Title
Examining the perceived impact of technology on teacher-student math discussions in early elementary classrooms

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Examining the perceived impact of technology on teacher-student math discussions in early elementary classrooms

A dissertation submitted in partial satisfaction of the requirements for the degree Doctor of Education

by

Derek Weisel

2017
The quality of mathematics instruction has been the subject of greater scrutiny as an increasing number of external measures compare American students with students internationally. Scholars and teachers agree that improvement in the quality of mathematics education in the United States is crucial to maintaining a high level of competitiveness for American students. This mandate has intensified the search for instructional techniques to help improve math achievement, and technology is often at the center of this discussion. The increased presence and diversity of digital tools in the classroom offers the opportunity to improve math instruction by allowing teachers to employ diverse instructional strategies that center around the teacher-student relationship. Technology-supported learning environments have been predicted to increase student math achievement, but research findings have been mixed. It is still too early to dismiss this approach as unsuccessful. These technologies hold tremendous promise if they can be designed and executed in a way that meets educational goals. This qualitative study investigated the perceptions of teachers as they engaged in cognitively guided instruction math activity using digital tools to support math discussions. The findings from this study help provide a more nuanced understanding of the role teacher perceptions play when using a digital tool to support math discussions. These results may serve to help schools design professional development with more practical and research-based
expectations for producing change in teacher practice, ultimately leading to improvements in student math learning outcomes.
The dissertation of Derek Weisel is approved.

James Stigler
Jody Priselac
Megan Loef Franke, Committee Co-chair
Christina A. Christie, Committee Co-chair

University of California, Los Angeles
2017
To my wife
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Chapter 1:

Problem Statement

Introduction

The quality of mathematics instruction has been the subject of increased scrutiny as more external measures compare American students with students internationally (Darling-Hammond, L., Wei, R. C., Andree, A., Richardson, N., & Orphanos, S., 2009; International Association for the Evaluation of Educational Achievement, 2011). Many scholars also agree that it is crucial we improve the quality of mathematics education in the United States (Hill, Schilling & Ball, 2004; Stigler & Hiebert, 1999). This is particularly important at the early elementary levels where the foundation for all future mathematical thinking is built (Clark & Clark, 2004). However, early elementary teachers often teach all academic subjects and they consistently cite mathematics as their weakest domain. Thus, improving early elementary math instruction can be a challenge to address (Clark & Clark, 2004; Frank, 1990).

This is a serious concern because the first three to five years of students’ time in school can be the most critical period of their mathematics education (Copley, 2009). During this time young children develop rapidly on several levels including intellectual capacity, cognition skills, and language skills crucial for learning. The development of these skills allows early elementary teachers to use student pre-knowledge and student-generated strategies as an important piece of their instructional approach in almost every subject they teach, but mathematics is often an exception because many early elementary teachers have an anxiety about mathematics can negatively impact math instruction (Beilock, Gunderson, Ramirez & Levine, 2010; Ramirez, Gunderson, Levine & Beilock, 2013).
The increased presence of various digital tools in the classroom offers the opportunity to improve engagement across K–12 and enhance math learning. The International Society of Technology in Education (ISTE) has reported that technology has a statistically meaningful overall positive impact on student learning outcomes in math, literacy, and reading (2008), but other studies have struggled to find consistent evidence of prominent and pervasive improvement in math. (Cheung & Slavin, 2013; Burns, Klingbeil & Ysseldyke, 2010; Slavin & Lake, 2008).

What is clear in the research is that despite some amazing technological gains in recent years, many teachers have not developed the necessary skills to unlock the ability of technology to enhance the classroom learning experience (Hsu, 2010; Savery, 2002). Moreover, even with technological advances, ample resources, and administrative supports, teacher perceptions still play an important role in the success of any technology integration. Failing to consider the way teachers perceive the use of technology in the classroom can lead to ineffectual professional development and squandered resources (Wartella, Schomburg, Lauricella, Robb, & Flynn, 2010).

Research has consistently shown that well-designed professional development for teachers can have a positive effect on their beliefs, actions, and instructional practices (Darling-Hammond et al., 2009; Carpenter, Fennema, Franke, Levi & Empson, 2015). The best way to design professional development focusing on educational technology is still being investigated, however (Braak, 2001; Roschelle, et al., 2010; Wartella, et al., 2010). We need a better understanding of how teachers perceive technology use when engaging in math discussions. This will be essential for crafting better professional development experiences that empower them to more effectively use digital tools to improve student math learning. With this in mind, the goal of this study was to better understand the perceptions of K–2 teachers when they have math
discussions with students engaged in a cognitively guided instruction (CGI) activity while employing iPads as a technological tool.

