky, 1978). Students are actively engaged in conversations about mathematical experiences, solutions, relationships, and concepts, which promotes greater depth of understanding. Further, the inherent connectivity and interactivity of technology extends these conversations to the real world through Jenkins' (2009) participatory culture of Web 2.0 (Lesh, Hamilton, & Kaput, 2007; Zbiek et al., 2007).

Mathematical concepts are encountered in more realistic situations; access to mathematical content and real-world contexts further connects students to the mathematics disciplinary knowledge. Students are often required to employ digital tools in learning and assessments in "authentic" ways that mirror those of real life disciplines (Li & Ma, 2010). In addition to supporting student intellectual engagement, learning and achievement, Information and Communications Technology (ICT) can contribute to the design of more authentic mathematical assessment and AfL in three ways. First, by making it possible to design and use tasks with high intellectual demand. Second, by making tasks more accessible for students. Finally, by revealing students' thinking and solution processes. Well-designed, technology-enhanced assessment can become a tool to grow, exercise and measure the greater depth of knowledge by providing "the means to capture students' knowledge and performance in many different ways, and in an authentic environment, and to assess them more robustly and in innovative ways" (Campbell, 2010, p. 163). When comparing technology adoption in Grade 3-6 mathematics and writing, Hare, Ault, and Nileksela (2009) found technology-poor classrooms engaged students in *reproduction of factual and procedural knowledge* (low level tasks). In contrast, technology-rich classrooms engaged students in *applied procedural tasks* required them to demonstrate higher-order cognitive skills such as knowledge production, criticism, manipulation, and construction.

The National Council of Teachers of Mathematics (NCTM, 2000) endorses assessment task design that incorporates different representations or lenses through which to interpret problems or solutions. The representational affordance of technology allows the exploration of multiple approaches to the same mathematical idea and encourages connections between representations to gain a more robust understanding of a concept (Lesh et al., 2007; Roschelle et al., 2000; Zbiek et al., 2007). Although mathematics teachers claim to be supportive of technology use in teaching and assessment, the degree and type of use in actual classrooms does not seem to correlate. A substantial body of literature has shown that technology is often used in a supplemental way, such as for information gathering, production of lesson materials, presentation, and acting as a mere substitute for existing classroom tools (Kaput & Thompson, 1994; Li & Ma, 2010; Roschelle, Pea, Hoadley, Gordin, & Means, 2000; Schacter, 1999a;).

Researchers asserts that incorporating technology meaningfully into teaching and learning requires significant pedagogical shifts. Technology, alone does not support learning. However, research in the field "struggles to tackle the complexity of the integration of the evolving technologies. To date, there is no consolidated view of how to integrate technology appropriately or effectively into mathematics teaching" (Loveless, 2010).

Building Teacher Capacity in Authentic Assessment and Technology Integration

Numerous intervention studies have been conducted beyond the Canadian context that detail how sustained forms of professional development build teachers' capacity in authentic assessment and AfL (Koh, 2011; McMunn, McColskey, & Butler, 2004; Sato, Wei, & Darling-Hammond, 2008). Researchers found that teacher's active contributions in the design and implementation of authentic assessment tasks and AfL strategies such as formative feedback, and self and peer assessment, has significant positive impacts on the quality of student learning and achievement. Moreover, utilizing an inquiry stance/method to build teacher capacity facilitates more effective teacher learning and professional development (Cochran-Smith & Lytle, 2009; Wyatt-Smith & Gunn, 2009).

Empirical studies in the eastern provinces of Canada have shown that the majority of teacher candidates reported a low level of assessment literacy (DeLuca & Klinger, 2010; Volante & Fazio, 2007), especially in new forms of assessment such as authentic assessment and AfL.

The western provinces of Canada, Alberta included, have moved towards improving teachers' assessment literacy through school-based, professional development based on professional learning communities (PLCs). However, these initiatives have not been altogether successful. Sumara and Davis's (2009) study showed that many of the school-based PLCs had failed to produce deep change in school cultures due to a lack of teachers' bottom-up initiatives.

