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Factors that influence secondary mathematics teachers' integration of technology in mathematics lessons

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ABSTRACT

While many studies describe the use of technology in the mathematics classroom, few explore the factors that influence teacher decisions around its use. The participants in this study were 21 early career secondary mathematics teachers who had completed an undergraduate mathematics teacher preparation program in the USA with a strong emphasis on the use of technology to teach mathematics. In this qualitative study, interview data were collected and analyzed with attention toward why teachers choose to use technology to teach mathematics, what tools they chose to use and why, as well as the general factors they consider when selecting particular technology tools. Findings indicate that one of the most important factors when deciding whether to use technology was how well it aligned with the goals of a lesson. The range of technology used spanned mathematical action tools, collaboration tools, assessment tools, and communication tools. When selecting particular tools teachers most heavily considered ease of use for both themselves and their students. These findings suggest that when considering how to infuse technology into teacher education programs we suggest that it is important to focus more broadly on types of tools, ways teachers can position them, and how particular activities align with specific mathematics learning objectives.

1. Introduction

The number and variety of technological tools that teachers and students have access to in schools has risen sharply over the last two decades, and the mathematics classroom is no exception (Gray et al., 2010; Snyder, de Brey, & Dillow, 2016). However, it is not enough that students simply have access to technology. The teacher plays a critical role in determining how this technology is used. The National Council of Teachers of Mathematics' (NCTM) position on the use of technology, for example, includes the statement that "Effective teachers optimize the potential of technology to develop students' understanding, stimulate their interest, and increase their proficiency in mathematics" (NCTM, 2015). Thus, it not only matters that teachers integrate technology in their mathematics teaching, but it matters *how* they integrate it. However, not every teacher uses technology in ways that align with NCTM's position. Many mathematics teachers (and their students) primarily use technology as a simple calculational tool, or for data storage, or for the display of static materials, methods which are unlikely to develop student understanding, stimulate their interests, or increase their proficiency in mathematics (Cuban, Kirkpatrick, & Peck, 2001; Ertmer, 2005).

While various studies have been performed that describe technology use in the mathematics classroom (e.g., Afshari, Bakar, Luan,

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Samah, & Fooi, 2009; Bauer & Kenton, 2005; Cuban et al., 2001; Goos & Bennison, 2008), limited research has been conducted on factors that influence decisions teachers make when integrating technology into their teaching (Bray & Tangney, 2017). Discovering these factors may be a significant benefit to mathematics teacher educators, who in turn can better prepare pre-service teachers and equip them with the tools needed to successfully teach mathematics with technology. For in-service teachers, professional development can be designed to meet the needs of teachers, and to address and overcome obstacles that they face when considering technology integration. This study addresses the following research questions: Why do teachers choose to use technology to teach mathematics? What technology tools do teachers choose to use and why? and What general factors do teachers consider when selecting a particular technology tool to use?

2. Literature review

While the use of technology tools for learning mathematics has been widely researched and the field is in agreement that incorporating technology into the teaching and learning of mathematics is important, there is still relatively little research focused on the ways teachers do so. Here we present the extant research on factors that influence technology integration in mathematics instruction, the ways that technology is positioned in the teaching of mathematics, and a synthesis of the research on preparing teachers to teach mathematics using technology.

2.1. Factors influencing technology integration in mathematics instruction

While research examining factors that influence *how* teachers (particularly secondary mathematics teachers) choose and integrate technology has been limited, there has been an increasing number of research studies examining factors affecting *whether* teachers integrate technology. Ertmer, Addison, Lane, Ross, and Woods (1999) classify barriers to technology integration into two categories: external barriers and internal barriers. External barriers include such things as the availability of computers, level of administrative support, and professional development opportunities involving technology. Internal barriers primarily involve teachers' attitudes and beliefs. Internal barriers include beliefs about whether students should use technology to learn mathematics or concerns that students will become over-reliant on calculators. In the United States, many of the external barriers have been largely overcome, as more and more states adopt standards requiring technology use in schools (Bakia, Means, Gallagher, Chen, & Jones, 2009; Ertmer, 2005; Means, 2008). As a matter of fact, it has been determined that access to computers in mathematics classrooms in the United States is nearly universal. In a 2009 survey, the National Center for Education Statistics (Gray et al., 2010) found that 95% of mathematics teachers had at least one computer in the classroom at all times; this number rises to 99% if we include those that are able to bring computers into the classroom as needed. While hardware is an external barrier that has been largely overcome, it is not the only one identified in the literature. Specific to mathematics, in their 2011 study Wachira & Keengwe found that teachers' lacked access to mathematics specific software due to the high cost of site licenses. Since the publication of that work, this barrier has also been largely removed as there now exist a variety of free dynamic mathematics tools available for classroom use (e.g., GeoGebra, Desmos, and many libraries of free online mathematics applets).

While most classrooms in the United States have technology available, alleviating the severity of external barriers, many internal barriers remain (Ertmer, 2005; Bauer & Kenton, 2005; Afshari et al., 2009; Kaleli-Yilmaz, 2015; Washira & Keengwe, 2011). For example, it has been found that secondary school teachers are less likely than elementary school teachers to have their students use technology with significant frequency, and within secondary schools technology use is lower in mathematics and science classes than in language arts and social studies (Becker, 2000; Gray et al., 2010; Means, 2008). Since there are no significant differences in access to technology between these classrooms (Bakia et al., 2009; Gray et al., 2010), these differences are likely due to internal factors, such as beliefs regarding the role of the teacher across different grade levels or beliefs about the nature of mathematics learning and teaching (Washira & Keengwe, 2011).

2.2. Positioning technology use in mathematics instruction

While the use of technology is believed to enhance students' learning, successful outcomes cannot be achieved simply by increasing use of technology in a classroom. The success of technology implementation depends, at least in part, on the type of software selected (Means, 2008) and the type of tasks implemented (Sherman, Cayton, & Chandler, 2017). When software is used mostly as drill-and-practice, for example, the impact on student achievement is often negligible or even negative (Hennessy, Ruthven, & Brindley, 2005; Means, 2008). Perhaps more important, however, than type of software used, is the role the teacher plays in its implementation. The teacher and the decisions he or she makes when integrating technology is critical to its successful implementation (Ertmer, 2005; Escuder, 2013; Li & Ma, 2010; Drijvers et al., 2009; NCTM, 2000).

In their review of research related to teachers' uses of technology, Zbiek and Hollebrands (2008) described the different concerns teachers had about integrating technology that included personal concerns, managerial concerns, and technological concerns. Teachers made decisions about whether to include technology in their instruction based on their comfort with the tool, their perceptions of whether students would be able to use it, and their confidence in the technology working. In addition, the different roles teachers took on while teaching with technology were also described (allocator of time, catalyst and facilitator, collaborator, counselor, evaluator, explainer, manager, planner and conductor, resource, task setter, technical assistant). It is likely that these roles were influenced by teachers' beliefs and affected teachers' instructional practices.