A Brief History of Math Instruction

Since the 1960s there has been a considerable amount of research on K–12 math instruction including detailed studies of how teachers work in classrooms (Artzt, Armour-Thomas, Curcio, & Gurl, 2015; Jackson, 1968; Jaworski, 1994, Lampert, 1985). A great deal has been discovered about how teachers interact with students, monitor their work, and provide them with feedback (Brophy, 1986). Much of this research has focused on the “process–product” approach, which looks at the process of teacher and student behavior that leads to the product of student achievement. In this context, quality instruction is defined by teaching behaviors that are connected to student achievement. This has led to many educators employing a “sage on the stage” approach to math instruction, where a teacher (sage) at the front of the room (stage) lectures to a group of students. The persistence of this approach in contemporary classrooms is an example of the challenge of fundamentally changing teacher practice.

There are three major limitations of the process–product approach. First, the student is largely ignored; little attention is paid to student thinking and understanding. Second, the approach neglects to examine what the teacher is thinking before, during, and after instruction. The process–product approach treats a teacher like a machine and ignores the special human qualities that the best teachers consistently demonstrate. Finally, a strict focus on student achievement can sometimes conceal student understanding, especially with respect to abstract mathematical concepts. Unless teachers recognize their own set of beliefs, thoughts, and knowledge, as well as the pre-knowledge of their students, the depth of their instruction will necessarily be superficial (Franke, Webb, Chan, Ing, Freund & Battey, 2009). This presents a
particular challenge for early elementary teachers, who often enter teaching without a strong background in mathematics and have anxiety about teaching in this domain (Furner & Berman, 2004).

After direct teaching methods did not boost student achievement as predicted, the National Institute of Education (Gage, 1975) released a report underscoring these limitations and spurring serious research into the thought and decision-making processes of teachers. In the decades since the report was released, research into these teacher processes has yielded meaningful insights into the connection between instruction and student learning. These insights helped inspire the research that led to the development of more progressive approaches including cognitively guided instruction.

**Using Cognitively Guided Instruction**

CGI offers an approach to improve student math learning that is grounded in the recognition that students and teachers are dynamic thinkers. There are two central assumptions of CGI. First, students are not apathetic learners who simply absorb knowledge thrust upon them. Even the youngest students bring a tremendous amount of pre-knowledge to any learning situation, including mathematics. Portions of this pre-knowledge may be incorrect, and some of it may even hinder learning, but all of it informs how student learn. Second, teachers are reflective, thoughtful people who approach the cognitively demanding task of teaching the same way any problem solver confronts a complex problem. They use their beliefs, thoughts, knowledge, and experiences to analyze their classrooms and make decisions about instructional strategies. The richest learning can only occur when teachers construct knowledge through classroom discourse that acknowledges both of these tenets (Carpenter, Fennema, Peterson, Chiang & Loef, 1989).
The essential process in CGI is the steady presence of productive classroom dialogue (Carpenter, Fennema, Peterson & Carey, 1988). This requires active participation in conversations such as elaborating on one’s own thinking, justifying conclusions, listening and responding to arguments of others, and asking clarifying questions to refute or improve arguments (Carpenter et al., 1988). The underpinnings of these types of conversations are the two dimensions that CGI cites as crucial for the productive sharing of ideas: articulating one’s own ideas and critical engagement with the ideas of others. These types of active discussions also provide a foundation for teachers to develop their own math understanding, particularly if they feel they are lacking knowledge in this domain (Franke, Carpenter, Fennema, Ansell, & Behrand, 1998).

Shulman (1986) noted that teacher knowledge can be placed into three categories: knowledge of content, knowledge of pedagogy, and pedagogical content knowledge. He found the majority of professional development focused on the first two of these categories—with limited impact on teacher growth—and ignored the third. CGI helps grow all three through active discussion in the classroom (Jacobs, Franke, Carpenter, Levi & Battey, 2007). When teachers engage in active discussion, they are not just looking for a correct statement, but are also trying to understand how students are thinking about mathematics. As teachers interact with more and more students, their exposure to the myriad ways these students think about mathematics increases.

