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Digital Storytelling as a Problem-Solving Strategy in Mathematics Teacher Education: How Making a Math-eo Engages and Excites 21st Century Students

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Abstract

This study examines whether creating a mathematics-based digital story increases pre-service teachers' understanding of the problem solving process, the relationship among visual, auditory and verbal representation in critical thinking/problem solving in mathematics. Survey results indicated that pre-service teachers were unfamiliar with the uses of technology in the teaching process. However, as they worked through the writing/problem solving procedures and constructed digital stories, they became more aware of the advantages of using this multimodal product, called Math-eos, to teach mathematical concepts to elementary/middle school students. The pre-service teachers perceived that Math-eos offered a "cool" new tool for their own learning and teaching and for integrating digital technology in mathematics education to increase student engagement, motivation and acquisition of content knowledge.

Keywords: Digital storytelling, mathematics education, multimodal technology, problem solving, pre-service teachers, teaching strategies.

Introduction

"As national and state standards require teachers to incorporate technology into teaching, methods courses in mathematics as well as all content areas of teacher education must be redesigned to infuse technology into all aspects of lesson design, instruction, and assessment" (Bowman, 2000, p. 98). The pilot study reported here responds to this charge, It examines whether engaging in a digital project increases pre-service teachers' understanding of the problem solving process and the relationship among visual, auditory and verbal representation in critical thinking/problem solving in mathematics and enables them to integrate digital technology in elementary/middle school mathematics education.

A digital story is a creative, reflective, multimedia narrative, edited on an IPad or tablet, computer or smartphone, using still images, voice, video, music, and sound to communicate with an audience (Lambert, 2006, Paull, 2002). In this way, a digital story combines the ancient art of storytelling with the modern application of technology. According to Jerome Bruner (1991), stories are accounts of events occurring over time. Stories serve as avenues to personal experience, and they are the way that human beings make sense of the world and create a personal reality (Bruner, 1991; Schank, 1990; Davis & Waggert, 2006).

A story has a specific shape or structure, generally involving these stages: 1) the introduction of a situation or a problem, 2) the transformation or presentation of the means of solving the problem, 3) the new situation or the result of applying the solution to the situation. A story thus contains three basic elements:

- A situation that involves a conflict or predicament
- A protagonist who engages in the situation for a purpose
- A sequence with implied causality during which the conflict is resolved. (Scholes, 1981).

Adding technology to the narrative allows pre-service teachers to construct digital stories. By doing this, they develop planning skills, learn to understand the relationship between words and images to convey meaning, and come to value digital devices as tools for thinking, learning, and sharing ideas and for integrating technology in a way that will increase their future student's engagement, motivation and learning (Green, M., Walters, L., Walters, T & Wang, L., 2015).

According to Pavio (1986), human cognition is unique in that it has become specialized for dealing simultaneously with language and with nonverbal objects and events. Mayer (1997) suggested that information provided both visually and verbally has a stronger impact on learning than information provided in a single mode. When images accompany the recorded narrative in a digital artifact, the learner performs dual coding by selecting and organizing both the visual and verbal together in working memory to better understand the information provided (Pavio, 1986; Blocher, 2008).

Storytelling is not a new approach to teaching and learning. In fact, it may be one of the earliest forms of human communication. But the potential of digital storytelling to open new possibilities for teaching students to write effective narratives and to utilize computers to construct knowledge and communicate globally makes it a meaningful strategy for delivering and demonstrating knowledge across the curriculum in the 21st century (Green, 2011)

A major goal of teacher educators is to prepare their students to use technology to support curriculum as an integral part of instruction, rather than as a separate course or component (Robin, 2006, Woodbridge, 2004). Effective technology integration engages students in learning and constructing knowledge through the utilization of meaningful activities that depend on digital media (Trilling & Hood, 1999; Sadik, 2008). "Teachers need to know not just the subject matter they teach but also the manner in which the subject matter can be changed by the application of technology" (Mishra & Koehler, 2006, p. 1028). Technology must be integrated into the classroom in a manner that encourages teachers to venture beyond the familiar and integrate, reorient, and evolve technology use (Hooper & Reiber, 1995).) Learning to integrate technology into the classroom enhances the teaching techniques of pre-service teachers and assists them in providing motivating and attractive learning environments for their classroom (Serhan, 2009).

Mishra and Koehler's (2006) TPCK, (now referred to as TPACK) (Technological Pedagogical Content Knowledge) extended Shulman's (1987) framework of pedagogical content knowledge to include technology as an influential factor in developing and implementing quality classroom instruction. TPACK describes teaching as a complex and dynamic activity between three overlapping spheres of knowledge — content, technology, and pedagogy. According to Mishra and Koehler, productive technology integration in teaching requires all three spheres to be interrelated, rather than isolated (See Figure 1). Mishra and Koehler (2006) argued that new technologies provide new curricular options. They "often disrupt the status quo, requiring teachers to reconfigure not just their understanding of technology but of all three components of the TPCAK model" (p. 1030).

Math-eos combine technology, pedagogy and content knowledge, which are all the elements in the TPACK model. Along with technology, pedagogy in mathematics teacher education has undergone significant changes in the last decade, shifting from teaching problem-solving methods to teaching through problem solving. Using real world contexts and inquiry strategies, pre-service teachers construct a deep understanding of mathematical ideas and processes by engaging in doing mathematics: creating, conjecturing, exploring, testing, and verifying (Lester, Masingila,, Mau, Lambdin, dos Santon & Raymond, 1994). The National Council of Teachers of Mathematics (NCTM) Principles and Standards (2000) stated, "Problem solving is an integral part of all mathematics learning" (p. 52). Thus, problem solving should be a critical aspect of pre-service preparation for teaching mathematics.