Research on the effect of computers on teachers' instructional practices has been limited. Ertmer (2005) reports that "although many teachers are using technology for numerous low-level tasks (word processing, Internet research), higher level uses are still very much in the minority" (p. 25). Cuban et al. (2001) examined two high-tech high schools in California, and came to a similar conclusion:

> Incremental changes in teaching style occurred as a consequence of enhanced accessibility to new technologies (especially computers). However, few fundamental changes in the dominant mode of teacher-centered instruction have occurred. Occasional to serious use of computers had marginal to no impact on established teaching practices. A classroom revolution has not occurred (p. 825).

A 2007 U.S. Department of Education Survey (Bakia et al., 2009) supports these assertions, as they found that only 20% of teachers (across all subjects) report using software to extend their students' learning on at least a weekly basis. A National Center for Education Statistics survey (Gray et al., 2010) provides slightly more encouraging numbers, with 61% of mathematics teachers reporting that their students use computers to solve problems, analyze data, or perform calculations; 45% reporting that their students use computers to conduct experiments or perform measurements; and 25% reporting that students use computers to design or run demonstrations, models, or simulations. (Frequency of computer use in these areas was not addressed.) This evidence suggests, as Ertmer (2005) states,

> While instructional computer use appears to be increasing (at least as measured by self-report data), the most common and frequent uses have resulted in only incremental, or first order, changes in teaching style and remain far removed from the best practices advocated in the literature (p. 26).

Although research has been scarce regarding factors that limit significant changes to instructional style, possibilities have been proposed. Teacher beliefs are often suggested as a factor – specifically, beliefs about teachers' own technological skills (Goos & Bennison, 2008; Wang, Ertmer, & Newby, 2004; Washira & Keengwe, 2011), beliefs about the nature of teaching and learning (Becker, 2000; Ertmer, 2005), beliefs about the nature of mathematical knowledge (Goos, 2005), beliefs about the role of computers in the classroom and their possible effects on student outcomes (Ertmer, 2005; Hall & Hord, 2011; Norton, McRobbie, & Cooper, 2000), beliefs about the role of the teacher (Noss, Hoyles, & Sutherland, 1990), and beliefs about their students' capabilities (Kendal & Stacey, 2001). Teacher knowledge is another commonly suggested factor – technological knowledge (Afshari et al., 2009; Koehler & Mishra, 2009; Goos, 2005; Pierce & Stacey, 2013; Washira & Keengwe, 2011), pedagogical knowledge (Koehler & Mishra, 2009; Li & Ma, 2010: Washira & Keengwe, 2011), and content knowledge (Koehler & Mishra, 2009), as well as the intersection of these areas of knowledge (Goos, 2005; Koehler & Mishra, 2009; Washira & Keengwe, 2011). Additional factors suggested by other authors include amount of curricular freedom afforded to the teacher (Becker, 2000), previous teaching experiences with technology (Escuder, 2013), adequate training and preparation of teachers (Afshari et al., 2009; Becker, 2000), adequate planning time (Bauer & Kenton, 2005), preferred style of teaching (Newhouse, 1998), lack of appropriate software (Bauer & Kenton, 2005), and time since adoption of the software (Ertmer, 2005).

2.3. Preparing teachers to teach mathematics using technology

Teacher education at universities and colleges plays a critical role in helping prospective mathematics teachers develop the knowledge and comfort needed to promote appropriate integration of technologies in mathematics classrooms. In the United States, the Association of Mathematics Teacher Educators (AMTE) has played an active role in making recommendations that mathematics teacher education programs should "provide opportunities [for teachers] to acquire the knowledge and experiences needed to incorporate technology in the context of teaching and learning mathematics" (AMTE, 2006, p. 1) and that "mathematics educators serve their students by considering the potential impact of a variety of forms of 21st Century digital technologies and planning accordingly" (AMTE, 2009, p. 1). AMTE's emphasis on the importance of the use of technology in mathematics teacher preparation is reiterated in their most recent standards by claiming, "Well-prepared beginning teachers of mathematics are proficient in using both digital tools and physical manipulatives for solving mathematical problems and as a means of enhancing or illuminating mathematical and statistical concepts" (AMTE, 2017, p. 12). In addition, Heid and Lee (2008) made strong recommendations that doctoral students (future faculty) in mathematics education should understand the research about use of technology in students' and teachers' learning and be able to consider appropriate uses of tools in mathematics teacher education.

The ways in which technology is incorporated into teacher education programs varies across institutions. In some cases technology integration is addressed in general methods courses, while some programs have specific courses focused on technology. In their 2003 survey of US mathematics teacher educators Kersaint et al. found 21% of respondents taught a course focused on technology. A few years later, Leatham (2006) reported 29% of mathematics teacher educators had courses at their institution focused on the teaching of mathematics with technology. According to Kersaint, Horton, Stohl, and Garofalo (2003) the technology tools that mathematics teacher educators noted were important to include in their courses included graphing calculators, dynamic geometry software, spreadsheets, and access to information on the web. For the current study, we focused on early career teachers who had completed an undergraduate pre-service mathematics teacher preparation program in the US that placed a strong emphasis on the use of technology to teach mathematics. We were interested in investigating factors these teachers described as influencing their integration of technology in their mathematics teaching.

3. Methods

3.1. Context

A mathematics teacher education program that infuses technology in several methods courses was the context in which this study was situated. All graduates of this program complete one course specifically focused on teaching secondary mathematics with technology, in addition to three other methods courses that use technology periodically. These courses utilize materials developed by the first three authors of this paper. A research-based approach that integrates pedagogy, content, and technology was used to inform the design of the instructional materials[1] (Lee & Hollebrands, 2008; Niess, 2005; Suharwoto, 2006). Materials include three modules focused on preparing teachers to teach data analysis, geometry, and algebra. The specific technology tools utilized in the Preparing to Teach Mathematics with Technology [PTMT] materials included TinkerPlots, Fathom, Excel, The Geometer's Sketchpad, GeoGebra, and various applets. These materials are available for free at https://ptmt.fi.ncsu.edu.

Previous studies have shown that teachers prepared using these materials improved their knowledge of content, technology, and pedagogy (Hollebrands, McCulloch, & Lee, 2016). In addition, an analysis of 129 lesson plans collected from 43 teachers showed that while all teachers were able to write lessons that integrated technology, approximately one-third of them positioned technology as a partner (Goos, Galbraith, Renshaw, & Geiger, 2000) to support students' understandings of mathematical concepts (Hollebrands et al., 2016). While we know that prospective teachers that have used these materials are able to plan and implement lessons that utilize technology in the context of their coursework, we do not know how these experiences and this knowledge has translated to their daily practice as high school mathematics teachers - especially during the early years of their teaching career.

3.2. Participants

Study participants included 21 secondary mathematics teachers. These teachers were all graduates of the same university in the southeast United States and used the materials as described in the context above. Teachers were recruited through an alumni email list that included graduates between Spring 2013 and Fall 2015 who had complete contact information (n = 105). The recruitment email noted that to be eligible to participate they needed to be currently teaching, their participation would require completing a 30 min interview that could be conducted either face to face or remotely using video-conferencing technology, and noted that to thank them for their time they would receive a $50 Amazon gift card if they chose to participate in the study. Twenty-five teachers responded to this email indicating their interest in participating in the study. Four volunteers indicated they were no longer high school teachers, so they were not included in the study.