In the literature the term "meaningful" technology integration involves selecting the "right" digital tool, to support the most effective pedagogy (i.e. constructivist) and purposefully aligning these with mathematical content, learning and assessment tasks and intended learning outcomes (Ferdig, 2006). Much of the literature focuses on ***what*** teachers must do rather than ***how*** they must do it. Several unified theoretical and conceptual frameworks exist to guide teachers in how to meaningfully leverage technology for assessment and AfL tasks. These frameworks stress the role of teachers as decision makers who design their authentic technology environments alone or in collaboration with colleagues (Mishra & Koehler, 2006; Puentedera, 2006). One popular framework is "technological content knowledge" (Slough & Connell, 2006), or "technological pedagogical and content knowledge" (TPACK) (Mishra & Koehler, 2006). The SAMR model (Puentedura, 2006) chosen for the purpose of this study operates within the TPACK "sweet-spot", was identified by Mishra and Koehler (2006). It provides educators an evaluative framework for assessing the integration of technology and its impact on student learning. The SAMR hierarchy (see Figure 1) divides technological innovation into four stages of technology adoption, each with progressively greater impact: technology as a direct substitute tool without functional change (Substitution); technology as a direct tool substitute with functional enhancements (Augmentation); technology as a tool for meaningful task re-design (Modification); and technology as a tool for the creation of new tasks, previously inconceivable (Redefinition).

Progression through each stage is contingent on user knowledge of integration and tool availability. Learning and assessment tasks within the Substitution and Augmentation stage result in the enhancement of learning, meaning the task could reasonably have been completed without the use of technology; whereas, tasks within the boundaries of the Modification and Redefinition stages lead to the transformation of learning. In each subsequent stage, the learning and assessment tasks, enhanced by technology, increase in intellectual rigor, student engagement and authenticity (Puentedura, 2013).

Technology usage in schools routinely enhances rather than transforms tasks, which results in surface learning. The design of authentic assessment tasks requires *transformative technology integration* to provide the ideal conditions for powerful learning. Puentedura (2013) cautions educators to focus on the redefinition of authentic task design and processes in a student-centered learning environment. Technology is a tool or a means to an end, which supports task execution and enable the creation of multiple and effective pathways to learning previously inconceivable.

The clear boundaries and anchors to learning theory inherent in the SAMR model guide and support educators to incorporate digital technologies into instructional practice. The focus on sequential technology integration facilitates appropriate scaffolding of instruction and assessment design. Further, SAMR provides a dialogue to frame discussion around, and evaluate, if digital tools have meaningfully transformed student learning and assessment.

Context of the Study

The implementation of the Alberta Initiative for School Improvement (AISI) in the last decade has documented glimpses of the evidence of AfL on student achievement. In 2013, the provincial government ended AISI funding for schools. Despite the AISI initiatives, the Alberta Student

Assessment Study (Weber, Aitken, Lupart, & Scott, 2009) identified three main barriers to student assessment in the Alberta education system: teachers' weak understanding of fair assessment practices; teachers' lack of understanding of external or perceived "high-stakes testing" purposes; and the effects of inappropriate assessment of at-risk students. Many teachers' assessment design favored rote memorization techniques over those that promoted deep learning and student engagement. Two additional pilot programs, namely the Emerging Technologies in the 21st Century initiative and The Technology and High School Success (THSS) initiative aimed to improve best practice in classroom technology implementation by demonstrating the innovative ways digital tools can improve students' learning experiences and 21st century skills (Alberta Education, 2010). However, over the course of two years, the researchers noted little evidence of any real change towards building system capacity in order to advance technology integration into teaching and learning to advance 21st century skills.

Purpose of the Study

Employing a critical inquiry approach and several pertinent frameworks, this research project aimed to build teacher capacity in the design and use of reliable and valid assessments and assessments for learning, while further leveraging technology to impact and capture students' learning in mathematics. During bi-weekly meetings held in a school-based professional learning community (PLC), five Grade 6 mathematics teachers actively engaged in a critical inquiry of their conceptions surrounding authentic assessment, AfL, and assessment task design, as well as their knowledge of technology integration and its inherent benefits for student learning and achievement.

A university researcher and a lead teacher co-facilitated critical reflections and professional conversations about task complexity and knowledge demands through the application of assessment criteria and standards. A set of reflective question topics were found to be useful for enabling teachers to consider the features of quality assessment: (1) alignment with curriculum; (2) intellectual challenges and engagement; (3) assessment scope and demand; (4) language used to communicate the task; (5) literate capabilities involved in doing and completing task; (6) performance contexts; (7) knowing what is expected both during and on completion of the task; (8) student self-assessment for improvement; and (9) intended purposes of assessment information (Wyatt-Smith and Gunn, 2009). Additionally, the SAMR model, an evaluative framework for assessing the integration of technology and its impact on student learning, was employed. Professional discourse focused on how technology could be leveraged to augment real-world authenticity of assessment design thereby enhancing student engagement and learning. The specific objectives of the research were threefold:

(1) To examine the mathematics teachers' conceptions of authentic assessment and assessment for learning before and after their engagement in designing authentic assessments;

(2) To examine the effects of the mathematics authentic assessment tasks on students' learning of mathematics and development of competencies; and

(3) To examine the benefits and challenges of integrating technology into the mathematics authentic assessments.