Beyond just problem solving, Silver and Cai (1996) suggested opportunities should be provided for pre-service teachers and in-service teachers to engage in problem-posing activities. "From the perspective of teaching and learning mathematics, problem solving and problem posing have become imperative instructional approaches in classroom" (Rosli, Goldsby, & Capraro,, 2013, p. 57). Math-eos are stories created on a digital device that enable their creators to explain complex mathematical concepts in a real world context and to pose problems of their own making. In this way this new tool meets the need for mathematical problem solving and problem posing within the TPACK framework.

Methodology

Participants in the Math-eo project were sophomore and junior pre-service teachers enrolled in two Spring (N=32) and two Fall (N=39) 2014, sections of MASC 351 (Problem Solving in Mathematics, also known as Math Methods) in the elementary or middle-school preparation program at a large university located in the South Central United States. For most of the students, MASC 351 was their second or third course in the mathematics concentration of their degree plan. MASC 351 provided a meaningful context for learning a mathematics problem-solving activity applicable to their own classrooms.

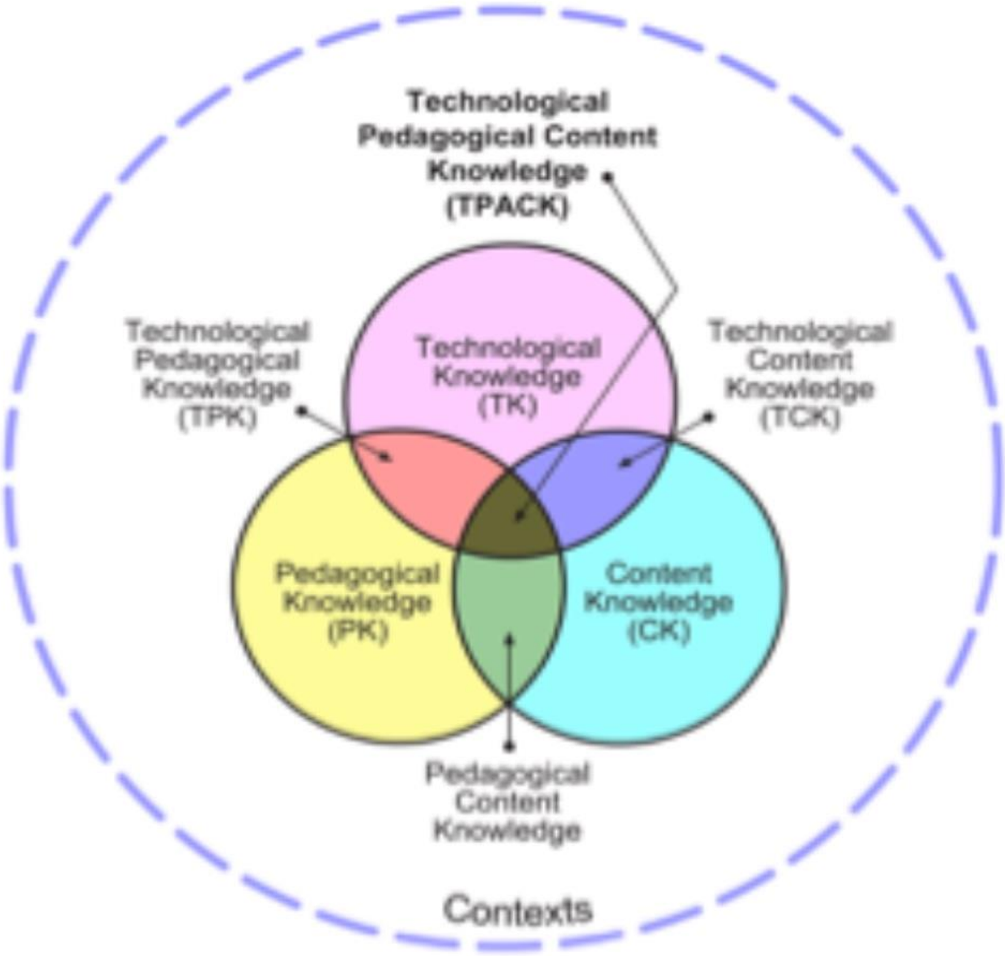

Figure 1: The Three Circles, Content, Pedagogy, and Technology (Note: Figure 1 adapted from Mishra & Koehler, 2006, p. 1025.)

Throughout the term instructors used Polya's (1957) model, which had four steps: 1) understanding the problem, 2) making a plan, 3) carrying out the plan, and 4) evaluating the solution. The last step of the Polya model involved examining the solution for the use of logical reasoning to make conjectures and verify conclusions, and for ways to identify and apply mathematics to everyday experiences. The process was orderly, step-by-step, and production oriented. It required the pre-service teachers to go beyond just finding the solution to analyzing the problem and taking the perspective of an instructor needing to see the mathematical topics required to solve the problem (Polya, 1957).

The MASC 351 students had been working with Polya's four-step model for several months when they were introduced to the concept of a digital story to explain a complex mathematic problem in a real world context. One of the researchers delivered an in-class presentation, distributed handouts on the production process and created demonstration videos to teach the technology required to construct a Math-eo on an IPad or tablet. The Math-eo project was a class assignment, required of all the students, but only those who consented were asked to participate in the Attitude Survey, the Technology Usage Survey, and face-to-face interviews.

