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Elementary School Teachers' Use of Technology During Mathematics Teaching

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Various educational technologies have been advanced as potential vehicles to transform teaching and learning. Still, research studies have documented that primary school teachers struggle to integrate technology in meaningful ways. This article presents the findings of a year-long study in which the author frequently observed three primary school teachers' enactments of technology into their mathematics teaching. Each teacher was observed between 25 and 30 times during the school year. The types of technologies used as well as the types of mathematical tasks and problems that participants posed while teaching with technology were inductively analyzed. Inductive qualitative analyses indicated that participants' technology use focused on presentation technologies such as the document camera or interactive whiteboard more than computer-based technologies or interactive activities. Further, teachers varied widely in their enacted pedagogies while integrating technology, and two participants demonstrated more frequent enactments of learner-centered pedagogies toward the end of the school year. Implications for researching teachers' use of technology in the future are also shared.

KEYWORDS *technology integration, mathematics, TPACK, mathematical tasks*

In the United States, billions of dollars have been invested in purchasing technology-related resources (New Media Consortium, 2014). In the past decade, this immense investment of federal and state monies has focused on

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purchasing technologies such as handheld devices, interactive whiteboards, and document cameras. Despite the purchase of these and other technological resources, there is mixed evidence about their impact on teaching and learning (International Society for Technology in Education, 2008; New Media Consortium, 2014).

Researchers have put forth many empirically based and anecdotal explanations about why technology has yet to largely transform teaching and learning in K-12 school settings. These ideas range from teachers' limited knowledge related to integrating technology (Niess, 2005), lack of effective professional learning opportunities (Lawless & Pellegrino, 2007; Polly & Hannafin, 2011), and teacher beliefs that there is conflict with expected enacted pedagogies and uses of technology (Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur, & Sendurur, 2012; Ottenbreit-Leftwich, Glazewski, Newby, & Ertmer, 2010). While these studies have closely examined barriers that impede teachers to effectively use technology, these studies have focused on general technology use, and not on content-specific use. This year-long study focused solely on primary school teachers' integration of technology into their mathematics teaching. The focus of technology integration in only one content area allows for a more focused look at the interplay between teachers, their students, the technology, and the mathematics content that they are teaching.

THEORETICAL FRAMEWORK AND LITERATURE REVIEW

Learner-Centered Instruction

This research study was based on the theoretical framework of learner-centered instruction (American Psychological Association [APA] Work Group, 1997; McCombs, 2003). In 1997, the American Psychological Association published the empirically based *Learner-Centered Psychological Principles: A Framework for School Reform and Redesign* (APA Work Group, 1997) that provides a foundation for processes of teaching and learning (McCombs & Whisler, 1997). The *Principles* were grounded in research from the fields of educational psychology, educational technology, or domain-specific fields (Alexander & Murphy, 1998). McCombs and Whisler (1997) adapted the *Principles* for K-12 education. Table 1 details the characteristics of learner-centered tasks along with alignment to the *Principles*.

Learner-centered epistemological views align with sociocultural views of learning (Tharp & Gallimore, 1988): an active process heavily influenced by social contexts such as collaboration with peers, scaffolding from teachers or more knowledgeable others, and social negotiating or discussing concepts. Learner-centered views also value information processing and cognitive theories regarding teachers' need to identify and build off of learners' prior knowledge and experiences (Alexander & Murphy, 1998). Through its

TABLE 1 Characteristics of Learner-Centered Tasks (Adapted from McCombs & Whisler, 1997; Polly & Hannafin, 2010)

Task	Characteristic	Learner-centered tasks are:	Learner-Centered Principles (APA Work Group, 1997)
Design	Relevant	Personally relevant to students' lives and build upon prior experience or prior knowledge.	The learning of complex subject matter is most effective when learners construct meaning from information and experience (Principle 1). The successful learner can link new information with existing knowledge in meaningful ways (Principle 3). An individual's motivation is influenced by his/her beliefs and interests (Principle 7), the learner's creativity and curiosity (Principle 8), and background and experiences (Principles 10, 12, and 13).
	Student-directed	Designed so that learners have ownership of the tasks they are completing, are able to choose their approach and have some influence about how the products of the task are represented.	An individual's motivation is influenced by his/her beliefs and interests (Principle 7), the learner's creativity and curiosity (Principle 8), and background and experiences (Principles 10, 12, and 13).
	Reflective	Reflective and allow learners to refine their understanding and make connections between concepts or approaches used to complete the task.	Higher order strategies for selecting and monitoring mental operations facilitate creative and critical thinking (Principle 5).
	Assessment	Aligned with assessment so that learning is evaluated in the context of the task.	Setting appropriately high and challenging standards and assessing the learner as well as learning progress—including diagnostic, process, and outcome assessment—are integral parts of the learning process (Principle 14).