The 21 volunteer participant teachers (13 female, 8 male) were from 19 different schools, all but one located in the same state as the university from which they graduated. Most were early career teachers with 90% (n = 19) of them having 5 years of experience or less. The two exceptions had 7 and 9 years experience. This participant sample is likely not representative of all graduates of the university program with respect to their access to technology or their integration of technology. It is possible that some teachers self selected not to participate in this study because they do not have regular access to technology for classroom use and that those who volunteered felt they had something positive to say about their experience using technology in their classrooms.

Having access to technology tools was not a prerequisite for participating in this project. Our goal was to understand the decisions teachers were making within their unique school contexts. That being said, all of the teachers had access to at least some graphing calculators and computers to use for instructional purposes. For example, 20 teachers had laptop carts they could bring into their classrooms, and 20 worked in schools that were 1:1, 2–3:1 environments. (Note: This is not the same set of 20 teachers. One did not have a cart available but did have a set in his classroom. Another did not have a set in his classroom but did have a cart available for checkout.) Sixteen teachers worked within the same large, urban school district which had recently adopted a 3:1 (students:laptop) policy for all core courses, meaning that all mathematics teachers had received a set of 10–15 laptops for their classrooms newly this year. In addition, all mathematics teachers had access to graphing calculators in their classrooms, but few had enough for every student.

3.3. Data collection

The data for this study were in the form of semi-structured interviews. The interview protocol was designed based on what the literature has identified as possible factors related to technology use including access, administrative approach, preparation, and beliefs (e.g., Bauer & Kenton, 2005; Ertmer, 2005). This included questions about teachers' general experiences during their first years of teaching, experiences with technology integration, their school environment, and access to support. Additional questions were designed to reveal factors that teachers say influence their decisions about which technologies they choose to use and how they implement it in their lessons. The full protocol is included in the Appendix.

The interviews were conducted by members of the research team. They took place either face to face or remotely, at the participant's request. All interviews were video recorded. The face to face interviews were recorded using a single camera and lapel

[1] Support for this work was provided by the National Science Foundation under grants DUE 0442319, DUE 081725, and DUE 1123001 awarded to North Carolina State University. Information and materials developed by project are available at http://ptmt.fi.ncsu.edu. Any opinions, findings, and conclusions or recommendations expressed herein are those of the principal investigators and do not necessarily reflect the views of the National Science Foundation.

microphone. The remote interviews were conducted using a video conferencing software, Zoom, and recorded using the platform recording software. The duration of each interview was approximately 30 min.

3.4. Data analysis

All interviews were transcribed verbatim and checked over by another member of the research team. Transcriptions were then divided into units of analysis ("quotations") that consisted of discrete ideas expressed by the participants. The quotations were coded using theory driven and data driven codes (Boyatzis, 1998). A codebook was created using the methods described by DeCuir-Gunby, Marshall, and McCulloch (2011), including an initial list of codes based on the literature and interview questions (i.e., theory driven). Additional codes were added as needed, when topics were regularly addressed across interviews (i.e., data driven). The final codebook included 26 codes. Each quotation was assigned zero or more codes to indicate the topic that the quotation was addressing.

The entire research team worked together to code a selection of the quotations. A portion of quotations were then simultaneously coded by individual members and checked for consistency, with all discrepancies resolved through discussion. The remaining quotations were individually coded by members of the research team, with any uncertainties brought to the team to discuss and reach a consensus.

For each of the codes, the selection of quotations assigned that code were then examined to identify common themes. Once themes were identified summaries were written for each code. For example, the code "decisions to use," defined as "teacher describes the factors that teachers consider when choosing to use technology or not", was applied to 28 quotations. All 28 quotations were read and themes identified: meeting the learning goal, time, classroom management, accessibility, and topic of instruction. Once all summaries were complete, the team revisited the research questions and identified themes that addressed each question. In the next section the findings are reported according to the common themes identified in the coding process.

4. Findings

Here we report the findings of our analysis in the order in which teachers expressed that they make decisions about technology integration: first considering whether or not to integrate technology, then what type of technology, and finally which particular technology to use (Fig. 1).

4.1. Why teachers integrate technology

All of the participating teachers in this study said that they integrate technology in their mathematics lessons when they determine it is appropriate to do so. Whether or not they felt technology was appropriate for a particular lesson depended on time constraints (both in preparing a lesson and in the classroom), whether or not the topic of instruction was amenable to technology integration, and their perceived ability to manage the activity. Given that most teachers in this study were early career teachers, issues related to time and perceived ability were heightened by the demands of being new to the profession. Teacher 6 described her first year as being a "whirlwind":

> Coming in as a first-year teacher, it's such a whirlwind. I feel like I was, just taking whatever anyone would give me, and just teaching exactly what they did. And so as a first-year teacher, I don't feel like I was ready for actually developing my own new things with technology[…]The first year it's kind of such a blur, and such a whirlwind[…]The second year was definitely better, I feel like I was able to develop more of my own lessons. Throw in some technology here and there.

Similarly, Teacher 12 reflected on her first year stating,

> And so my first year of teaching, technology is like icing on a cake, and they were lucky to get a cake that was half cooked. Like, it was not – I couldn't – I felt like I didn't have the time to research great technologies to go with these lessons, because I was trying to survive, and I think that that's every teacher.

Even with the stresses of early career, all teachers did integrate technology, thus we focused on their reasons for choosing to do so. All of the teachers' explanations indicated a consideration of the ways technology could support the goals of their lessons. Teacher 13 explained this well when she stated, "I want to make sure that whatever I'm using is going to actually get the point across from the lesson. I don't want it to be some kind of activity that's just busy work."

When expressing ways that technology could support the goals of their lessons, teachers' focused on ways technology provided

Fig. 1. Flow of teachers' decision making process regarding incorporation of technology into mathematics lessons.

opportunities to build mathematical understanding and opportunities to practice or review important mathematics. These factors are reported in detail in the following section.

4.1.1. Providing opportunities to build understanding

Technology tools have the potential to change the ways that students interact with mathematics. Teachers in this study noted that this was one of the reasons they chose to integrate technology in their teaching. However, not always with the same goal in mind. Sometimes the goal of their technology integration was to delegate procedures and other times the goal was to make sense of a mathematical idea.

4.1.1.1. Delegating procedures. One of the affordances of technology is the ability to use it to complete mathematical procedures quickly and error-free. Choosing to use technology to complete procedures quickly was noted by many teachers to be important because of the ability to generate a lot of examples very quickly. For example, Teacher 16 explained how valuable this was for her in the context of a geometry lesson. She said,

> So, you can easily give a discovery activity where the students are trying to figure out, okay, is the shape dilated, what is it the factor of, for instance in a geometry lesson, and they can manually do that by hand. Is it more productive for them to take that time, or is it going to be easier for them to focus less on, um, doing the actual constructions and the drawing with some sort of technology where they can just type in or change a slide, and it will actually do the dilation or the transformation itself? … And with the technology, they were able to run through different values quite fast and efficiently and actually visually see it happening before their eyes, versus looking at different still pictures.