The class, now divided in groups of four, used the next two months to follow a step-by-step procedure that involved a planning segment, emphasizing writing and organization, and a production segment, emphasizing digital technology skills using software and devices with which most students were unfamiliar. The end product was a 3-5-minute digital video (or Math-eo). The Math-eo narrative revolved around a real-world situation, suitable for exploration in the elementary/middle grades, to explain a mathematical concept. Participants creating their own settings, which included a trip to a grocery store or restaurant, planning a birthday party, or recording weather temperatures (see links to Math-eo examples).

Developing the Math-eo required the pre-service teachers to

1. Select a problem, solved using a mathematics-based approach, within the narrative;
2. Write the real-world problem situation (narrative)
3. Determine how to solve the problem using Polya's (1957) four-step model (understanding the problem, making a plan, carrying out the plan, and evaluating the solution);
4. Write a script for the video, breaking it into logical chunks;
5. Draw or develop the visuals, as their students would, using photos, drawings or videos from other digital devices, to extend the meaning of the script;
6. Create a storyboard to organize and visualize the video and to connect the narrative chunks with the illustrations;
7. Record the script using the free software program Audacity;
8. Assemble the video employing freeware including Window Movie Maker 2.6 or iMovie.
9. Share the Math-eo with fellow pre-service teachers on the last class day.

A 20 question pre-project survey was conducted to evaluate pre-service teachers' attitudes toward writing in mathematics, the problem solving process, digital technology and computers, and importance of visual representations. Students also competed a post-project survey on the same 20 questions asked in pre project survey. A technology usage survey, developed and validated by one of the authors, was administered before the participants began work on the Math-eo project. This evaluated pre-service teachers' regular usage of technology for communication, presentation, and development of digital projects (Green, 2011).

In the technology survey, which they took before they had exposure to the Math-eo process, respondents reported how often and for what purpose they used digital media hard and software, which turned out to be primarily for personal communication, writing, and for completing online or hybrid course components. The survey showed only occasional use of multi-media and presentation resources; thus students were largely unfamiliar with both the process and the technology that could be used in digital storytelling. What this means is that the pre-service teachers saw the importance of technology in their own lives, but they could not capitalize on its educational potential, not having the opportunity to see how it fosters learning and can be integrated into the curriculum (Goldsby, Rackley, Allen & Yetkiner, 2010).

After the written and video portions of the project were completed, participating students answered four open-ended questions online. These questions related to the process of creating the videos.

1. What was the benefit of the digital writing portion of project on your learning and understanding of mathematics problem solving?
2. How did engaging in the Math-eo Project change the way you feel about using digital technology and writing to teach mathematics?
3. What part of the project did you like best?
4. How would you use a similar digital writing and problem-solving project in a future classroom?

Their responses to the open-ended questions were analyzed by three of the researchers using emergent coding. The themes that developed can be grouped according to the three elements of the TPACK model: technology, pedagogy and content knowledge.

Results

Emergent Theme: Technology

The project improved pre-service teachers' digital skills as well as their understanding of how to incorporate technology in a lesson plan. A few students had problems with the hard and software and were reluctant to use the devices in the classroom. However, most of the project participants saw the end value of the technology, its ability to enhance mathematical understanding and to connect with digitally savvy young people in a future classroom. Said JJ, "Even though creating this project was very hard and took a lot of time, it was one of my favorite projects since I have been in college. It made me truly realize that a math problem don't have to be boring…. You can make it fun and engaging for your students."

Most project participants did not find the hardware difficult to master or the software complex or confusing and believed that students in their classrooms could use both without much difficulty. “I would let the students do it,” said KG. Audacity, IMovie and Movie Maker are not hard programs to use at all. Middle school students are more than capable of using them.”

“The Math-eo project and the technology that accompanied it were very simple to use,” said MM. “I normally am not a fan of using technology in complex ways, but the Math-eo project was more user friendly than I had originally thought.” Said another, “this project gave me a sense of familiarity with technology, to the extent that I do believe it can be beneficial in the classroom.”

Familiarity with this technology was seen as critical because teachers must keep up with the future. “Since technology is growing so fast,” wrote JJ, “it is important for teachers to understand and take advantage of the fact that so many students are attracted to the technological aspects of the classroom.” Said VR, “I think it helped me understand there are different ways you can teach mathematics to students.”

The benefit to KC “was to use new technology to… be able to explain the information I already know in a more visual way for different types of learners.” SM felt the project helped her “think outside the box” Another benefit was that, once created, the Math-eo videos could be saved and shared far into the future. “Although it may seem like a hassle to put together a video and audio presentation,” said JT, “an advantage is that you can save them and re-use them through the years.”

The Math-eo project was also viewed as an extension of technology in the classroom. “I now know how to create a fun video that will grab my students’ attention,” said AM. “Before creating a Math-eo, I thought the only way to use technology in a classroom was with a Smart-board.” Added BB, “The project changed the way I feel about using digital technology and writing to teach mathematics…. I didn’t realize how much adding visuals could help while teaching mathematics.” Said CC, “I used to think that math was best presented by hand. The Math-eo project helped me realize that math problems, especially word problems, can be used very effectively in a digital setting.” “Working on “the Math-eo project completely changed my perspective on using digital technology to teach math completely,” said HH. Creating my Math-eo video showed me just how many different ways you can make math enjoyable for students….”

Others agreed, noting that incorporating technology with writing and visual representation in mathematical problem solving would make mathematics more interesting and fun for students, increase their attention and motivation and get them more involved in the lesson. The conclusion was that creating a Math-eo was a “cool tool” (CB) and a “fun and easy way to enhance math lessons” (EK).

Said HH, “engaging in the use of digital technology and writing changed the way in which I want to present problems in the future because being able to illustrate my problem was fun, and I think students will really enjoy working problems on their tablets presented in this fashion.” Said SH, “I will use many of these digital and problem solving projects in my future classroom because it is important to keep the children in the classroom engaged and willing to participate in activities.”