(Continued on next page)

TABLE 1 Characteristics of Learner-Centered Tasks (Adapted from McCombs & Whisler, 1997; Polly & Hannafin, 2010) *(Continued)*

Task	Characteristic	Learner-centered tasks are:	Learner-Centered Principles (APA Work Group, 1997)
	Technology-rich	Able to be supported with technology that allows students to gather information, explore concepts, collaborate with peers, or represent knowledge.	Learning is influenced by environmental factors, including culture, technology, and instructional practices (Principle 6).
Implementation	Facilitated	Facilitated by teachers or peers that model, scaffold student learning, and facilitate the completion of the tasks.	The successful learner, over time and with support, can create meaningful, coherent representations of knowledge (Principle 2).
	Collaborative	Implemented in a manner that allows students to collaborate and share ideas with one another.	Social interactions, interpersonal relations, and communication with others all provide opportunities for learning (Principle 11).

empirical foundation, the *Principles* provides a pragmatic, research-based set of ideas to support the design of educational systems and instruction (McCombs, 2003).

Technology's Role in Learner-Centered Instruction

While educational technology is not a central aspect of the *Principles*, its authors and those who have built off this framework (e.g., McCombs & Whisler, 1997; Orrill, 2001) have cited the importance of technology as a tool to support teaching and learning. Principle 6 states that learning is influenced by environmental factors, including culture, technology, and instructional practices.

Technology as a learner-centered tool supports teaching and learning in a number of ways. This study focuses on technology integration in elementary mathematics classrooms where it has the potential to enhance teaching and learning experiences by providing opportunities to (a) support students' task exploration, (b) create dynamic mathematical representations, and (c) model mathematical situations.

Support Students' Task Exploration

Technology tools allow students to organize data, model mathematical situations, and support calculation work (National Council for Teachers of Mathematics [NCTM], 2011; Orrill & Polly, 2013). These functions decrease cognitive load by allowing students to focus more on mathematical reasoning, forming and testing conjectures, and evaluating various mathematical situations (NCTM, 2011; Zbiek, Heid, Blume, & Dick, 2007). For example, while exploring the concepts of area and perimeter (typically a Grade 3 standard), students could use a Web-based tool, such as Perimeter Explorer (http://www.shodor.org/interactivate/activities/PerimeterExplorer/), to support their exploration of this task*: If you want to build a garden that has an area of 12 square feet, what are the possible perimeters of your garden?* Students put in a specific area and the tool generates either rectangles or rectilinear shapes (shapes with only right angles). Students then must determine the perimeter of the specific shapes. This tool allows them to focus on determining the perimeter on the computer-based representations, as an alternative to building rectangles with plastic square tiles or drawing them on graph paper. While each of these approaches can deepen student understanding, the technology allows students to focus more exclusively on finding the perimeter without having to draw or build each shape.

After working with the tool for a few rounds, the student can click the button Compare Areas & Perimeters, which creates a table, allowing students to analyze and make mathematical generalizations about which dimensions lead to the smallest and largest perimeters.

Create Dynamic Mathematical Representations

Technology can also support the display of mathematical representations and has the potential to support student analysis and discussion of these representations (Arzarello, 2012; Zbiek et al., 2007). Document cameras and interactive whiteboards allow teachers to display students' mathematical representations or their own examples with ease, allowing more class time for analyzing these representations and discussing connections between them (Orrill & Polly, 2013; Polly & Mims, 2009).

While solving this task—*Your family travels 100 miles in two hours. If they drive somewhere between 41 and 50 miles in the first hour how far do they drive in the second hour?*—students can use virtual base-ten blocks (http://www-k6.thinkcentral.com/content/hsp/math/hspmath/na/common/itools_int_9780547584997_/basetenblocks.html) to explore how many possible answers they can find. They can use the online tool to make 100, using 9 rods which each have a value of 10 and 10 cubes which each have a value of 1. By moving the blocks into two piles, students can explore