Another, Teacher 19, explained the value of generating examples in a statistics lesson,

> I can ask a simple question, "what does that mean?" And … that's where the struggle sets in for some of those kids. And that's where, I think, like maybe some of those applets where, all of a sudden, kids can see "well, what do you mean by a normal distribution?" Like, it's always normal … You know, some of those tools that we have access to now, you can have a thousand examples at once.

For these two teachers, and many others, being able to generate examples quickly saved time during their lesson and allowed their students to focus on making sense of examples and drawing conclusions about relationships represented within and across them. This was not only time-saving, but it also allows for students to focus on the goal of the lesson rather than procedures with which they might otherwise struggle. These amplifications allowed teachers to focus on building their students' mathematical understandings.

4.1.1.2. Making sense of mathematical ideas or procedures. While some teachers described the elimination of procedures as driving their incorporation of technology into a mathematics lesson, others described their decisions as being driven by the desire to develop students' understanding of why a mathematical procedure or property works. These teachers were guided by the general question "will it be beneficial." This idea was expressed by Teacher 15,

> Will it be beneficial, or is it just using technology just to use it, to say I used it, because it looks good, or is it actually going to promote deeper thinking and further understanding? That's what I, you know, try to look for versus just using it just to use it.

In these situations, the teachers made it clear that they were considering the goals of their lessons carefully and how using technology might help their students make sense of those goals. Teacher 13 noted that she considers ways her students might be able to "discover something or put to use something that they have learned in a different way." She provides the following example, "Learning how to factor and finding zeros is very different from looking at graphs and determining could this image be the graph of this particular quadratic, for instance."

Similarly, Teacher 5 explained that once he determines the learning goal for a lesson he considers whether or not "technology is the easiest way to, or the most efficient way, or the most beneficial way to achieve that goal." He accomplishes this by thinking about his students' opportunities for sense making. An example he shared was related to his students' opportunities to make sense of asymptotes within a lesson on rational functions. He shared,

> So like, something like rational functions for example, it's – sliders are great way for them to be able to see: "oh, so the – when I change these values of the denominator, when it's factored, the vertical asymptotes move" or even if they don't know what the word vertical asymptote is yet, these vertical lines on the screen move. As opposed to just being told, like, to find the vertical asymptotes, you have to find the zeros of the denominator.

Given his learning goals, he determined that in this situation providing his students with an opportunity to explore functions using a technology tool was going to be more helpful than giving students a set of rules.

4.1.2. Providing opportunities to practice

Another reason teachers in this study said they integrated technology in their lessons was to support practice and review concepts. Technology integration of this type was not considered "busy work", but an important aspect of the lesson that was improved with technology. In most cases, making the decision to incorporate technology to support practice or review was driven by wanting to provide an engaging activity during which students - and teachers - had access to immediate feedback.

Teacher 6 explained that she uses technology "as more of a review and practice type thing." She explained that technologies of this type provide "time for the students to really show what they know, but it's also in a fun environment, so they kind of are tricked into enjoying doing practice problems. And so it's a nice option instead of just a worksheet. And so I think it just gives them time to quickly put their knowledge to the test, to see what they know and what they don't, and it's nice for me as a teacher because I immediately get the results." The sentiment of looking for engaging activities that provide feedback to both students and teacher was common. Similarly, Teacher 15 noted,

> And, big thing is, it gets them all engaged. Even the kids that are typically in the back that don't – want to avoid participating, they'll get into it … And that's also nice for quick feedback … But I can get real quick feedback and to talk about what we need to keep going on and look over to clear it up. So, I love the quick feedback of the technology.

4.2. Which technologies teachers use

As part of the interview protocol, teachers were explicitly asked if they integrated technology in their math lessons. If they answered affirmatively, we asked them what types of technology they used. We categorized the technology tools they described into four different categories: mathematical action tools, collaboration tools, assessment tools, and communication tools. In this section we will describe the types of tools teachers u and why they selected to use these tools.

4.2.1. Mathematical action tools

We characterized mathematical action technologies as tools, software, and applets that can "perform mathematical tasks and/or respond to the user's actions in mathematically defined ways" (Dick & Hollebrands, 2011, p. xii). The mathematical action technologies described by our participants included: graphing calculators and dynamic mathematical environments (e.g., Virtual Manipulatives, Desmos, GeoGebra, TinkerPlots). There were a variety of reasons why teachers selected these technology tools to use in their classrooms.

4.2.1.1. Graphing calculators. Although not always the first technology teachers mentioned, graphing calculators were prevalent and often easily accessible to the teachers we interviewed. Graphing calculators have a wide range of capabilities depending on variety. These include tools for not only creating graphs, but also tools for computing descriptive and inferential statistics, and tools for operating on functions, matrices, vectors, and complex numbers. For the teachers in this study, it seemed as though graphing calculators were technologies they assumed we knew they had access to, much like a whiteboard or desks might be an assumed feature of a classroom. For example, after Teacher 14 described different technologies he used, the interviewer asked if he had access to graphing calculators. He responded:

> Uh, we have TI-84's. So, yeah, and I guess that's, that's actually probably the biggest use of technology. I guess I forgot to mention that, because it's something that I've grown so accustomed to, that I don't even consider it technology. But I – you're exactly right, it, that's probably the biggest use of technology (Teacher 14).

The prevalent use of graphing calculators was reiterated by Teacher 8 who stated, "So, we use the graphing calculators every single day in my class, for the most part … So, the graphing calculator is definitely a huge piece of technology that I use." Teacher 19 remarked, "you know, everybody's using the graphing calculator."

While most teachers noted that they had access to graphing calculators, a few stated that they did not have enough for each student in their classroom. Teacher 10 explained, "Oh yes, graphing calculators. Yes. A small amount, not a big amount, not a class set. We have like five, maybe, total." Teacher 4 described how he addressed the shortage of calculators. He said he had:

> … a classroom set of 24 right now. So I have 37 students in my biggest class. So obviously I don't have enough we are hoping the students bring their own which does happen enough. So there are 84's and there are some Nspires that … you know how the face plates that change out … So there are some 84's in those too. But in my classroom, I have the 83's. And if I needed the technology of the others … other calculators that would be available. We are going BYOD, every class is getting 10 laptops and students all have a cell phone or smartphone. I think, I only have 2 students across all my class that don't have a cell phone so the laptops can supplement that. And there is a cart of iPads in the media center.

Many teachers found ways to overcome the shortage of calculators in their classroom. Some had students share, others used different types of graphing calculators (e.g., TI 83, TI 84, TI Nspire). Some teachers had students bring their own graphing calculators, while other teachers had students download a graphing calculator app on their phone or had a few laptops or iPads available for students to use.