Innovative teachers are always looking for new ways to present information, as the likelihood of facing a diverse classroom, the emphasis on technology and the demand for accountability require them to use many different instructional methods. “Today, children are more comfortable using digital technology than a pencil, so I think it is extremely important that we evolve with them.” Added KS, “Teaching the same way every day can become boring, but if you use a new approach every once in a while, it will help the students say focused during class.”

Emergent Theme: Pedagogy

Of the 71 pre-service students who participated, only a few said that the project offered little or no benefit to teaching or learning. Some, like JJ, were “unsure how the Math-eo might aid in the student’s understanding.” Others believed that the project was very time consuming and the video was too short to make any significant difference to instruction or understanding. However, as BS noted, “videos take a lot of time and energy to produce, but it is worth it in the end when it helps in lesson planning and delivery and makes it possible for a student to better engage in class.”

Engagement was a term that cropped up often in the pre-service teachers' responses to the open-ended questions. Boredom was noted as a key issue, particularly with respect to mathematics and particularly with respect to today's students, who are used to being entertained. "Based on what I hear from most students today," said KG, "math is boring and irrelevant. Students feel they will never use the information presented to them in their math classes. This project goes on to prove that math is used in our daily lives, even when we don't notice."

The pre-service teachers also felt that creating a Math-eo would help their own students learn. CA said, "I was able to experience how students can understand a problem better by presenting it visually." JB added, "I learned that I could not assume that the students knew everything required to solve the problem. I had to include all the details."

Another term that appeared in many pre-service teachers' responses to the open ended questions was creativity. Many liked the creativity that the process inspired. Some expressed delight in drawing the visuals, even if they were not particularly skilled in drawing, and many more expressed pleasure in making the video. "I liked creating the video and using the voice-over tool," said KM. "I really enjoyed using my creativity and planning the video." Added JM, "my favorite part of the project was getting to draw it out…. It gave me a chance to come up with my own scenario." Wrote JD, "My favorite part of creating the project was making the digital story myself. It was very interesting to see how exactly you create a digital story and how many different components go into creating one."

Additionally, many noted that learning the technology was interesting, though challenging. JB "liked learning how to use new software the best," Added JT, "I like how there is a great degree of customization that comes with using digital technology. With enough knowledge, there are endless possibilities for how a teacher would implement digital story telling into the classroom." Lastly, KG liked the attention-getting possibilities of the end problem. "I believe hooking the children in on a casual topic that leads into the material makes learning more enjoyable. Then helping them try a similar problem on their own would help me to see who is understanding the material and who needs clarification."

Collaborative learning was seen as another benefit of creating digital stories. Students, who had been divided into groups of four to design and produce their videos, liked the brainstorming process and working in groups to develop lesson plans. For some, this was the first time they had worked in collaborative learning groups in a math methods class. They were pleasantly surprised that it worked so well. Said SS, "our group had a particularly good time working together in authoring our problem, and we all remarked how we hope to have moments like this when we are actually teaching in the field." Added, JX, "not every individual was talented in all aspects of the project, so we were able to pull our strengths together to make a better project than any of us could have made on our own."

Emergent Theme: Content Knowledge

Most believed that the Math-eo product and the problem solving process were valuable because they encouraged orderly thinking necessary to attain and retain mathematical knowledge. The process made the project easier for several reasons. HH found it helped "to write out what I was thinking." RC "liked being able to draw out what I want(ed)" and breaking the problem down, required by the storyboarding process, also "made me understand a lot more." PT felt that "It was helpful in learning how to break apart problems into manageable sections, so that the problem could be explained clearly."

This step-by-step understanding was also important for their classroom students. "I think the video helped me realize how important it is to effectively connect many ideas," said IT … I feel that this video was a good way to introduce a concept step by step and make it appealing to the students." Added AM, "Through the entire project we were able increase our awareness of how students approach problems by having to break down the concepts into simple steps.".

Some of the respondents focused on the ways in which writing could contribute to understanding of mathematical concepts. "My view on incorporating writing has changed," wrote KJ, "because I was able to see the benefits to writing out the steps on how to approach the problem. It provided a lot of clarity in places in which just talking out the steps would lead to confusion." As noted by Bicer, Capraro, & Capraro (2013) the writing process serves as a mediator of students' problem solving skills. This integration of writing into mathematics classrooms develops students' mathematical thinking abilities and skills, as writing in mathematics requires students to demonstrate how and why they know things, as well as what they already know (NCTM, 2000). Pugalee (2001) in his study stressed the importance of implementing writing as an integral part of the mathematics curriculum. This inclusion of writing in a project, exemplified here by the creation of the script for the Math-eo, supported the students' learning of a problem solving process. Said JJ, "The part of the project I enjoyed the best was the actual writing of our problem and the outline for the rest of our story….It was not just another run-of-the mill textbook problem."

Visualization was important too; many of the participants noted the differences between visual and verbal learning. Thus, one benefit of the digital writing project was by "visually seeing the different steps of the problem-solving process. I am a very visual learner so to see how you could break the steps down and do so in a visual way was very beneficial to me," noted TJ. The writing process provided enhanced cognitive opportunities for externalizing internal representations for direct interpretation; the writing process enabled students to gather, analyze, and interpret data (Nahrgang & Petersen, 1986).

An additional benefit was creating better and more creative lesson plans. CB believed that the pre-video writing process helped "me think more deeply about mathematical concepts and the problem-solving project. I really had to think about what I was going to say and how I would say it." This supported Emig's (1977) idea that writing helps students analyze, compare and contrast, and synthesize relevant information.