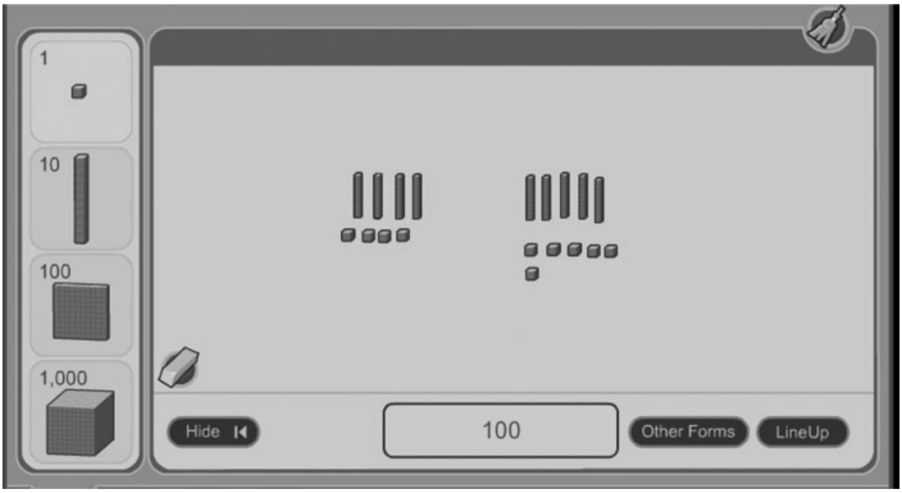

FIGURE 1 Screen capture of virtual base-ten blocks. Applet provided by Houghton Mifflin Harcourt. Reproduced by permission of Houghton Mifflin Harcourt.

different answers. (Figure 1 shows 44 in one pile and 56 in the other pile.) Based on the task, they traveled 44 miles in the first hour, which means they traveled 56 miles during the second hour. In order to find multiple solutions to the task, the student can move cubes between piles as long as one of the piles has between 41 and 50 cubes in it, since that is the range of miles traveled in the first hour.

Model Mathematical Situations

Various interactive Web sites and mobile device applications allow students to model and create representations of mathematical situations (Arzarello, 2012). Since these representations are digital, they can be easily manipulated, allowing learners to see multiple representations to compare and analyze in a short period of time (Zbiek et al., 2007).

Consider the task, *In order to set up tables for a banquet the reception company is planning on connecting hexagon tables in each row. They can put one person on each side of the table. How many people can they put around one table? two tables? three tables? four tables? five tables? As you add a table how many more people can you seat?*

Using virtual pattern blocks (http://www.mathplayground.com/patternblocks.html, Figure 2), students can model this mathematical situation and explore how many people can be seated. Students use the tool to drag and rotate the blocks and determine how many seats

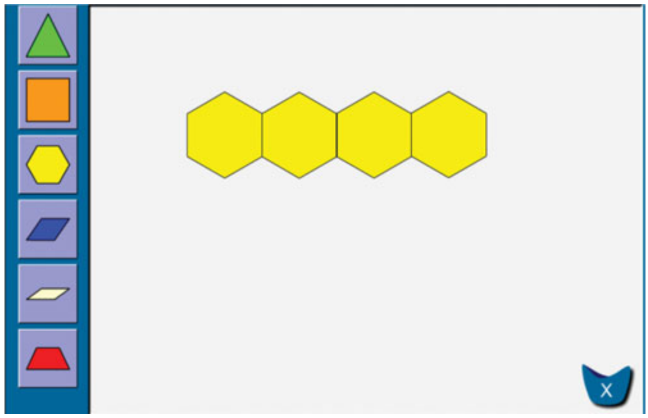

FIGURE 2 Screen capture of virtual pattern blocks. Applet provided by Math Playground. Reproduced by permission of Math Playground.

there are for each arrangement of pattern blocks. The number of seats needs to be recorded in some other way, such as on paper, in order for students to analyze and make generalizations about what they notice. While concrete pattern blocks can also be used, the virtual pattern block tool can be used easily on an interactive whiteboard, computer, or iPad, and allows students to quickly set up and modify the manipulatives on the screen.

Potential of Technology in Mathematics Classrooms

As the examples demonstrate, technology can support students' task exploration, create dynamic mathematical representations, and model mathematical situations. In each example, while concrete manipulatives or pictorial drawings could be used to explore the mathematical content, using technology provides learners with the ability to quickly generate and manipulate mathematical representations, thus allowing them to concentrate more on examining the mathematical concepts, making and testing generalizations, and making connections between the representations and the mathematics that they explore. In their position statement on technology, NCTM (2008) wrote: "With guidance from effective mathematics teachers, students at different levels can use these tools to support and extend mathematical reasoning and sense making, gain access to mathematical content and problem-solving contexts, and enhance computational fluency" (p. 1). The next section examines research on teachers' use of technology in their mathematics classrooms.

Difficulties Integrating Technology in Learner-Centered Ways in Mathematics

Researchers (Bransford, 1997; Polly & Hannafin, 2011) have documented teachers' efforts to implement technology into elementary and middle grades mathematics classrooms. The Cognition and Technology Group at Vanderbilt (Bransford, 1997; Cognition and Technology Group at Vanderbilt,1992) found that while trying to implement learner-centered technology-rich tasks, teachers struggled with implementing tasks that maintained the rigor and opportunities for reasoning for which the tasks were designed. More recently, the author (Polly, 2011b, 2012) found that, even after intensive professional development focused on effectively using technology in mathematics instruction, teachers *only demonstrated* sound implementation of technology-rich mathematical pedagogies after opportunities for onsite or email-based support from professional developers. Toward the end of the school year, however, Polly (2012) noticed that teachers enacted tasks that were learner-centered and allowed students to use technology in meaningful ways.