The teacher can use these diverse student approaches to construct a detailed mosaic of how the classroom is thinking about mathematics. This provides insight into the best questions to help probe understanding and encourage students to expand their own understanding. The teacher is central to stimulating these discussions in the classroom, but analog resources like
scripting and teacher editions are not helpful when the teacher is trying to generate guided suggestions. There have, however, been advances in educational software that may help teachers generate suggestions and examples more easily for elementary school educators (Ficklen & Muscara, 2001).

**Technology and Student Engagement**

Technology use in schools has been gaining momentum with the increased sophistication and capabilities of mobile phones, tablets, and social media. For example, computer tablets, which many researchers cite as a crucial ingredient in any effective technology curriculum (Burns, Kanive, & DeGrande, 2012; Cheung & Slavin, 2013; Shapiro & Gebhardt, 2012), only entered the market in 2010 and they are still gaining a foothold in classrooms. Considerable financial resources have been invested into classroom technology with mixed results (Hixon & Buckemeyer, 2009; Levin & Wadmany, 2008), in part because technology benefits student learning only when teachers use it effectively (Gulbahar 2007, Kim & Hannafin, 2011).

Educational technology content developers often design software that is either too specific or too complicated for many teachers to use (Savery, 2001). An application on a device that is useful for only one lesson may be effective, but if the time it takes to master the software is prohibitive, teachers are not likely to repeat the time investment for every lesson. Educational technology offers the greatest advantage when it can be used across many lessons. Software like Educreations, Explain Everything, Draw and Tell, and Book Creator are like blank canvases for the teacher and student to use in concert on almost any lesson with oral, visual, and/or animated components unique to the experience at hand (Neumann, 2016). Each of these applications adds their own twist to creating a white board app for the iPad. Educations allows the digital sharing of voice, handwriting, and digital pictures. Explain Everything can be used by a larger spread of
student ages and allows the sharing of screen casting, annotation, animation and narration. Draw and Tell is designed for younger students who may be new to apps like these. It allows the use of different colors and has the ability to record student voice. Book Creator began its existence as a bookmaking tool but has been quickly adapted to be used in many different learning domains.

Book Creator, which was used the current study, acts as an interactive white board on iPads. Students record their written work, take pictures or add images, and narrate their thinking. These responses can be saved onto the devices so that the student or the instructor is able to easily access and review them. This simple but powerful feature allows teachers to reproduce student work while in discussion with the student and to observe student strategies without having the student present. In most versions of CGI, the most common way to observe student thinking is during precious classroom time and it may use multiple teachers; this is prohibitively time-consuming for teachers who have not mastered CGI strategies. Using iPads to reproduce students’ work and processes has the potential to greatly streamline how teachers observe and explore student thinking.

**The Project**

The goal of this study was to investigate how teachers perceive the impact of iPads on teacher–student math discussions during a CGI activity. The following research question guided the work: *How does using a technology tool during math instruction—in particular, one that facilitates a counting activity and that can also record student work—impact K–2 teachers’ perceptions of their ability to have math discussions with their students?* I focused on the following three subquestions:

a) How do teachers perceive the impact of using this technology on engaging with students?
b) What do teachers report as ways this technology is supportive of math discussions?

c) What do teachers report as the challenges when using this technology to have math discussions?

Qualitative research methods offered the best way to understand the meanings, motives, reasons, and patterns of these perceptions. Quantitative measures such as student math performance or standardized class observations may have provided additional context for student learning, but these assessments are not ultimately insightful in understanding the perceptions of a teacher during math discussions or while using a digital tool, so qualitative methods were the primary tools of this research. Furthermore, iPads were used because this was the predominantly available digital tool in the site’s K–2 classrooms, and because studies have found that tablets are the most developmentally appropriate tool for the K–2 student population (Blackwell, Lauricella & Wartella, 2014; Falloon, 2013, Neumann, 2016; Price, Jewitt & Crescenzi, 2015; Wollscheid, Sjaastad, Tomte & Lover, 2016). Book Creator was used as the app for this study because the participants had more experience with Book Creator because many of them had used it in other non-math lessons in their classrooms. This previous experience with Book Creator was preferred as opposed to making the participants learn a new app just for this study.