Tying the projects to the real world was seen as another benefit. Added one participant, the "digital writing project helps us in creating a real-world type problem that is applicable to the middle-school classroom setting." Said MP, "I was able to formulate a scenario from the real world where we are supposed to use mathematics problem solving." Others agreed with this perspective. Said JI, "the benefits I saw in this project were creativity and knowledge-based because it had to be an interesting problem appealing to middle school students."

While a few pre-service teachers "didn't like this project," the majority enjoyed the creative process, the creation of materials, and learning the technology. Many participants noted that learning to use Polya's four-step process changed the way in which they learned by making the process more orderly. "My favorite part of the project," wrote KJ, "was using Polya's four-step problem solution. I really liked using this tool because I have seen how it efficiently organizes problem solutions." AD "liked getting to discuss why each step of my process was important, and it was fun to match my explanation to the pictures."

EK said that her favorite part was "developing a story that would engage student interests," and PT added, "Sometimes I struggle when trying to explain a problem only using words, so visuals were a huge benefit to me in this." Added, PS, "My favorite part was being able to come up with my own story. There is such a broad range of creative stories to implement…."

Emergent Theme: Math-eos in a Future Classroom

Several pre-service teachers saw making Math-eos "tedious and time consuming" and were unsure if they would incorporate them in a math curriculum when they had elementary/middle school classrooms of their own. Others felt that the process and the technology were useful, but had to be modified based on grade, mathematical knowledge, course structure, student motivation, that is, Math-eos were "not meant for all," One kindergarten teacher suggested modifying the process for the youngest students. "I don't think I would have (my students) create a digital writing project on their own," she said. "I would create a problem and then in groups have the students draw pictures to represent what the problem was about. Then I would put it all together to create a digital problem-solving project for them to use and view."

Others agreed that the process should be age appropriate. Using this digital and problem-solving project in a future classroom would depend largely on the age group I am teaching," said JB. "If I have younger students, I would present them with a written problem and ask them to draw out illustrations to follow the problem. If I had older students, I would use a process very similar to how we used it." Added RH, "depending on the grade level, we could simply use it as a great way to engage our students in a lesson we are about to teach."

Many thought Math-eos would help their middle school students learn. LS would "use it in a flipped classroom setting." KS agreed that "videos are good if you make your classroom a flipped classroom. The videos can be used for the students to watch at home so they come to class the next day already knowing the material."

BT "would have the kids make their own video," as would KM, who "would create a problem for students to solve through the video." Added ST, "I will use digital writing to introduce new concepts. This will grab their attention and get them excited to learning new things."

A principal reason for using this technique was that the Math-eo was seen as an engaging, helpful tool available inside or outside the classroom. "I could put extra help videos online for struggling students," said AG. AD said that she "would create similar videos that students can download on their computers/ iPads/tablets/other devices in order to receive supplemental instructions and problems." The students," she said, "could access in the classroom as well as at home so they can re-watch it if they get confused."

Noted JS, "the project was also a good starting point for getting used to integrating technology into our future lessons. Problems in digital formats, like the ones we created, are the future of integrated involved math courses." JB explained how the experience had changed her perspective. "Before I did not think technology should be used this way in a mathematics classroom because it would hard for the students," she noted. "But after the project I realized that digital writing can be used."

Many participants thought that their students would also be more active in a process using the Math-eo technology and process. "In the future, it would awesome to pretty much use this exact lesson plan in a classroom," said JB Reflecting on this process, BP wrote, "I could have the students fill out a chart or something where they are basically filling in all the necessary components of Polya. Afterwards, I would have them apply what they have used to another problem so they can see different applications of a solution style. I would also like to compare how they have solved their problems differently so they can know that solutions can vary and still be correct."

"Any problem can be put to a story because all problems have an application," said JB. "If the time is taken to put together a solid lesson plan with a quality digital story, they can be used year in and year out." Added JT, "I would use a similar setup in my future classroom. Instead of a generic mathematics problem, I would create a math problem related to the school and bring in the principal or administration to voice over the storyboard…. This would help bring mathematics to life."

This student recognized the importance of being able to pose appropriate problems to students. As Rosli et.al (2013) noted from an instructional perspective, teacher educators should emphasize problem-posing activities in class and provide scaffolding for pre-service teachers to experience the process of generating and reformulating mathematical problems. When they gain some background knowledge and experience posing their own mathematical problems, they should not hesitate to incorporate them into their repertoire of teaching strategies. JB appeared to agree. He wrote, "I think that this project is very applicable to several different classroom settings. A problem-solving video is truly limitless in its potential to have a place in any age level or math content area." JT said, "I can see myself making different Math-eo presentations for all kinds of problems or any new concepts that come to the attention of the class."

Many believed that using real-life situations make mathematics most relatable for students. Said AM, "you could even do a project as a class and come up with the story together to ensure the students really understand the mathematical process because you are helping to guide the story." Added AJ, "I would use it as an engagement activity. I think that it would give something for students to attach to and realize what they are learning is going to be used in real life."

"I would have my students find a topic that they were not particularly strong in," said JB, "and have them do a narrative that could relate to that topic and challenge their minds." Said HW, "I could assign this project to groups, assign topics, and have the students search in the real world on how to use these topics or math skills outside of the classroom and convert their information into a video of what they found and how it can be solved." Said AT, "I would give different sections of a specific chapter to groups in the class and allow them to create their own digital video to show to the class. This gives the students incentive to really learn and under the material they will be given… It will also give me a chance to see what interests them and helps them learning so I can implement that in my future classroom. Added, KB, "I could also make up my own problem if the children are having difficulties with a certain skill, so they will have another way to see the problem being worked out."