Research from the Milken Family Foundation found that using technology in drill and practice and non-learner-centered ways was associated with lower student achievement for eighth-graders compared to students who did not use technology at all (Wenglinsky, 1998). Further, eighth-graders who used technology to develop higher level mathematics skills such as problem solving scored a third of a grade level higher than students who had not. Additionally, from an analysis of thousands of students in the Early Childhood Longitudinal Study, the study found that using technology paired with mathematical reasoning was associated with statistically significant gains in mathematics achievement compared to reasoning without technology (Polly, 2008). This supports and extends the work of Wenglinsky (1998). Clearly, there is potential for technology to support students' mathematics learning.

In the research base around technology integration, the TPACK (technological, pedagogical, and content knowledge) framework has been advanced for teaching with technology (Mishra & Koehler, 2006; Niess, 2005; Polly & Orrill, 2012). Research indicates that teachers with developed knowledge about the intersection of technology, pedagogy, and content integrate technology into their teaching more effectively than their peers (Koehler, Mishra, Kereluik, Shin, & Graham, 2011; Polly, 2011c). Furthermore, research (Ertmer et al., 2012; Ottenbreit-Leftwich et al., 2010) indicates that teachers' beliefs also play a substantial role in their classroom use of technology. In the mathematics classroom, teachers are able to enact aspects of their TPACK knowledge after being able to make sense of the intersection between their knowledge and skills, the mathematics concepts, and their knowledge of students (Polly, 2011b).

While there is potential and promise supporting the use of technology in learner-centered ways in mathematics classrooms, there is still a gap in the literature about how to best support teachers' use of technology in these ways (Polly, McGee, & Martin, 2010). To this end, there is a need to examine more in depth teachers' use of technology in their mathematics classrooms, and how to possibly support that use.

Research Questions

This study aimed to further examine teachers' integration of technology in the mathematics classroom by answering the following questions:

1. What technologies do primary school teachers integrate into their mathematics classrooms?
2. What pedagogies do primary school teachers' enact while teaching with technology in their mathematics classrooms?
3. What types of mathematical tasks do teachers pose while teaching with technology?
4. How do teachers discuss and evaluate their decisions to integrate technology into their mathematics classrooms?

METHODS

Context

This study took place in a high-need Title I school in the southeastern United States. At the time of the study, the school had 18 self-contained classrooms from kindergarten through Grade 4 (ages 5 through 10). Over 70% of the school population qualified for the U.S. free and/or reduced lunch program, and approximately 40% were English Language Learners, with Spanish being the primary language spoken at their homes. Each classroom was equipped with a projector, a Mimio interactive whiteboard, and at least one teacher computer. The school also had available a few iPad carts for teachers to use throughout the day.

Teachers in the school had recently been part of two districtwide professional development programs—one related to technology integration, the other related to mathematics pedagogies. The technology program was a week-long summer institute focused on the interactive whiteboard, Web 2.0 tools, Google docs, and the use of the document camera. At the end of the institute, teachers collaboratively planned how technology could be integrated more effectively into their classrooms. The mathematics program was a 72-hour year-long set of experiences focused on implementing standards-based mathematics pedagogies that embody learner-centered instruction.

Participants

Three teachers were purposefully selected for this study based on their variant participation in the district's technology and mathematics workshops. Each held an elementary education license (Kindergarten through Grade 6) and had been teaching between 7 and 16 years. Zoe, a Grade 3 teacher, had not participated in either professional development program and shared that she did not have much prior knowledge of current technology tools or mathematics pedagogies. Kelly, a Grade 4 teacher, had participated in both programs. She reported having an interest in using technology more, but had been vocal about not wanting to use learner-centered pedagogies and problem solving to teach math. Mindy, a Grade 4 teacher, participated in the technology program and served as a member of the professional development staff for the mathematics program.

Procedures and Data Sources

In order to get a comprehensive picture of how each teacher was using technology, I conducted a year-long study with frequent observations and interviews at the beginning and the end of the study. Each teacher was observed between 20 and 30 times during his or her mathematics instruction during the year. Zoe, who had not participated in any professional development, was observed 21 times; Kelly, who had participated in both technology and mathematics professional development, was observed 22 times; and Mindy, who had co-facilitated mathematics professional development and attended technology professional development, was observed 30 times.