The research took place at an independent college preparatory day school in Southern California. This study included nine grade-level teachers in grades K–2—three at each grade level. Data were gathered via journals, focus groups, and interviews with the participating teachers. They reflected on how using Book Creator on the iPad impacted their ability to engage in math conversations with students, as well as the challenges of using technology during math lessons. Because I investigated teacher perceptions, it was useful to compare and contrast what each teacher described in the various data collection methods. The gaps or inconsistencies in
these multiple data sources offered useful insights into perceptions teachers had about the impact of iPads on math discussions.

**Public Engagement**

It is important that this work is not just shared internally at the school site but also disseminated to other schools as well. The findings are useful in designing professional development experiences that help instructors utilize digital tools to improve math learning outcomes. Many studies on CGI have predominately taken place in public schools, so showing how it can be applied with an independent school population is evidence of the generalizability of the approach. One potential forum is a meeting of local Southern California independent school math department chairs. This group meets multiple times each year and would be particularly receptive to these ideas because of similar issues with math instruction in their K–5 classrooms. Another useful forum would be the NCTM annual conference, which includes math educators from both public and independent schools. The more places educators see CGI being used, the more likely they are to believe that it may be useful at their own sites. Finally, it would be useful to publish these findings in a journal so that other educators doing research on CGI will have an understanding of how it can be applied in an independent school setting. It will be a useful contribution to the CGI literature, which already includes studies looking at different public school populations.

It is important that this and other CGI research be shared with as many educators as possible. Teacher-centered math instruction has dominated classrooms for far too long. Many teachers may not even be aware that there is a well-researched alternative approach that utilizes student math thinking—an approach that is now more accessible than ever with the use of digital tools. Most importantly, teachers who are stymied on how to incorporate student math thinking
in their lessons and discussions have great difficulty improving math instruction overall. CGI can address that challenge.

Summary

Many K–2 teachers identify math instruction as the area in which they feel they need the most improvement (Carney, Brendefur, Thiede, Hughes & Sutton, 2016). Many have attended numerous professional development events and have even taken additional coursework, but still do not report any appreciable improvement in their math instruction. The CGI approach uses instructional strategies in math that are much more aligned with how K–2 teachers teach other non-math subjects. Previous research has shown that many students learn mathematics better when using the CGI approach, but the best way to engage schools is by teachers sharing their experiences (Carpenter et al., 2015).

For many teachers, having multiple math conversations with students without extra support is time prohibitive. This keeps them from accessing the positive benefits of a CGI approach. Digital tools offer a tantalizing opportunity for them to engage in CGI-like math discussions with their students while conserving precious classroom time. Unfortunately, teacher perceptions about integrating technology in the classroom have played a part in deadening the greater impact digital tools could have. It is my hope that the current research will stimulate school discussions about technology use and enhance professional development experiences so that teachers can utilize digital tools to improve math instruction in the early elementary classroom.
Chapter 2:

Literature Review

Introduction

The National Center for Educational Statistics (2011) recently reported that students in the United States ranked 32nd in math proficiency when compared to other nations in the industrialized world. These findings have intensified the search for instructional techniques to help improve math achievement. A variety of methods have surfaced, but the findings of studies that measure their effectiveness in raising mathematics scores have been inconsistent (Lee, Grigg, & Dion, 2007; Rakes, 2010). Because the interactions between student and teacher are the foundation of classroom instruction, improving student learning must begin with investigating this relationship.

It is well supported that engaging students as active participants in their learning is critical for math understanding and skill development; this approach shows tremendous promise in helping to improve math learning (Barron, 2000; Mercer, 1996). One of the most powerful approaches to math instruction is to encourage students to explain their thinking with guided suggestions. This has consistently been shown to improve students’ math achievement and create better learning experiences (Franke et al., 2009; Webb et al., 2008).

In spite of this compelling research, more archaic methods persist; teacher-centered instruction is still the norm in many classrooms across the country (Inan, Lowther, Ross, & Strahl, 2010; Cuban, 1993; Goodlad, 1984). Students rarely ask questions when compared to working with a tutor (Graesser & Person, 1994), and teacher-talk often monopolizes discussions (Cazden, 2001). Perhaps of even greater concern is that this classroom culture has been persistent
for at least thirty years (Gall, 1984), underscoring the urgency to find ways in which to improve classroom instruction.