Overall, graphing calculators were widely used. Teachers found ways to make sure students had them available to use whether it involved sharing devices or gathering different types of graphing calculators or tools for students to use. The variety of options did not seem to be an issue for teachers. They were able to address the differences in tools by focusing instead on the purpose and goal for using the technology. This included offloading tasks that were too messy or complicated to do by hand so students could solve "real world" problems and providing support to students who hadn't yet mastered or forgot the prerequisite skills that were needed in the lesson they were learning.

4.2.1.2. Dynamic mathematical environments. Teachers also selected a variety of different technologies that we describe as *dynamic mathematical environments (DME)*. DMEs included apps students could download or websites they could visit to interact with mathematical objects to support their learning. DMEs mentioned most often were Desmos, dynamic geometry programs (e.g., GeoGebra, The Geometer's Sketchpad), Dynamic Statistics programs (e.g., TinkerPlots, Fathom) and Virtual Manipulatives.

4.2.1.2.1. Desmos. Desmos is a free HTML5 graphing calculator (www.desmos.com), that works across devices (laptops, tablets, phones). In addition to the calculator feature, teachers and students have access to a wide range of activities that can be used, or they can create their own (www.teacher.desmos.com). When using Desmos activities, teachers can provide students with a code which allows the teacher to observe what students are doing, monitor their work, share and discuss it with the whole class.

Teachers explained that they selected to use Desmos in their class because it could be used to support the development of students' understandings of mathematics, is fun for students to use, is easy to enter mathematical notation, provides students with feedback, is similar to graphing calculators students are already familiar with, produces graphs more quickly and accurately, and it is available on multiple platforms. For example, Teacher 11 stated, “there is an app on their phone for Desmos, so they were able to get their phones out on that lesson for graphing some things on Desmos.”

Several teachers referred to the names of particular pre-created Desmos activities that they liked to use with students. Teacher 13 described the “polygraph activity where students are questioning one another using the right language, mathematical language, to describe an object, a polynomial that they've discovered. So, things like that are a lot of fun” as one of her favorites. She also explained how Desmos supports students' learning. She said, “I often use Desmos to demonstrate how functions change as you're solving. And that sometimes helps them to grasp why the solutions, like, for instance, extraneous solutions, occur when a function is changed so drastically, you know, that you get something that just doesn't work.”

> Teacher 19 also noted how Desmos could be used to support students' learning:
> I know with Pre-Cal, I've always loved the function within Desmos. Just the ability to use sliders. Love that. Because then all of a sudden, you know, kids are figuring out how to do transformations, and you don't have to teach them. They develop, and get their own “rules” that make sense to them, that work. And then maybe you come back later and formalize it with them. Maybe not, you know, depending upon what level the course is, where the kids are headed

He also noted that he liked Desmos because it could be used for multiple purposes and it was user friendly. He remarked, “It's pretty user friendly, pretty simple initially … but, I mean, you can do some pretty amazing stuff with it … once you kind of get into it. Yeah, functionality and then, user friendly, yeah.” He [Teacher 18] also liked the color-coded features and the ability to easily connect graphic representations with symbolic representations. He mentioned,

> Desmos has allowed me to explain those pieces of the graph in a more efficient way … so graphing the standard form equation of the parabola, and also graphing the vertex form, they'll see exactly the same thing, with a very clear picture. It's also nice when it's color-coded … so that helps students a lot.

The ability to use Desmos on multiple platforms was described as an important feature by Teacher 9. He explained that Desmos,

> has totally just changed how I teach, because I mean we'll do Desmos investigations and everyone … you know they all get out their phones or they get an iPad or a computer and they kind of progress through a discovery activity.

4.2.1.2.2. Dynamic geometry. Several teachers talked about how they used dynamic geometry environments like GeoGebra (www.geogebra.org) or The Geometer's Sketchpad. There were a few teachers who expressed an opinion that it was easier to find good technology-based activities to use with geometry topics. For example, Teacher 19 talked about specific classes he was teaching and the technology he was using in each, “Obviously, geometry, there's a lot of really good tools out there to help kids. I know, Sketchpad, I use that quite a bit.” Teacher 21 shared, “I think there were times where I used Geometer's Sketchpad in my – because I taught Geometry at that point in time.” She went to explain that because of the cost (of the software) she now used GeoGebra instead. In talking about this choice she explained “But, I only had it [The Geometer's Sketchpad] for, like, the one computer. I didn't have it for, like, everybody, so we couldn't really use it for every single kid … I used GeoGebra, because that was free.”

Two teachers noted the use of GeoGebra for topics other than geometry, like graphing. Teacher 9 described one of his favorite lessons that used GeoGebra. He said,

> we knew how to graph lines, and so we talked about lines and we used GeoGebra to have a product of two lines, essentially. And they develop a quadratic. Well then we say “ok well let's multiply three lines together” and we have a cubic, and so it's slowly using GeoGebra and graphing technology … we were able to discover the Fundamental Theorem of Algebra.

4.2.1.2.3. Dynamic statistics. For teachers who taught statistics, many described their uses of technology to include dynamic statistics programs like Fathom and TinkerPlots, as well as applets they found online to illustrate particular statistical ideas. In describing what you might see him do in a typical class using technology, Teacher 20 described what he does in his AP Statistics class by saying, “I use different things on the Internet like little Statistics applets or um … So, I don't know the specific names, but I know that there's one that I use for sampling.” He went on to say, “If you catch me in Unit 2 of Statistics, when we describe bivariate data, I use Fathom a lot.” Teacher 7 mentioned the use of TinkerPlots, “Anything with stats I love to use technology. I love to do the calculator simulations, TinkerPlots and stuff like that.” Other teachers mentioned applets they could access online because students didn't have access to TinkerPlots and Fathom. Teachers 19 and 21 provided examples of applets they found online. Teacher 19 said,

> I end up using a lot of applets that I find online, just that will kind of let kids see what's happening, instead of –because statistics is kind of a – I mean, you know this – it's a different animal for a lot of these kids. They haven't seen something like this, and so some of the applets that are out there that let them see what a – how to build a sampling distribution.

Teacher 21 mentioned the use of TuvaLabs (an online tool for graphing data). "TuvaLabs, we've used a lot as well." She also described how she used Census at School (a free site for collecting data from students using a survey on topics they may care about) for students to investigate data they download from the site and pose questions and analyze data related to relationships among two variables.

Many teachers used mathematical action tools in conjunction with tools to support collaboration. Google Forms and Sheets were mentioned often as tools that allowed teachers to have students collaborate on a project using a shared document and submit their work to obtain feedback from the teacher. Tools like those provided by Google and other tools are described in the next section.

4.2.2. Collaboration tools

Teachers often described using multiple technology tools in their lessons to support students' mathematics learning. Many times if teachers were using collaboration tools, they were used in conjunction with mathematical action tools. Collaboration tools were defined as tools that enabled students and teachers to see and discuss each other's work. Common collaboration tools included Padlet, Google documents (slides, docs, sheets, forms), as well as the collaborative features of Desmos. Teacher 1 described an introductory lesson and the way she used Padlet:

> So I have like some definitions and I've asked them to … It was on rotations and translations … and I said "just tell me what you know" and I even said "if you don't know anything, look it up and at least put it down" … and you can see other people's feedback, I really like that aspect, because you can learn a lot from other people.