Several participants noted the power of the Math-eo to attract attention and make learning more fun. "I would incorporate a funny story in some of the more boring lessons," said JB. "By doing this, I hope that the students would be a little more engaged. If they did not pay attention to me, they might at least remember the video." Said MY, "I think that by doing this the students would really enjoy working with technology and making their own story." KA thought that this project would "help keep the students interested and excited about problem solving" … and also would help them "understand and connect to the problem better."

One barrier to incorporating the Math-eo project in the classroom was the need for administrative support. "I do not see myself making math videos for my students because in middle school," said KS, "the content is more formula-based than it is story based." Added KR, "These videos take a lot of time to put together, so I do not plan on using them often. However, I plan on implementing voice threads, podcasts, and technologies such as IPads and smartphones to engage my students in the lessons and take learning outside the classroom." Students did note that having access to the videos created by classmates would give them some examples to utilize in the classroom and offset the time constraints.

Recommendations

This pilot study showed that engaging in a digital project increased pre-service teachers' understanding of the problem solving process and their awareness of the relationship among visual, auditory and verbal representation in critical thinking/problem solving in mathematics. Project participants said that the Math-eo was a "cool new tool" for their own learning and teaching and for supporting their ability to integrate digital technology in mathematics education. The inclusion of technology, the pre-service teachers noted, would increase their own students' engagement, motivation and understanding of content.

Responses to the Likert scale attitude survey with the largest pre- and post-score differences were those concerning visual representation, using digital technology, writing, and organizational skills. The pre-service teacher indicated that writing about a mathematics problem helped them to solve it. They agreed that digital images are a symbolic form of language and that reflecting on writing helps with the revision process.

Results showed that these pre-service teachers believe that visual representations help their students and themselves remember information and understand math problems. Whether they intend to use the Math-eo in the classroom depends upon several considerations. One is how strongly pre-service teachers felt that creating a classroom product, like a Math-eo, motivated them and their future students. The higher they perceived the level of motivation, the more likely they were to use digital storytelling as a teaching strategy.

Another consideration is how they felt about technology and learning new software. The better they felt about computing, using a tablet and learning new technology, the more likely they were to use that devices in the classroom. This suggests that pre-service teachers heading for careers in mathematics education should be taught technology skills early and often in their college courses. As Heo (2009) noted, exposing them "to effective educational technology early in their learning can have a critical impact on their long-term development toward technology efficacy" (p. 410).

Lastly, though many pre-service teachers in the Math Methods course believed that writing helped them learn, some seemed uncertain of their ability. The more confident they were in those writing skills, the more likely they were to enjoy writing. The lesson here for teacher educators is to provide more support and practice in writing for the nascent elementary/middle school instructors in their college classrooms.

The technology frequency survey indicated that pre-service teachers actually were not familiar with the educational applications of hard and software. They used digital devices primarily for personal communication, writing, and online course submission. The survey showed only occasional use of multi-media and presentation resources, including video cameras, audio recorders, scanners, simulations and graphics tools. This might explain the difficulty some had with digital storytelling and their reluctance to use digital technology in their future classrooms. While these pre-service teachers may be from the digital age, they mostly use the communicative and entertainment functions of the media. Their previous usage of technology was based on being an end-user not a content provider.

Two principal obstacles to development and use of Math-eos emerged in this research project. First, was the need for training to overcome the notion that the process and the software were too challenging for classroom use. The research design may have contributed to the notion that Math-eos were difficult to create. The project was embedded in an established course, one in which students were neither expecting nor prepared to use technology in this fashion. What may be needed instead is "guided entry" to help teachers who might want to develop videos for teaching and learning in the classroom. This means a stand-alone course whose content includes a pedagogical framework and justification for developing these digital materials and more practice using hardware and software. Second, time and support are required of a school district. If content is to be developed to inspire today's students, administrators must be willing to help.

One benefit of developing the materials is that, in essence, the development and use of a Math-eo makes every teacher an action researcher and every student a designer of lessons that can be used to teach mathematics to fellows around the world. Imagine the database of Math-eos that could be created and supported by an online library of completed materials, available for all to use.

Future Research Directions

Collier and Veres (2006) stated that universities must provide pre-service teachers with opportunities to learn and value technology skills to understand how to utilize technology as tools for learning and teaching. Disrupting the educational status quo requires teachers to reconfigure not just their understanding of technology, but also of content and pedagogy, that is, all the elements of the TPACK framework (Mishra & Koehler, 2006)

The TPACK-grounded video instrument for mathematics education discussed here also requires an understanding of writing. The Math-eo is based on a script of 250-500 words, the creation of which is the first step in the production process. Writing in the classroom is a topic that has generated much research and literature. Bunnett (2007) saw writing as "extremely important tool" in assessment of the student's understanding (p. 3). Writing in the classroom guides students to justify their thinking and solutions. As students write more in math, they became deeper thinkers of math. Kjos and Long (1994) found that, with more experience in writing, students' "attitudes about their own mathematical ability improved and [they developed] an increased ability to write about their thinking. "Writing also permits students to collaborate with each other. "Effective communication is an important skill to mathematics because it is a way to share the knowledge and understanding that one has built" (Bunnett, 2007, p 4).

As students become deeper thinkers in the classroom, their confidence level and self-esteem grow. Beyer (2011) said, "There is a direct correlation that writing in mathematics can improve students' written mathematics expression, thus improve their mathematics" (p. 14). Mastery of a skill or concept happens when students feel confident. And that confidence is what allows them to learn and teach with the creation of Math-eos.