This literature review begins with a brief description of the evolution of math instruction at the early elementary level, identifying areas that demand immediate improvement. Next, I provide an overview of the traditional instructional approach, setting the stage for the development of CGI. After a brief description of CGI, I discuss the professional development necessary for adoption of this approach and the research supporting its positive impact on student mathematical learning. I also discuss the role digital tools can play in supporting and stimulating math discussions and the importance of teacher perceptions when implementing digital tools in classrooms. I conclude with a discussion of the application of CGI with student populations who have different demographics and the possible incorporation of digital tools to aid in enhancing math discussions and improving math learning in early elementary classrooms.

Mathematics Instruction

Early Elementary Math Instruction and Problem Solving

Mathematics instruction throughout the United States has employed traditional instructional approaches that emphasize acquiring and practicing skills rather than developing conceptual understanding and problem solving (Cuban, 1993). Teaching problem solving to early elementary (K–2) students has historically involved performing arithmetic operations with whole numbers—joining (addition), separating (subtraction), grouping (multiplication), and portioning (division) problems. Up until the middle of the 20th century, the narrow definition of teaching mathematical problem solving was for the teacher to present a concept or algorithm directly to the class, give students several rote examples to practice, and then assess on the same types of problems at some later time (Cuban, 1993; D’Ambrosio, 2003). This traditional form of
instruction has been shown to be ineffective in helping students learn, particularly students who have difficulty learning mathematics (Jitendra, et al., 2007; Griffin, 2005). Moreover, it often leads to students learning math as a series of steps as opposed to using critical thinking to solve a problem, with the unfortunate consequence that many students do not feel they understand mathematics (Fuson, Kalchman & Bransford, 2005).

A New Mathematical Teaching Approach

Polya’s 1957 book on problem solving thinking, *How to Solve It*, initiated a reconsideration of the traditional approach to teaching mathematical concepts. Polya described a basic structure for problem solving: understand the problem, devise a plan, carry out the plan, and review the solution. To help students devise a plan, Polya generated an impressive inventory of strategies including guess and check, solve a simpler problem, draw a diagram, or work backwards (Polya, 1957). His approach stood in direct contrast to the learning algorithm approach of traditional mathematics, namely because a student could create an entire new algorithm to solve a particular problem.

To help students learn to problem solve using Polya’s (1957) approach, a different framework for teaching mathematics had to be developed. Teachers trained in the traditional approach had limited tools to handle students using algorithms that the teachers had not seen before; the teaching guide and the problems written for specific algorithms had limited effectiveness. Subsequent development of Polya’s ideas incorporated Vygotsky’s early social development theory, Bandura’s social learning theory, and the constructivist theories of Vygotsky and Piaget (Bandura, 1977; Piaget, 1953; Vygotsky, 1980).

In Vygotsky’s (1980) social development theory, the crucial concept is the zone of proximal development. This is the zone of learning between a student’s current level of
independent problem solving and his or her potential to improve. This potential is reached by interacting with a more knowledgeable “other.” With assistance from a teacher or peer who is better skilled at problem solving, the student’s potential is developed until a problem that had been too difficult can now be completed independently. This approach shifts markedly away from the traditional model where all information comes from the teacher. Instead it is considerate of the initial knowledge that a student brings to the learning process.

Next, social learning theory asserts that children in a classroom learn from each other by observing behaviors and outcomes and deciding if they want to recreate the behaviors (Bandura, 1977). This is a basic description of the type of learning that happens in most American classrooms. Whether it is working formally together in small groups or learning stations, or in free time during recess, elementary students are constantly observing each other and deciding which actions to replicate to generate outcomes. Applying this to how students learn mathematics is an extension of how many students approach learning naturally (Carpenter et al. 2015). The type of learning that occurs when students are interacting with each other is decidedly different from how students learn from sole teacher instruction. This shifts the image of an effective teacher from someone who explains content so students can understand to someone who gets students to be able to explain things to others in a way that demonstrates understanding.

This new conception of the teacher as someone who is cognizant of student thinking and who empowers students to demonstrate understanding through two-sided interactions alters the kind of knowledge a teacher needs to make instructional decisions. A list of pre-written algorithms with accompanying problems will no longer suffice. For teachers steeped in a traditional instructional method, it can be daunting to adapt and grow their math knowledge and sharpen their awareness of student thinking so they can teach in a more constructivist style.
Contemporary Views of Teaching Mathematics Via Problem Solving

NCTM (2000) has now devised a more modern definition of problem solving in grades K–2, describing it as drawing on “knowledge, skills, and experiences to engage in a task for which a solution is unknown” (p. 12) This more open definition of problem solving does not connect with the traditional use of applying a known algorithm to a specific type of problem. Authentic problem solving can only occur when the solution is unknown to the student and he or she must do more than simply plug numbers into a memorized algorithm (NCTM, 2000). Without an algorithm to plug into, students must construct a new problem-solving strategy from their own understanding of mathematics.