Designing Authentic Assessment Tasks

During the first PLC meeting, the five teachers including the lead teacher were involved in critical inquiry of their conceptions of authentic assessment and AfL. They were also involved in analyzing the quality of assessment tasks and associated student work samples using two sets of criteria for authentic intellectual quality (AIQ, Koh, 2011; Koh & Luke, 2009; Newmann, Marks, & Gamoran, 1996). This activity has enabled the teachers to internalize the criteria for AIQ and the features of authentic assessment. Using the design principles of authentic assessment, the criteria for AIQ, the Patchwork Text Assessment strategy, and the Structure of the Observed Learning Outcome (SOLO) taxonomy, the teachers co-designed mathematics performance-based tasks for the geometry (i.e., shape, space, and angle) unit of work. The patchwork text assessment strategy enables the mapping of the assessment tasks in the geometry unit to the specific instructional objectives across five different levels of the SOLO taxonomy: pre-structural, uni-structural, multi-structural, relational, and extended abstract. In short, the mathematics assessment tasks provide students with opportunities to engage in mathematical reasoning and critical thinking, application of mathematical concepts to solve real-world problems, extended communication, collaboration, generation of new knowledge, and making connections to other subject areas. The patchwork text assessment strategy has also enabled the teachers to scaffold students' learning of mathematics using quality feedback across a series of assessment tasks, which vary in their levels of cognitive complexity and intellectual challenge.

As the school is a 1:1 environment, conversations surrounding technology integration began to unfold organically. As the various frameworks were used during the different stages of task design, teachers further considered how specific technologies might enhance the intellectual quality and rigor of the task design. In recent years the school has adopted the SAMR model to guide and evaluate technology integration. Through both teacher and student recommendations a variety of technologies were identified to support each task along with ideas for implementation. Final decisions surrounding the level of technology integration into each task and the overall assessment was left to the professional judgment of each individual teacher. As a result, the nature and extent of integration varied. In one setting, technology was fully integrated into all aspects of the project design. Some of the technologies and applications leveraged for teaching and learning included buy were not limited to:

- Multi-media and presentation software (powerpoint; prezi; voicethread; i-movie; photo-booth);
- Learning Management System; Moodle and digital portfolios with teacher, peer and parent to encourage feedback loops;
- Web 2.0 tools, GIS-based map sites, websites, blogs, twitter to grant access to participatory culture;
- Augmented Reality Tools: protractors, slope and clinometers;
- Rhinoceros for Mac 5.0: an Autocad based software for 2D and 3D design.

In classrooms, students worked through a series of carefully scaffolded tasks over a 3-week period pertaining to a unit on shape and space, with and without the use of technology. The final authentic assessment task culminated in the students designing a garden for their community school grounds. A community expert from the Calgary Zoo's Grounds for Change facilitated the project providing students with feedback towards their final designs. After the implementation of the assessment tasks in classrooms, the participating teachers were trained to judge the quality of student work samples in relation to the assessment tasks. This enabled them to make meaningful linkages between quality task design and student learning outcomes. In addition, a focus group was conducted with the participating teachers to probe into their conceptions of authentic assessment and AfL. A selected group of students was interviewed for their experiences in completing the authentic assessment tasks. Some of the students we interviewed had used technology in their garden design project.

Preliminary Findings: Benefits and Challenges

The literature indicates that effective technology incorporation into teaching, learning, and assessment can have positive impacts on student engagement, participation and collaboration, support formative assessment and make authentic real-world connections in mathematics.

Our preliminary findings indicate that the rich professional conversations over the features of high-quality assessment tasks, the criteria for AIQ, the identification of specific instructional objectives using the SOLO taxonomy and the ways in which the SAMR model introduce transformative technology use into said tasks have shed light on the teachers' understanding of authentic assessment and AfL and how technology can augment authentic task design. This has also led to their collaborative effort to co-design authentic assessment tasks or performance-based tasks for the Geometry unit of work with recommendations on how to incorporate technology in a transformative manner in the design and implementation phases.

Teachers' critical inquiry and analysis of the quality of assessment task features and technology integration using the criteria of AIQ and the evaluative SAMR model were found to develop "designers' eyes" so that they are competent to select, adapt, and design well aligned assessment tasks and are somewhat more equipped to use technology at the transformative level in order to promote students' learning of mathematics and the essential 21st century competencies.