In each observation, I served as a participant-observer, seated near the students, and recorded field notes on the technology used, how it was used, and the types of mathematical tasks and questions the teacher posed. Different from previous studies (e.g., Polly, 2011a; Polly & Hannafin, 2011), where participants were observed on days that they explicitly stated they were going to integrate technology, I observed participants regardless of their intent to use technology. In addition to observations, I also conducted two semi-structured interviews with each teacher-participant, one at the beginning and one at the end of each school year. The opening prompts follow: How are you using technology during your mathematics lessons? What impact is technology having on your mathematics lessons? What impact is technology having on your students' mathematics learning?

Data Analysis

All data sources were analyzed using an inductive analytic approach, looking for common themes in the data set (Coffey & Atkinson, 1996). For question one about the types of technologies used, field notes were transcribed with a word processor prior to coding. Notes were taken to record the types of technologies used and to quantify the number of observations that each technology was used.

For question two, which examined teachers' pedagogies while using technology, I also analyzed field notes using an inductive analytic approach and coded those notes using an open-coding process, in which excerpts were chunked by code and organized in a spreadsheet. In the spreadsheet, details were recorded including the date, classroom teacher, and topic of the lesson, as well as the excerpt from the field notes. In a different spreadsheet, interview excerpts were organized. Codes were first given to each excerpt of data. Upon the second review of excerpts, I organized excerpts by codes to examine the number of excerpts for each code.

I also analyzed field notes as well for question three, using the framework of cognitively demanding mathematical tasks (Table 2; Smith & Stein, 1998) in order to examine the types of tasks that participants enacted in their classroom. This framework has been used in prior research studies (Polly & Hannafin, 2011; Stein, Grover, & Henningsen, 1996) to analyze mathematical tasks that have been enacted in classrooms as well as tasks written in lesson plans and curricula materials. According to the framework, the most effective mathematical tasks are those that are cognitively demanding, and this study includes the categories Procedures with Mathematical Connections and Doing Mathematics. Data for this question were split into the first half and second half of the year to see if there was a difference between teachers' enacted mathematical tasks. There was more of a focus on posing cognitively demanding mathematical tasks during the second half of the school year, due to using mathematics curriculum materials.

For question four, each interview was transcribed verbatim and analyzed inductively. Data were organized, coded, and sorted in a spreadsheet, similar to the data for question two. Themes were constructed from the data, and then the data set was revisited to confirm or modify the initially constructed themes.

FINDINGS

What Technologies Did Primary School Teachers Integrate into Their Mathematics Classroom?

The teachers' desktop computer was used during eight observed lessons; once by Zoe (4.76% of her observed lessons), four times by Kelly (18.18%), and three times by Mindy (10%). Math activities on iPads were used by Zoe's third-grade students in 12 (57.14%) of her lessons, while Kelly's students used iPads once (4.55%) and Mindy's students used them once (3.33%). In

TABLE 2 Mathematical Task Framework

Cognitive demand	Category of task	Description	Example
High cognitive demand	Doing mathematics	Students explore mathematical tasks that require them to choose an approach, complete the task, and explain their steps and decision-making.	There are 24 yards of fencing for the garden. If you want to make a rectangular garden with side lengths that are whole yards, what are the possible dimensions of the garden? Which garden has the largest area?
	Procedures with mathematical connections	Students explore tasks that can be solved with an algorithm, but have to generate more than one representation.	There are 9 dozen cookies in the bag. If you eat 6 cookies how many are left? Show your picture using a picture and an equation.
Low cognitive demand	Procedures with mathematical connections	Students explore tasks that require only an algorithm and only one mathematical representation.	There are 9 dozen cookies in the bag. If you eat 6 cookies, how many are left?
	Memorization	Students recall a fact that is expected to be known.	What is the product of 9×6?

every lesson, teachers used their projector and document camera to display mathematical tasks or examples of student work.

What Pedagogies Do Primary School Teachers Enact While Teaching with Technology in Their Mathematics Classroom?

Participants employed various technologies while integrating technology into their observed mathematics lessons. When teachers implemented Internet-based activities on the interactive whiteboard, they always kept the whole class together, and either the teacher or students used it to manipulate the objects or write on. For example, in Mindy's fourth-grade class, students played the Fraction Game (Figure 3;