This much more open and creative approach to teaching mathematical concepts via problem solving began to be used in earnest in the 1970s and has since gained in popularity (Loucks-Horsley, Stiles, Mundry, Love & Hewson, 2010; Schoenfeld, 1992). Nevertheless, the approach still has its critics. Stacey (2005) contended that problem solving should be a culminating goal of mathematics learning, not a means to learning concepts. Likewise, Avital and Barbeau (1991) argued that students may internalize incorrect mathematical conclusions if they only use intuition to solve problems. Even in light of these criticisms, NCTM (2000) has maintained that problem solving should be a key component of mathematical instruction.

Even more recently, the Common Core State Standards have used the Standards for Mathematical Practice to help promote the proper implementation of the problem solving standards found in the Common Core (Common Core State Standards Initiative, 2010). These standards were designed to help students develop the process of solving problems and to enhance their overall problem solving skills, as opposed to simply trying to get the correct answer as quickly as possible without understanding. Soon after the release of the Common Core State
Standards, NCTM took the initiative to publish a series of articles to help give math teachers of all grade bands specific support so they can get the most student learning while using the Common Core Standards (Dacey & Polly, 2012; White & Dauksas, 2012).

**Centrality of Teacher Knowledge**

Educators have discussed the importance of understanding student thinking while teaching mathematics for over 90 years. Buswell and John (1926) believed that understanding student thinking helped avoid “blind teaching of the whole class without knowledge of the specific needs of the individual pupils” (p. 86). Slowly, over time, the image of teachers as rigid dictators of knowledge has been giving way to a view of teachers as reflective, thoughtful individuals engaged in the complex process of teaching.

As reasonable as these historical references appear, there has not been a systematic contemporary exploration of how teachers use this knowledge of student understanding to inform instruction. Until recently, most research in early elementary math instruction has either been prescriptive or has included blanket assumptions that teachers apply discretion correctly. An emphasis was usually placed on teachers’ knowledge of mathematical content and success was measured by student achievement. The limitation of these studies is they used global metrics of teacher knowledge, such as number of college math courses completed or scores on standardized tests—measures not directly connected to classroom instruction (Romberg & Carpenter, 1986). With a new emphasis placed on open-ended problem solving by NCTM and others, these findings steered researchers to find a better framework for measuring teacher knowledge.

To find a better way to measure teacher knowledge, Shulman (1986) devised “pedagogical content knowledge,” which he defined as “the understanding of how particular topics, principles, strategies, and the like in specific subject areas are comprehended or typically
misconstrued, are learned and likely to be forgotten” (p. 26). This definition helps distinguish between various categories of knowledge that impact classroom instruction in different ways including: (a) knowledge of content matter; (b) knowledge of pedagogy; and (c) pedagogical content knowledge (Shulman, 1986). These three different measurements have enabled researchers to develop a detailed framework that allows for teachers’ knowledge beliefs and has accounted for how students construct math knowledge.

Carpenter et al. (2015) adapted these categories into four principles of teacher learning: “(1) knowledge of mathematics, teaching, and learning is organized in a rich network of connections; (2) knowledge is generative so that it provides a basis for ongoing learning; (3) teachers describe, analyze, and justify decisions about teaching; and (4) teachers develop an identity as learners capable of learning in their classrooms and making decisions based on what they learn” (p. 194). These principles clearly show that teacher learning is intimately connected with the capacity to have engaging math discussion with students, to the extent that a teacher who is not growing his or her knowledge would struggle to create the constructivist style classroom where creative mathematical problem solving can flourish.

With these measures and this framework it became possible to convince more teachers to adapt their practice with respect to how students construct their own understanding. A crucial consequence of adapting teacher practice in this manner is that the instructor, by exposure to student knowledge construction, begins to continuously grow his or her own mathematical knowledge and confidence in mathematics (Carpenter et al., 2015). This increase in math knowledge and confidence is much more evident with this approach than with professional development or additional outside classwork. This framework led to the formation of CGI.
Cognitively Guided Instruction

As discussed in the previous chapter, CGI is an approach to teaching mathematics, introduced to teachers in a professional development model, that utilizes the way children naturally think about problem solving. It has consistently demonstrated a positive impact on improving the quality of classroom instruction (Carpenter, et al., 1989; Fennema, et al., 1996). CGI focuses on “student understanding of specific mathematical concepts and can provide a basis for teachers to develop their skills more broadly” (Carpenter, Fennema & Franke, 1996, p. 6).