Several teachers referred to the collaborative feature of Desmos and how it enabled the teacher to display the work of all students, share, and discuss it. Teacher 1 described how she used the teacher view, "On Desmos you can show the teacher view. And so at the end I said "I want you to put your teacher cap on and tell me which one of these are right." Teacher 9 also liked the way Desmos could be used to share solutions,

> So, it gives them … for math, it gives them graphing capabilities, it gives them … it gives them a couple of different capabilities just to kind of showcase what they're doing. It gives them a couple of different options for how they get back – give feedback. It's an excellent classroom management tool because I can see all their screens and we can come together and we can share what they're doing on their screen without them necessarily having to have their name on it. If they want to, that's fine … but like it … that encourages them to take a little more risks, being anonymous, and so it gives that component of, we can all come together and look at what we're doing but we're not judging anyone for if it's wrong or if it's not cause we don't know who it is.

Several teachers mentioned using Google Forms and Google Classroom. Teacher 15 explained why she liked Google Classroom "And that's also nice for quick feedback. Especially depending on what kind of assignment I've put on the Google Classroom. But I can get real quick feedback and to talk about what we need to keep going on and look over to clear it up." Teacher 10 explained what she didn't like about Google Classroom, "I think it will take more work for me in the math aspect because the math language is not, in my idea, it's not where it needs to be; it takes just a little bit too long to type in math."

4.2.3. Assessment tools

Teachers mentioned a variety of assessment tools that they used including Kahoot!, Socrative, Plickers, Quizlet, Mastery Connect, GradPoint, Kudo, and GradeCam. These assessment tools were typically used for review, quick in-the-moment assessment, or formative/summative assessment. Kahoot! was the assessment tool most frequently mentioned by teachers. For example, Teacher 15 explained,

> [I] usually use Kahoot near the end of a lesson, nothing – never for anything new, but as kind of, like, review. And, big thing is, it gets them all engaged. Even the kids that are typically in the back that don't – want to avoid participating, they'll get into it.

Teacher 6 had a similar explanation stating,

> So, Kahoot, I like to use it as a review game, and so, it's just a time for the students to really show what they know, but it's also in a fun environment, so they kind of are tricked into enjoying doing practice problems. And so it's a nice option instead of just a worksheet. And so I think it just gives them time to quickly put their knowledge to the test, to see what they know and what they don't, and it's nice for me as a teacher because I immediately get the results. And so we can see how many people got it right, and how many people got it wrong. And so whenever we have those questions where a lot of people in class got it wrong, we pause the game, and we'll work it out on whiteboard and just have an opportunity for everyone to see what they did wrong and fix their mistakes.

Beyond Kahoot, teachers also noted the use of online quizzes for assessment. This included programs like Mastery Connect, GradPoint, and GradeCam. While Kahoot! was seen as a fun way to assess, a few teachers noted that the speed aspect of the game was not always conducive to their assessment goals. For example, Teacher 2 expressed she preferred an online quiz,

> I found a online quiz that they worked in pairs and they were able to … I put in some problems that I made up and they could see if they got it right or they got it wrong and they could kind of gauge their own learning and move at their own pace.

Teacher 3 mentioned she preferred Socrative to Kahoot! because students could take their time with Socrative. She explained,

> I really like Socrative. Socrative is really nice for Math, just because if we need to take a little bit of more time to solve something

… I cared more about if the problem was correct, not necessarily who got it done first. So Socrative is a really nice way to make it fun, and make it a race, but it wasn't timed. It was based on accuracy.

4.2.4. Communication tools

All teachers who participated in this study had access to document cameras and projectors that allowed for communication in their classroom, but many did not mention this when asked about their uses of technology. Similar to the way they talked about graphing calculators, these were not initially mentioned because they are viewed as typical tools in classrooms. In contrast, teachers mentioned tools like learning management systems (e.g., Canvas, Blackboard) and Remind 101 as technologies they used to communicate with students and parents. Teacher 10 explained why she used Remind 101, “I have Remind 101, so I can text them if I need to without them having my phone number and I can text their parents if I need to.” Perhaps because these tools were just assumed to a part of the classroom, teachers did not frequently mention or describe them.

4.3. Factors teachers consider in choosing technologies

Once a teacher has decided the *type* of technology tool that is appropriate for a learning goal, the next decision they have to make is which specific technology tool to use. In contexts where different hardware and software might be available to choose from, teachers consider many different factors as they make this decision. As part of the interview protocol, if teachers indicated they used technology, then they were asked what they considered when deciding which technology tools to incorporate in their mathematics lessons. Some teachers described these factors in response to other interview questions as well. Quotations in the interview transcripts that addressed this issue were coded as “decisions to use - what to use” and then themes were developed from these data. The following themes emerged when considering which technologies to use for a lesson: ease of use, supports the lesson, access and compatibility, and interactive features of the technology.

4.3.1. Ease of use

The most common factor mentioned by teachers related to usability of the technology, addressed explicitly by 13 (62%) teachers. For many of these teachers, the reason they looked for easy to use and intuitive technologies was so that they could minimize the time needed for students (and themselves) to learn how to use the technology, allowing the focus to remain on the mathematics. For example, Teacher 18 explained that when comparing using the graphing calculator to using Desmos she would need to spend a lot of time explaining how to use the calculator (e.g., changing the window), “So, I've used Desmos” she explained, “and the reason is because it was clear to the students. So, going back to your question, it's because of how it's going to benefit the students … are we going to use our time efficiently, basically.” This reasoning is also exemplified in the following statements,

> I play with the technology too just to see if it's user friendly. I don't like to use something if I'm going to have to teach … spend time teaching them how to use it. I want it to be pretty easy for them to figure out how to use so I don't have to spend as much time. I can spend more time on the lesson versus teaching them how to use the technology. (Teacher 7)

> One, is it usable? Right, is it kind of intuitive for the kids because … I mean, anybody's that in the classroom will tell you, you have limited time anyway. So if you have to spend a class period or two telling kids how to use the technology, it's kind of frustrating before you can even get into it. (Teacher 19)

> Is the technology intuitive? Because if it takes me 5, 10, 15 minutes to figure it out, then it is going to take the class at least that long if not longer. Some of them might know it but then other ones are going to be like “I've never seen anything like this”. So if it is intuitive or not. (Teacher 4)

Other teachers noted that technologies that were easy to use were important because they did not want their students to be distracted by figuring out how to use the technology. They noted that this could be frustrating for students and detract from the mathematical focus of the lesson. For example, Teacher 3 explained, “I really just want to make sure that the students are able to utilize it … with minimal problems and use that to get to an end result of understanding whatever the math topic is that we're learning.” Similarly, Teacher 14 said, “if you're gonna use technology, I don't think you want the technology to be burdensome. Um, you know, you want the technology to be easy to maneuver so that the burdensome part is the math, right? We don't want make them dislike something because they can't operate it properly.” As is implicit in this statement, ease of use allows for a focus on the technology supporting the mathematical goals of the lesson - another theme that arose explicitly as well.