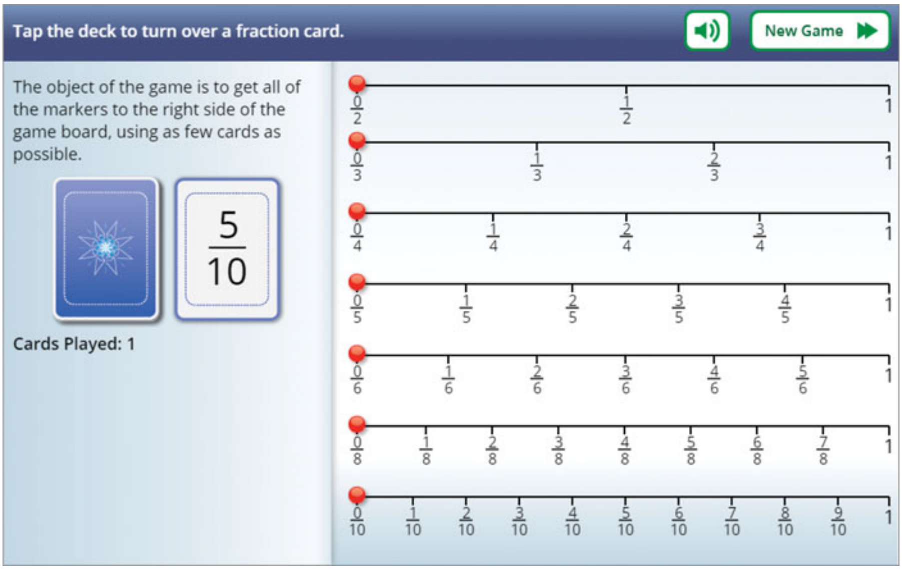

FIGURE 3 Screen capture of the Fraction Game. Reproduced by permission of National Council of Teachers of Mathematics.

http://illuminations.nctm.org/Activity.aspx?id=4148) as a whole class. To play the game, students click on a card and a fraction appears. Students then move one of their game pieces on one of the number lines. The distance that they move has to match the value of the fraction on the card. The object of the game is to move all of the red pieces across the board in as few turns as possible. The game incorporates multiple mathematics concepts, including representing fractions, modeling fractions, and finding equivalent fractions. The interactive whiteboard allowed students to see the number lines and play the game with a larger group of students rather than individually or with a partner on a computer.

Teachers also used the same pedagogies each time that iPads were used in their mathematics classrooms, especially Zoe, who had found iPad math activities or applications that focused solely on drill and practice. The iPads were only used as an independent activity in the math class without any teacher supervision. It was observed that using an iPad was considered a reward for finishing work, which caused some students to rush through their work in order to get more time on their iPad. When student work was analyzed on activities that preceded iPad use, students appeared to have missed some questions, yet they were still allowed to use the iPads without having to go back and make corrections.

Each time students used handheld quiz devices, a teacher projected questions from the desktop computer, and students entered their answers to a multiple-choice question through the handheld device. Teachers then posted data about students' responses and facilitated a conversation about

TABLE 3 Types of Enacted Mathematical Tasks During Observations

	First half of year	Second half of year	Total
Zoe's Enacted Mathematical Tasks			
Memorization	27 (30.68%)	5 (6.41%)	32 (19.28%
Procedures without mathematical connections	51 (57.95%)	25 (32.05%)	76 (45.78%)
Procedures with mathematical connections	10 (11.36%)	45 (57.69%)	55 (33.13%)
Doing mathematics	0 (0%)	3 (3.85%)	3 (1.81%)
Total	88	78	166
Kelly's Enacted Mathematical Tasks			
Memorization	25 (26.88%)	3 (3.30%)	28 (15.22%)
Procedures without mathematical connections	53 (56.99%)	6 (6.59%)	59 (32.07%)
Procedures with mathematical connections	13 (13.98%)	79 (86.81%)	92 (50%)
Doing mathematics	2 (2.15%)	3 (3.30%)	5 (2.72%)
Total	93	91	184
Mindy's Enacted Mathematical Tasks			
Memorization	8 (11.43%)	4 (4.76%)	12 (7.79%
Procedures without mathematical connections	2 (2.86%)	1 (1.19%)	3 (1.95%)
Procedures with mathematical connections	59 (84.29%)	71 (84.52%)	130 (84.42%)
Doing mathematics	1 (1.43%)	8 (9.52%)	9 (5.84%)
Total	70	84	154

their strategies, reasoning, and answers. Teachers' desktop computer use was limited; they were only used to display problems that were found in the state's test preparation item bank.

What Types of Mathematical Tasks Did Teachers Pose While Teaching with Technology in Their Classroom?

Table 3 shows the types and number of mathematical tasks posed by Zoe, Karen, and Mindy, respectively. The framework for tasks that have a high cognitive demand (high level) and low cognitive demand (low level) was provided earlier (Table 2). Data for both Zoe and Karen showed a substantial shift in the types of mathematical tasks enacted between the first half and the second half of the study; both enacted more cognitively demanding tasks during the second half of the study. Mindy's data indicated a similar trend, but not to the same extent.