CGI was designed at the University of Wisconsin’s Center for Educational Research using contemporary scholarship in cognitive science, experimental teaching methods, and innovative professional development approaches. Initial research on cognition by Carpenter in the 1980s led to the precursor to CGI: a 1989 experimental study by Carpenter, Fennema, Peterson, Chiang, and Loef, which revealed that a teacher’s specific knowledge about a student’s cognition had a positive impact on student achievement. The initial goal was to study “the impact of research-based knowledge about children’s thinking on teachers and their students” (Fennema, et al., 1992, p. 1). The project expanded, however, to include research on professional development, early elementary student thinking, urban school instruction, and preservice education (Fennema, et al., 1992).

Connection to Learning Theory

The crucial idea that underpins CGI is Vygotsky’s (1978) assertion that a child begins to learn mathematics well before beginning any formal schooling. Carpenter et al. (1999) used this assumption as the basis of the instructional approach in classrooms employing CGI. A teacher overseeing a CGI classroom is applying social constructivism by having students learn in group
settings and using real world understandings to develop mathematical understanding. Although Vygotsky and Piaget shared similar notions about constructivism, Piaget (1953) promoted a slightly different perspective, preferring a cognitive constructivism where ideas and understanding are constructed through an individual’s interpretation of a situation (Kamii & Rummelsburg, 2008). This contrasts with Vygotsky’s social constructivism, where children build understanding through interactions with peers and teachers. But educators rarely apply only one pure theory in the real-world classroom. In fact, a dynamic constructivist teacher has the discretion to apply both flavors of constructivism, depending on the context, to help create the richest learning for the students.

This hybrid approach goes along with the recommendation of NCTM (2000) of using constructivist practices in the mathematics classroom that are sensitive to a student’s current level of understanding. There has also been ample support in the literature demonstrating the success of posing and discussing mathematical problems that are designed to build upon math knowledge already possessed by the student (Powell & Kalina, 2009; Harel & Behr, 1991; Romberg & Carpenter, 1986). When a teacher is considerate of the prior knowledge a student brings to problem solving, this allows the student to develop a deeper understanding, expand the student’s knowledge, and generate new understandings (Lambdin, 2003).

**Math Discussions and Cognitively Guided Instruction**

Considering that mathematics has been formally taught in schools for almost 100 years, it is perhaps surprising that it was not until the late 1980s that a formalized mathematics instructional approach, CGI, was developed for that incorporated student pre-knowledge and thinking in a fundamental way (Shulman, 1986; Carpenter, et. al., 1989). CGI is based on the principle that “children enter school with a great deal of informal or intuitive knowledge of
mathematics that can serve as the basis for developing understanding of the mathematics of the primary school curriculum” (Carpenter, et al., 1999, p. 4).

CGI is not a curriculum and it does not dictate instruction to teachers. Rather, it is a philosophy of teaching based on three fundamental precepts: “(1) Young children have a rich informal knowledge of mathematics that can serve as a basis for developing understanding for mathematics, (2) Mathematics instruction should be based on what children understand about mathematics, and (3) When teachers understand a research-based framework of children’s thinking, they can make instructional decisions about what and how to teach that expand children’s knowledge about mathematics” (Fennema, et al., 1999, p. 1). The goal of CGI is not to tell teachers how to teach. Rather, it is to help them understand how students learn mathematics so that they are able to make effective instructional decisions (Fennema, et al., 1999). CGI is not only pedagogically sound but also aligns much better with the way many elementary instructors teach other subjects at their grade level.

Teachers who use CGI focus on student understanding because “when children understand something, they can use that knowledge in numerous ways, they remember it longer, and they can use it to learn more mathematics” (Fennema, et al., 1999, p. x). Instruction in a CGI classroom is grounded in three basic assumptions about student learning:

**Cognitively Guided Instruction with Different Student Populations**

The authors of CGI have published two major studies concerning its impact on student achievement, one in 1989 and one in 1996, both involving students from the state of Wisconsin and finding that understanding children’s mathematical thinking can help teachers improve classroom achievement in concepts and problem solving (Carpenter et al., 1989; Fennema et al., 1996). Villasenor and Kepner (1993) were interested in applying CGI with disadvantaged
minority students, and used a quasi-experimental approach in a large, urban district with a significant minority population. As in the 1989 and 1996 Wisconsin studies, students improved their mathematical problem solving abilities.