In the real world, content, pedagogy, and technology exist in a dynamic equilibrium. The traditional view of the relationship is that content drives most decisions and pedagogical goals and technologies normally flow from the choice of what to teach. However, today's relationships are rarely that clear cut. Especially when newer digital devices are considered, technology drives the decisions made about content and pedagogy (Mishra & Koehler, 2006). In the scientific disciplines, Dunleavy and Heinecke (2007) found that computing had a positive effect on achievement among at-risk middle school students. A meta-analysis showed technology, collaborative learning, and enhanced learning contexts were among the teaching strategies that had significant, positive effects on scientific knowledge (Schroeder, C., Scott, T., Tolson, H., Huang, T. & Lee, Y., 2007).

Such are the very features of the digital projects in mathematics. Previous research has indicated that computer technology and classroom collaboration can help support learning and, in combination, are especially useful in developing the higher-order skills of critical thinking, analysis, and inquiry "by engaging students in authentic, complex tasks within collaborative learning contexts" (Roschelle, Pea, Hoadley, Gordin, & Means, 2000.)

There are four fundamental contributions that allow technology to enhance both what and how children learn in the classroom (Roschelle, et al. (2000): 1) active engagement, 2) participation in groups, 3) frequent interaction and feedback and 4) connections to real-world contexts. Nevertheless, technology per se is not the total answer, regardless of whether that technology is pen and ink or computer software and electronic devices. Technology is always more effective as a learning tool when embedded in a broader education reform movement that includes improvements in teacher training, curriculum, student assessment, and a school's capacity for change. The characteristics of digital technology, its spontaneity, immediacy, interactivity, and its capacity to promote self-evaluation, offer a new type of data with interpretive potential and global and community based applications.

Technology is easily accessible to this generation of students, as repeated surveys from the Pew Charitable Trust have shown (Lenhart, 2015). Using the tools, like the IPad or tablet, with which students are comfortable and showing them how they can use these various tools to enhance their learning experiences in school can lead to positive literacy teaching and learning. Clearly the inclusion of multiple modes of meaning making in the curriculum puts the program of study "in sync" with the changes in today's public communication.

Many teens download video from the Internet and upload their own work. This interest and skill in student-generated media products should cause teachers to assign digital documentaries that address topics within the curriculum. Students learn better through words and pictures than words alone and learn better from graphics and narration than graphics and text (Green, Walters, et. al, 2015).

Effective technology integration requires leadership, support, and modeling from teachers, administrators and the community/parents. Effective professional development for teachers in the integration of technology into instruction is necessary to support student learning (ISTE, 2015). Teachers' direct application of technology must be aligned with curriculum standards, and technology must be incorporated into the daily learning schedule. Used properly, student collaboration in the use of technology is more effective in influencing student achievement than strictly individual use. Project-based learning and real-world simulations are more effective in changing student motivation and achievement than drill-and-practice applications (ISTE, 2015).

Conclusion

Digital storytelling can serve as a bridge between people and disciplines, encouraging a historian, for example, to delve into multimedia applications, while exposing a computer scientist to the ideas of narrative through family lore. Creating and watching digital stories potentially increases the information literacy of a wide range of students. Moreover, digital stories are a natural fit for e-portfolios, allowing students to select representative artifacts from their academic careers and to create compelling resources that demonstrate the student's learning and growth (Lombardi, 2007).

Student-produced digital video can also enable more authentic learning experiences (Schuck & Kearney, 2004), additionally providing students with a sense of ownership (Kearney & Schuck, 2005). In many instances, the creation of student-produced films provides students with opportunities to engage more deeply in the subject matter than otherwise possible (Hofer & Swan, 2008-2009).

Problem-solving teaching strategies for mathematics, that include storytelling and provide a meaningful context that connects mathematics and literature (Casey., Kersh, & Young, 2004, Wilburne & Napoli, 2008), may also increase literacy for the interpretation of mathematics in various environments (Albano & Pierri, 2014). Multiple representations of mathematical problems in stories may support comprehension in mathematical problem solving, understanding of textual information and visualization of data (Jonassen, 2003).

Appropriate technologies are increasingly available to both pre-service teachers and school children. Immersed in multimodal digital designs, these learners are able to create personal representations of concepts that can provide a powerful cognitive and social learning space (Hoban, Loughran, & Nielsen, 2011). Hence, digital storytelling has the potential to facilitate narrative by means of multiple modes of representation and the sharing and consumption of interactive content (Spaniol, Klamma, Sharda, & Jarke, 2006).

When taught through digital storytelling, students learn how to apply conceptual processes. Albano and Pierri (2014) suggested that this comprises three steps: 1) the formulation of a scenario incorporating a mathematical problem in the form of a story, 2) the application of mathematical concepts, procedures, reasoning; and 3) interpretation by applying the mathematical problem-solving strategies in a context of the chosen story. Students in the Starcic, Cotic, Solomonides, & Vok, study (2015) reported that they were developing technical competency, pedagogical competency and mathematical content knowledge through designing the digital stories. Integrating the narrative with the mathematical problem helped facilitate their understanding of problem structure and developed their problem-solving skills. Multimodal digital design, with respect to the concrete and visual representations of a mathematical story, offered advantages in comparison with analogue "paper and pen" designs.

Pre-service teachers in the Starcic, Coltiv, et. al study (2015) argued that digitalization of artifacts created by students is stimulating for parents, teachers and for the children themselves. First, the stories are authentic expressions of children's lived experience and builds on their imagination. Second, creating a story with a narrative, integrating various forms of creation and expression, is both an enjoyable and intrinsically motivating learning activity. Digital storytelling facilitates creativity and personal expression in the learning process and provides connections with prior experiences and schema needed to actively construct knowledge. Third, digital storytelling is perceived as providing opportunities for the co-creation of artifacts and creating understanding between and among teachers and the children in their classrooms.