Based on our observations, we found that the Geometry unit of work designed by the teachers and accompanying recommended digital tools positively impacted the quality of student learning and performance. The intentionality of the PLC reinforced an already-present, constructivist and inquiry-based learning environment well suited to supporting students' engagement and learning with technology.

Where technology was incorporated successfully into the planned tasks and assessments the benefits reflected those dominant in the literature on technology and mathematics assessment;

(Li & Ma, 2010; Roschelle, Pea, Hoadley, Gordin, & Means, 2000; Schacter, 1999a; Kaput & Thompson, 1994). The nature of the technologies used sparked student engagement, particularly intellectual engagement. Active student-centered teaching and learning occurred as students took the lead in the choosing and implementing technologies. As purported by the literature digital tools were ideally suited to supporting the data-collection, complex analysis, and individualized feedback and scaffolding, all features indispensable for AfL and authentic assessment task design (Brown, Hinze, & Pellegrino, 2008). When effectively leveraged technology supported greater knowledge construction, conversation, articulation, collaboration and reflection (Jonassen, 1996) Through the use of technology, the nature and quality of student assessment tasks were altered and teacher expectations of student performance were elevated. The lens of technology provided students a greater number of mathematical representations as well as multiple pathways to learn and express their mathematical understanding of geometric concepts. Student knowledge and performance, captured in several ways, revealed higher order thinking, competencies and processes otherwise difficult to measure in the absence of technology (Glaser, Chudowsky, Pellegrino, Eds., 2001). The SAMR model served not only as an evaluative tool throughout for teachers, the simplicity of the model enabled student use to consider the impact of their technology choices. Student work samples and interviews are currently undergoing analysis against the criteria for authentic intellectual quality and against the SAMR framework. There is evidence of technology use at all levels: Substitution, Augmentation, Modification and Redefinition. Although our results are preliminary, a relationship has been noted between transformative ICT use and the strong authentic intellectual quality of student work samples.

Despite the collaborative effort in the redesign of the mathematics assessment tasks supported by technology, only some of the recommended strategies and digital tools from the PLC discussions were used in classroom assessment tasks and the level of technology adoption varied significantly between classes. The challenges for technology adoption align with those of Alberta Education (2010) and research surrounding barriers to technology integration (Snoeyink & Ertmer, 2001). We found that teachers need to engage more actively in the design of and ongoing evaluation and modification of technology use in their own classrooms. Schools need to build time into teachers' schedules for PLC style professional development and provide adequate technical support during implementation preferably from an IT specialist. The crowded Grade 6 Alberta curriculum and busy schedules of teachers prompted discussion surrounding the time limitations of deeper technology use. Individual teachers made professional judgments regarding the nature and extend of technology adoption as a result. Becker (2000) found that some teachers perceive that technology use for classroom and assessment tasks will distract from timeline outlined for knowledge dissemination. However, teachers were less wary if they knew they would be provided support. Another principal barrier was the Grade 6 student Provincial Assessment Tests (PATs) in Alberta. Hegedus & Roschelle (2012) detail how concern over, and preparation for, high-stakes state assessments can take precedence over authentic technology supported learning and assessment design. Further, teacher self-efficacy is another challenge (Bandura, 1986). Feeling unprepared to incorporate increasingly complex and unfamiliar technological tools in the teaching of mathematics can halt integration (Larreamendy-Joerns & Leinhardt, 2006). Personal comfort levels and not feeling technologically 'savy' can directly impact the use of instructional technologies in teaching (Favero & Hinson, 2007; Groves and Zemel, 2000). The lead teacher put several informal supports in place (i.e. a team of student experts and professional expert to provide 1-1 support) but, the lack of a more formal, real-time and accessible support system stalled ICT adoption. Finally, research agrees that teachers' pedagogical beliefs and attitudes are critical for successful technology adoption (Ertmer, 2005; Sugar, Crawley, & Fine, 2004). Teachers must engage in the "letting go process" and allow students to explore and construct their own learning and meanings using technology (Noss & Hoyles, 1996). Only one of the teachers who was involved in our study had additional expertise in pedagogic approaches surrounding technology and inquiry integration resulting in higher levels of technology adoption in their classroom.

Given that the benefits of co-designing mathematics authentic assessment tasks rich in technology far outweigh the aforementioned challenges, we aim to sustain our school-based PLC through a negotiation with the school administrators in terms of allowing the teachers to have 'white space' so that PLC meetings can be held within the normal school hours. Additionally, the school has recently appointed a specialist to support technology integration across the curriculum in hopes of addressing some of the findings in this study.

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