Analysis of field notes indicated some relationships between the types of technologies used (Question 1) and the types of mathematical tasks

(Question 3). In many observed lessons where teachers or students used the interactive whiteboard to explore an Internet-based activity, the tasks were coded as high-level tasks that were either categorized as Procedures with Connections, or Doing Mathematics. In one lesson, Karen allowed students to take turns on the interactive whiteboard to examine the Area Explorer (1994) activity where the class determined all the possible rectangles that could be made with a perimeter of 10 units. During this lesson, Karen allowed students to explore this task, reason about their strategies, and discuss the similarities and differences between the various representations that students had generated using the Web site. The technology in this case supported the exploration of a high-level mathematical task as well as higher level thinking skills. Zoe, who had implemented a lot of lower level tasks using the iPad posed higher level tasks when using the interactive whiteboard in a lesson during her fractions unit. As a whole class, students explored the Bounded Fraction Pointer Web-based tool (http://www.shodor.org/interactivate/activities/BoundFractionPointer/). Also, as a whole class, students identified fractions on a number line representation and compared two or three fractions in terms of their size.

The iPad applications used by all three teachers were limited to primarily memorization types of tasks. These low-level iPad tasks included one-step questions in which students had to type in or click on the correct answer. There was no problem solving or higher level thinking involved, as students either had the answer memorized or they didn't know it at all. However, Zoe used a higher level iPad application, as did Karen and Mindy, which was coded as Procedures without Mathematical Connections due to the multiple math representations and problem solving involved. In Karen and Mindy's classroom students played the game Kakooma (http://kakooma.com/Kakooma/Kakooma?gameType=Addition), where they had to find the answer to subtraction problems and work on finding the missing numbers in an equation.

The handheld quizzing devices included a variety of Memorization, Procedures without Connections, and Procedures with Connections tasks. Most of the state-generated practice questions for the end-of-grade test were not cognitively demanding and were categorized as Memorization or Procedures without Connections, while teacher-created questions tended to include more cognitively demanding tasks.

The document camera, used in each lesson, was not associated with any particular type of mathematical tasks. In every observation, the document camera was used to project tasks, and in some cases student work. As indicated in question two, participants varied in how they used the document camera during their observed lessons: Mindy consistently used the camera to facilitate a discussion of students' strategies, while Zoe and Karen tended to rely on the camera to project tasks for students to see or examples of the teacher's work showing the correct way to solve a task.

How Do Teachers Discuss and Evaluate Their Decisions to Integrate Technology into Their Mathematics Classroom?

Analysis of the interviews indicated a few prominent themes: technology makes teaching easier, technology engages students, technology helps students see the math, and technology has the potential to give teachers information about student performance.

Technology Makes Teaching Easier

During interviews at the beginning of the study, all three participants felt that technology makes teaching easier, with specific references to the projector and document camera. Mindy commented, "We are fortunate to be able to use the document camera to display problems and examples of student work. It makes teaching easier and more flexible by having the power to display a variety of things."

Furthermore, at the beginning of the study, Karen commented about how technology supports her teaching: "The technology will let me model and demonstrate math to students more easily. Being able to project my work on paper for the class will definitely help my teaching." In every observation, teachers projected tasks and sometimes teachers' or students' work using the document camera. In all three classrooms, the projector and the document camera had become an everyday technology.

Technology Engages Students

Participants at the beginning of the year discussed the potential for technology to engage students. Zoe commented, "All of the technology that we have engages students and keeps them interested in learning. I am excited about starting to use the iPads and do more with technology during class time." During her observations, Zoe's students used the iPads for independent work time. Often times, students rushed through class work in order to work on iPad activities.

Karen added, "My students in past years have loved using the [interactive whiteboard] and playing computer games. I think that the technology can keep them interested in topics that are more difficult and complex." While Karen did not have her students use many technologies on their own, her students appeared engaged and used technologies to facilitate and support whole-class activities.

Technology Helps Students to See the Math

At the end of the year, Karen and Mindy, both fourth-grade teachers, commented that technology supported students' work with many concepts, but they specifically cited fractions, area, and perimeter. Mindy commented,

> The different Web-based activities and the use of the document camera helped avoid student confusion between area and perimeter. When they were able to project their pictures and then talk with the class about their thinking, they were better able to make sense of the math.

Zoe made a similar comment about fractions: "My third-graders benefited a lot from the fractions Internet activities and being able to use the document camera to talk about their work in the fraction unit. It made a huge difference." In all three classrooms, teachers used the technologies to complement lessons and activities that were non-technology based. Often students would see the same mathematical representations with manipulatives, on paper and also via technology, providing multiple ways to engage in mathematics concepts.

However, all three admitted that they needed more information and resources about Internet-based and iPad activities. Mindy, who had facilitated districtwide mathematics workshops and participated in technology workshops, commented, "I feel like I need more ideas about where to find challenging, technology-based activities for students to use." Karen and Zoe also shared similar thoughts during their end-of-study interviews.