One significant criticism of pre-service education has been that it does not prepare teachers to feel confident in using computers or digital devices in their teaching (Huang, Lubin & Ge, 2011; Sang, Valcke, van Braak & Tondeur, 2010) and that this deficiency remains despite the presumed digital literacy and abilities of the "next-generation" university students (Funkhouser & Mouza, 2013; Lei, 2009; Mouza, Karchmer-Klein, & Hu, 2014). Integrating technology into pre-service teacher education, based on the experiences of these students, should promote new tools for the development of learning activities.

Computer-based learning designs use the affordances of digital media formats, such as text, graphics, audio and video, so that the symbolic, static and dynamic representations of problems and other learning activities might be presented in several ways (Bodemer, Ploetzner, Feuerlein, & Spada, 2004). Thus, multimodal design in teaching must respond to new literacy requirements by providing instruction that can support multiple representations in learning (Miller & McVee, 2012) and help student teachers move from teacher-centric views to more student-centered conceptions and beliefs. (Chai, Ling, Tsai & Tan, 2010).

Incorporating technology capacity-building into the curricula and pedagogies for pre-service education can be facilitated in several ways: through stand-alone courses, integration into existing courses or through practicing technology in the field (Kay, 2006). However, the effectiveness and impact of education for digital literacy is limited when technology skills are taught in isolation, removed from the broader curriculum, or de-contextualized (Huang *et al.*, 2011; Moursund & Bielefeldt, 1999; Hare & Howard, 2002). Teaching computer-based technology in context is the most effective way to achieve the ends (Kay, 2006).

Mouza *et al.* (2014) identified an integrated approach, combining educational technology courses with methodology courses and student teaching, as being most efficacious. Practicum placement in schools provided an authentic context for observation and reflection of computer-based technology to use and test the digital stories with pupils. The design of authentic tasks, developed during an educational technology course, prepared pre-service teachers to integrate technology in lesson plans and activities (Evans & Gunter, 2004). The strategic use of digital storytelling in an educational technology course, specifically applied to mathematics, is effective in developing the pedagogical, technical and content knowledge of pre-service teachers (Starcic, Coltiv, et. al, 2015).

The literature highlights various uses of digital storytelling, including those for educational purposes. In a survey conducted in 26 countries, Yuksel, Robin, and McNeil (2011) investigated the educational uses of digital storytelling around the world. Their results showed that digital storytelling has been used in education from early childhood to adult programs, and most research participants stated that digital stories were beneficial for supporting learning, enhancing academic achievement, and improving writing, presenting, reflecting, and language skills. Other research studies also have indicated the benefits of digital storytelling when children compose their own stories, emphasizing how preparing digital storytelling enhanced students' creativity (Bran, 2010; Liu, C., Liu, K., Chen, W., Lin, C. & Chen, G., 2011).

Schiro's (2004) study of the uses of digital storytelling to teach students algorithms and bolster problem-solving skills resulted in improving students' competencies and presenting mathematics in an interesting, engaging, and relevant context was important. Casey et al. (2004) investigated the benefits of using storytelling to teach geometry to kindergarten students. They found that storytelling was useful for improving mathematics learning in children from culturally diverse backgrounds. Similarly, other studies, such as those of Schiro (1997, 2004) and Welchman-Tischler (1992), showed that digital storytelling provides a meaningful context for mathematics problem solving by facilitating children's engagement and learning, but it should be based on a purpose and carefully aligned with teaching objectives.

The reality is that advocates of instructional technologies in schools have, for many years, been urging educational administrators and policymakers to change the focus from the technology itself to ways in which that technology can be used to bring out the very best in teaching and learning (Robin, 2008). Teacher familiarity, confidence, and skill in integrating technology into the curriculum depend on teacher training, time for self-directed exploration and learning, and available technology. The combination of powerful, yet affordable, technology hardware and software meshes perfectly with the needs of many of today's classrooms, in which the focus is on providing students with the skills they will need to thrive in media-varied environments (Riesland, 2005). Yet, many teachers have not received adequate training for selecting appropriate technologies and lack administrative support for using them.

Teachers who can create their own digital stories may find that they can be particularly helpful in engaging students in the content and in facilitating discussion about the topics presented in a story. A multimedia-rich digital story can serve as a hook to capture the attention of students and increase their interest in exploring new ideas. Teacher-created digital stories may also be used for enhancing current lessons within a larger unit, both as a way of facilitating discussion about the topics presented in a story and as a way to make abstract or conceptual content more understandable (Robin, 2008).

The TPACK model is the basis of good teaching with technology and requires an understanding of the representation of concepts using technologies; pedagogical techniques that use these "cool new tools" in constructive ways to teach content; knowledge of what makes concepts difficult or easy to learn and how technology can help redress some of the problems that students face; appreciation of students' prior knowledge and theories of epistemology; and understanding of how technologies can be used to build on existing knowledge and to develop new epistemologies or strengthen old ones. As Hicks (2006) suggested, this framework might be helpful in guiding teachers to apply their knowledge in the classroom by providing "the ability to think about and use technology in critical, creative, and responsible ways—will then develop and enhance TPCK" (p. 50).

The Math-eo Project, then, seems to meet pressing needs for learning and teaching mathematics in a way that allows educators and their students to process information critically, creatively, logically and multi-modally; to communicate digitally, visually and narratively, and to meet the needs for an engaged, informed and numerate citizenry required by the technologically-driven 21st century. Such technology leads to increased learner motivation, better outcomes on standardized tests, increased student reflection and a wider and deeper understanding of mathematical problem solving.

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