4.3.2. Supporting instruction

Ten of the teachers explicitly expressed that they chose technology that would enhance the lesson or was aligned with the learning goal of the lesson. As Teacher 17 said, “is it truly applicable to what I'm supposed to be teaching them, to the curriculum, or is it something that just looks fun and I'm trying to make it work? Because if I'm just trying to make it work, then it's not worth our time, even if it is fun and they will learn something, but they may not learn exactly what we need.” This idea is further exemplified by the following statements,

> That really depends on what you're teaching. Can it show off … the concept, so to speak? The whole concept, and not just one little thing. (Teacher 20)

> Well. It depends on what the lesson is … of what I want to accomplish … So if it's a more of a review thing … Is it something that's engaging to the kids? Something that I can get feedback from?. So, I mean, that in itself is part of it … If it is something to do with the project … Is it going to help the students understand where we want to go with the project? It depends on what the lesson is." (Teacher 3)

> You want them to be able to make that connection, like "why are we doing this here?" … You can bring all sorts of stuff into the classroom, but if it doesn't tie in with where you are, and where you're going, and allowing kids to make the connections, then I don't see a value. (Teacher 19).

It was also noted that there are some topics that lend themselves more toward technology use than others - as is indicated by Teacher 7's comparison of a discrete math course and a statistics course, "There's really just what the lesson is and it depends on the class I have, too. Discrete math is a little bit … there's not as much technology that I can use when teaching it … Anything with stats I love to use technology. I love to do the calculator simulations, TinkerPlots and stuff like that. And then just the geometry stuff. If it's geometry I absolutely will include some type of technology whether it's GeoGebra or something else. It just depends on the topic that I'm teaching."

4.3.3. Access and compatibility

Teachers who participated in this study had a variety of devices in their classrooms, including laptops, Chromebooks, iPads, and graphing calculators, as well as devices available to check out for use in the classroom. Additionally, many of the teachers in this study work in bring-your-own-device environments, where each student has their own device. This may include several different varieties of phones and tablets. Many teachers noted that issues related to access and compatibility were important factors that they considered when selecting technology to incorporate in a lesson.

Access issues included having enough of a particular technology for large classes. Teacher 16 noted the desire to identify technology that works on devices so all students experience the activity. He stated, "I look for something that each of my students would be able to put their hands on … I want them actively involved, and not just looking and staring at it. Um, and them to be the ones to do the activity themselves." This was an issue for many teachers, even those that had laptops in their classrooms. Teacher 6 noted, "My class that has computers, I only have 10 … so that's – the goal is for it to be a three to one ratio but with 35 students, there are going to be, you know, a couple of extras in there. So … that's something to think about." For those that do not have devices in their classrooms but have access to checking them out, decisions about which technologies to use often depend on how far in advance they would need to arrange for using them into the classroom.

One of the ways teachers addressed issues of accessibility of devices was to use a variety of devices at the same time, ensuring that all students would have access to the mathematics. Given the variety of devices that students might have available to use in the classroom, another factor that teachers considered was whether or not an application would work across multiple devices. Teacher 9 explained, "I want something that can format to an iPad or a computer or their phone and so is it compatible with an iPhone and an Android."

One final access barrier that several teachers mentioned was related to application choices. Teachers prefer applications that are free and do not require extra steps (e.g., login) prior to engagement. For example, Teacher 21 noted, "I mean, usually if I'm deciding whether or not to use something, it's a big decision is, if it's free. [laughs] If it's free, I'm much more likely to use it." This is further emphasized by Teacher 13 who stated,

> I want to use an app that has to already be downloaded on all of those laptops, with a certain username, you know, for it to actually register on that, then that doesn't help me whatsoever. If it's something that I can just say, 'Here, go to this website, this is available' give them some code to enter.

Teacher 9 further explained, "Does it require students to login like I don't like when they have to login because it's an extra barrier."

4.3.4. Interactive features

Two other factors, each mentioned by four teachers, that were considered when deciding what technology to integrate in a lesson are whether or not the technology allows for exploration and whether or not it provides feedback (e.g., Teacher 3 said, "Is it something that's engaging to the kids? Something that I can get feedback from?") In their descriptions of technologies that allow for exploration, the teachers identified dynamic features being consistent with this goal. For example, the following teachers remarked on the importance of being able to manipulate and look for invariances,

> I would say one where students are very hands on and manipulating things and noticing differences. If we're talking about characteristics of quadratics for example. (Teacher 15)

> Being able to, like, drag things, so … But yeah, the instantaneous part is kind of important to me, because like, if a kid types in a function in Desmos, it immediately appears. And they can – if they have sliders like that, it's something that they can do, and it's, like, instantaneously with the graph, so that's nice. And that's not really something you get on a graphing calculator, so … (Teacher 21)

When remarking on technologies that provide feedback a few teachers mentioned they prefer those that provide feedback directly to students. For example, Teacher 8 noted,

> So, one of the features would be, you know, something that can give the students immediate feedback. So being able to type in an answer and get feedback "is it correct?" or "is it incorrect?" so they are not able to move forward with the lesson unless they are getting the right answer.

Another type of feedback opportunity a few teachers mentioned was the ability for them to see students' work and provide feedback themselves through the interface. This goal was explained well by Teacher 9 when he noted,

> I think Go Formative is a website that I've started to use a lot for the assessment because they don't have to login, they can just put their name and it pops up and I can see, kind of real time, and I can interact with them through that. So if they're doing a practice problem I can see them do it and then I can comment feedback to them while they're doing it in real time.

All of the factors teachers in this study mentioned when deciding what technologies to incorporate in mathematics lessons fell into the categories of ease of use, supports the lesson, access and compatibility, or interactive features of the technology. As evident by the data, their reasons for considering any one of these features was often due to how it impacts the way they use their time in a lesson. As Teacher 16 stated,

> I have to weigh whether or not to be able to take the time to teach them how to do that, or is it something that they can easily play with it, and learn on their own, and then be able to see the math behind it.

This kind of clear statement about efficient use of time was made by teachers talking about all four factors, making it an important aspect to consider for anyone working with teachers on incorporating technology in mathematics lessons.

5. Discussion

All mathematics teachers in the study used technology in their teaching to some extent. Although earlier studies reported that external barriers like lack of access to technology impacted teachers' decisions whether to use technology (Ertmer et al., 1999), this did not seem to be the case for the teachers in our study as they all had graphing calculators and computers available. While these teachers had technology tools available, they experienced a different type of access issue. Many teachers in this study noted that they had different types of hardware available (e.g., laptops, tablets, desktops, cell phones, graphing calculators) but not enough of any one kind to ensure all students could use the same type of device. As a result, teachers would piece the different technology tools together to assure all students had a device to use. This required teachers to ensure the software they were using was accessible across different devices and platforms. Other factors that informed teachers' decisions about whether or not to use technology in a lesson that were consistent with previous literature included - adequate planning time (Bauer & Kenton, 2005) and access to software (Bauer & Kenton, 2005).