Technology Has the Potential to Provide Teachers with Immediate Feedback About Student Performance

Despite limited uses of the handheld quizzing devices, Mindy and Karen both commented about the potential that technology could have to give them feedback about their students' understanding. Karen commented, "I have not gotten to use them much, but I love the idea of being able to have students each use a clicker, enter the answer, and then I can immediately see what they do and do not know."

Mindy stated, "There is a lot of potential in those clickers. I am excited about spending time over the summer learning more about them and using them next year to help check my students' understanding." Toward the end of the study, Mindy and Karen and their other teammate on their grade level used the handheld clickers and worked collaboratively to assess their data and then plan subsequent lessons to address student misconceptions.

DISCUSSION AND IMPLICATIONS

Teachers Enacted a Variety of Pedagogies

iPads

During this study, another difference observed was the technology-rich activities that the students worked on. As stated earlier, Zoe's students used the iPads frequently in observed lessons, but the quality of tasks and activities was low on the framework of cognitively demanding tasks. In essence, Zoe saw the technology as a way to give students more practice with low-level computation skills. In most lessons, Zoe's students chose which iPad activities they used, which meant many third-graders wanted to work on computation and skills-based games and activities. Zoe reported in her interviews that she believed that technology should engage students and that there is a need for students to practice their computational skills. Aligned with her beliefs, Zoe allowed technology to be used to support these ideas (Ertmer, 2005; Ertmer, et al., 2012).

Student Uses of Technology

Karen's and Mindy's students rarely used technology independently during observation. Their uses of technology primarily included whole-class activities and discussions, in which they used the technology to project tasks, quizzes, or computer-based activities. Part of Karen's and Mindy's tendency to use whole-class activities rather than allowing students to use technology independently could be associated with the districtwide technology professional development, which focused primarily on interactive whiteboard activities for whole class use, the handheld quiz devices, or general computer-based applications that are not content specific. Prior research indicates that teachers tend to use only technology that they are comfortable with and that it takes time and adequate support to begin to adopt new technologies or use previously used technologies in new ways (Ertmer, 1999; Lawless & Pellegrino, 2007; Polly & Hannafin, 2011). In this study, Karen and Mindy continued to enact only the technologies they were comfortable with in a manner that they were used to. Teacher support needs to provide opportunities for teachers to use new technologies and if possible provide classroom-based help in implementing technologies in the classroom (Lawless & Pellegrino, 2007; Polly & Hannafin, 2011).

A Relationship Between Technology Use and Mathematical Tasks

When examining the data on the types of enacted mathematical tasks, there was a noted relationship between the technologies used and the mathematical tasks. Each use of the iPads resulted in low-level tasks focused on computation or using an algorithm to find an answer. Zoe reported how engaged her students were and how much fun they were having using the iPads. When discussing the iPads, Zoe never talked about the types of tasks on the iPad.

The use of handheld quiz devices included a variety of tasks based on the origin of the questions. Questions from commercial resources used for practice for end-of-grade tests were low level. Meanwhile, some teacher-created questions included a mix of Procedures without Connections (low level) and Procedures with Connections tasks (high level). The limited number of observations where the interactive whiteboard was used included high-level tasks that included multiple representations. Uses of the teacher's desktop computer included some low-level test-preparation tasks, but most uses included Procedures with Connections activities that included multiple representations of a mathematics concept.

In this study, some general technologies were noted, including the document camera, the teacher's desktop computer, and the handheld quiz devices that supported a variety of mathematical tasks. However, the association between iPads with low-level tasks was clear in the data. Furthermore, a clear association between the use of interactive whiteboards to manipulate Internet-based tools and activities with high-level tasks indicated a need to support teachers in their selection of mathematical tasks and technology-rich activities (Lawless & Pellegrino, 2007; Polly & Hannafin, 2011).

Implications for Future Research

This study examined three primary school teachers' enactments of teaching with technology in their mathematics classroom over the course of a year. While only three participants were studied, the number of classroom observations provides a detailed picture of how the teachers and their students interacted with technology in relation to mathematics concepts.

In an era where school leaders continue to purchase educational technologies, future studies should examine how to best leverage these technologies to support student learning. In the context of mathematics, the interplay between technologies and the types of mathematical tasks was apparent in this study, and there is a need to further investigate which technology-rich activities best support student learning. In relation to the mathematical task framework one question to consider is, Does the enactment of technology-rich, cognitively demanding tasks translate into student learning? If not, what are more effective ways to develop students' mathematics understanding?

Furthermore, the findings indicate a need for more support related to mathematics-specific technologies. While Mindy and Karen had participated in both mathematics and technology-specific workshops, they reported a need and desire to learn more about technologies to support mathematics, specifically on the iPad or interactive whiteboard. Future studies should consider how to best support teachers' learning and use of mathematics-specific technologies and how they apply those learning experiences in their classrooms.

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