As noted by Ertmer et al. (1999), internal barriers like teacher beliefs about students, technology, and learning acted as factors in our teachers' decision making regarding types of technologies to incorporate in their mathematics lessons. (Though rather than *barriers*, we refer to them as internal *factors* as they did not stop these teachers from choosing to use technology.) For example, similar to previous studies (e.g. Ertmer, 2005; Hall & Hord, 2011; Norton et al., 2000) we found that teachers' beliefs about student learning and technology played into their decision making. However, for teachers in this study these decisions were about which particular technologies to use to best support student learning of particular mathematical ideas, discovery of mathematical properties, or ways of collaborating with others.

Some other factors that emerged from this study have not been commonly reported. First, many teachers chose to use technology only when they felt it was appropriate for a given mathematical topic (e.g., exploring function families is amenable to the use of sliders). This careful consideration about whether or not a particular mathematical idea is amenable to teaching using technology is important and in need of further study. Second, teachers chose technology they felt was well-aligned with their instructional goals (e.g., building mathematical understanding, practicing skills, assessment). As a consequence of these two things, this meant that features of the technology were an important factor in deciding whether to use it. For example, beyond accessibility, teachers considered ways in which the technology would allow for collaboration, exploration, assessment, or communication when deciding on a particular tool for a particular lesson. This means that decisions about technology integration are being made often, with different decisions being made from lesson to lesson. These findings align with Zbiek and Hollebrands (2008) who noted teachers' concerns about technology integration typically falls into the categories of personal concerns, management concerns, consequence concerns and technological concerns. However, there were few, if any, personal concerns noted by the teacher participants in this study. This is likely due to the fact that they were comfortable with utilizing the technology themselves since they had recently graduated from a program where teaching with technology was emphasized. Most commonly among these participants was a stated concern about consequence (i.e., making choices about technology integration that supports student learning). As far as technology concerns, the participants in this study were concerned about how software works across platforms in a way that has not been identified in previous literature.

A phenomenon that was commonly reported by teachers in this study that has not been noted in previous research is the practice of using multiple technology tools within a single lesson. The availability of easily accessible devices and free online software that meets their pedagogical needs are likely the reason for the recent emergence of this practice. For example, teachers noted they might use certain tools for assessment, but an entirely different set of tools for group work or for introducing a new topic. Most teachers had an entire suite of tools at the ready that they could choose from, depending on the situation. Interestingly, few of the teachers noted using tools they learned about in their preparation courses (that incorporated the [project] materials). Instead, teachers were using technologies they learned about in other places, technologies that were new (e.g., Desmos), free, and sometimes including technologies that are not math specific. This may indicate that these teachers have developed a broader understanding of how and why to integrate technology for mathematics teaching and learning. In addition, these teachers appear to be inquisitive, taking the time to learn new technologies that might meet their needs.

It is important to note that the findings from this study are limited to those who volunteered to participate in the interviews. Teachers self-selected to participate and it is likely only those who were already using technology chose to be interviewed. It is also likely that the teachers reported what they believed the interviewers wanted to hear regarding their use of technology. However, while the teacher preparation program that the participants experienced included lots of opportunities to learn and use technology, many tools teachers were using were either not available, or not used by faculty, when they were a university student. Thus, it appears, that after completing their teacher preparation program, teachers still continued to learn about and incorporate new technology tools. An additional limitation is related to the reporting of technology use, specifically the graphing calculator. As was reported in the findings, teachers noted the use of graphing calculators in an off handed way as if they did not think this was a technology we were interested in hearing about or assumed we knew about since they are so prevalent in schools. This was not something that we anticipated and as such, did not appropriately ask questions to probe the ways they were using this tool. As a result, the examples of graphing calculator use that were shared were limited and likely do not represent the variety of ways in which they are incorporated into these teachers' lessons.

6. Conclusion

Today, teachers have access to a variety of different technology tools. Those working with teachers need to ensure teachers are prepared to use the technology they have available at their school, in addition to those technology tools their students are bringing to class. This often results in the teacher having several different types of technology in use at once. Preparing teachers to be knowledgeable about the specific operation of each device is likely not possible to do in a teacher preparation program alone. Rather, teacher educators can focus more broadly on types of tools, ways teachers can position them, and how particular activities align with specific mathematics learning objectives.

The findings in this study suggest that teachers go through a series of questions as they consider the integration of technology in their lessons. The process with which they made their decisions and the factors that were important therein provide a framework with which we can support others in their decision making (See Fig. 2). Such a framework will help teachers focus on the connection between their technology integration decisions and student learning, as well as issues related to the realities of today's classrooms that might be otherwise overlooked (i.e., access and compatibility).

Furthermore, it is important that teachers are provided support towards becoming knowledgeable about where to find resources and support knowing that the particular technology tools rapidly change. Teachers today find themselves as curators of technological resources that span different devices, and platforms, rather than creators of activities and experts in using a single technology tool or program. In order to appropriately curate apps and activities that meet strong learning goals in a mathematics class, teachers may benefit from having access to rubrics that could help them develop the skill of recognizing a quality app or activity (e.g., Harrison & Lee, 2018; Sherman et al., 2017). Thus, approaches in the development of future teacher education materials needs to reflect this reality and assist teachers in developing broader TPACK knowledge (Koehler & Mishra, 2009) and flexible ways of thinking about their use of technology to support learning.

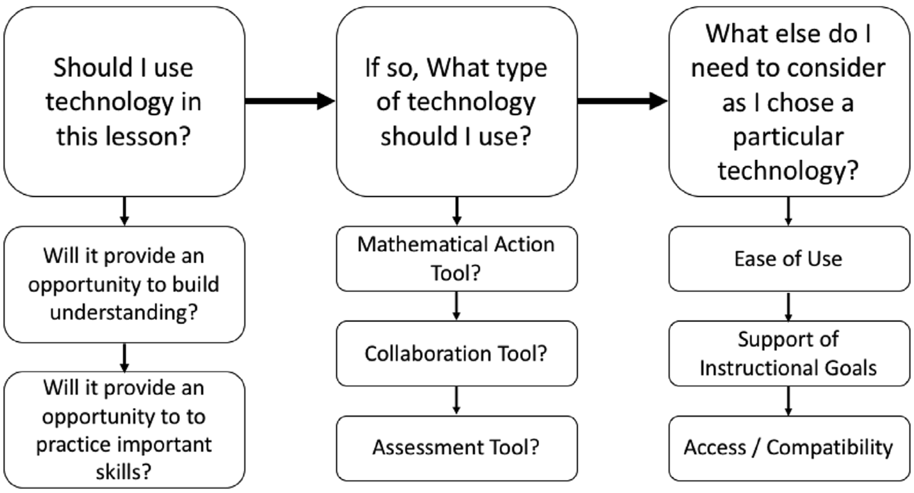

Fig. 2. Framework to guide technology integration decisions.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.compedu.2018.04.008.

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