An extensive study by Slavin and Lake (2008) analyzed the research on a comprehensive range of math programs that were available to elementary educators at the time of the study, with the goal of comparing them on a common scale. They separated the programs into three categories: mathematics curricula, computer-assisted instruction, and instructional process programs. They investigated 87 studies, 36 of which were instructional process programs that included CGI. The ranked each study on a four-tier scale ranging from “insufficient evidence of effectiveness” to “strong evidence of effectiveness.” CGI was ranked on the third tier described as a “moderate evidence of effectiveness” one of only two classroom management models to be ranked on this tier. This evidence is encouraging in that CGI appears to be effective for a large variety of student populations.

Technology Integration

Technology to Support Cognitively Guided Instruction in the Classroom

Technology-supported learning environments have long been predicted to increase student math achievement (Ke, 2008; Kebritchi, Hirumi & Bai, 2010), but research findings have been mixed about the impact of technology on learning outcomes (ISTE, 2008; McDonald, 2002; Dynarski et al., 2007; Ke, 2008; Slavin & Lake, 2008; Kebritchi et al., 2010). Despite these findings, it is still too early to dismiss this approach as unsuccessful. These technologies hold tremendous promise if they can be designed and executed in a way that meets educational goals.

Even with the advent of increased access to a wider array of computers and other devices, the actual use of technology continues to be sporadic across K–12 classrooms (Gray, Thomas,
and Lewis, 2010; Kulik, 2003) and especially in K–3 education (Vockley & Lang, 2011; Wartella, Blackwell, Lauricella & Robb, 2013). Even when technology is used in the classroom, it is not done in a meaningful way to enhance student learning; it is used more for administrative and superficial purposes (Cuban, 2003; Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur, & Sendurur, 2012). Eteokleous (2008) found that technology was most frequently integrated in didactic ways like homework and practice. This leads to an important question: Now that technology is present in the classroom, how do schools incorporate it in a meaningful, student-centered way? Some argue for computer-based assessment, curriculum-based management, and computer assisted instruction (Cheung & Slavin, 2013; Ysseldyke, Spicuzza, Kosciolek & Boys, 2003). Others argue that digital tools can complicate and inhibit learning and must be reduced to their simplest form to maximize their effectiveness in the classroom (Tobin, 2015).

There is another long-standing debate about how to research technology’s impact on learning. Clark (1983) initially argued that the medium used to deliver instruction, like technology, does not influence learning. Rather, any gains can be attributed to the novelty of the approach or a revitalized curriculum. As technology continued to play a more prominent role in classrooms, research on the impact of media differences independent of the curriculum continued but a meaningful measure was elusive (Clark, 1989; Tamim, 2011; Winn, 2002). Others concluded that technology and curriculum are so intertwined that it is impossible to analyze them separately (Kozma, 1994; Kozma, 2000; Sahasrabudhe, 2014). Since freezing curriculum for extended periods of time is not a luxury that many schools have, integrating digital tools within existing, well-researched teaching approaches like CGI begin to answer the question posed by Kozma: “In what ways can we use the capabilities of new media to influence learning for particular students, tasks and situations” (p. 18)?
Tablets that use white-board applications have matured enough since the introduction of the iPad that they are suitable for use in K–2 classrooms (Blackwell, 2013; Falloon, 2015; Price, Jewitt & Crescenzi, 2015; Murray & Olcese, 2011). Using a simple white-board app like Book Creator, which records students’ writing and words, gives teachers a supplemental way to access student thinking without face-to-face discussions. This could help teachers make better use of class time and student discussions by already having an idea of where the class stands before they enter the classroom. A time saving technique like this may make adopting a teaching philosophy like CGI more accessible to schools.

**Teacher Perceptions and Technology Integration**

Assuming that the hardware and software have the technical capability to support math discussions, it is still a challenge to integrate digital tools into traditional instruction. Even in settings where resources, time allotments, and administrative supports are available for adoption, it can still be a challenge to change practice because of teacher perceptions of educational technology (Ertmer, Ottenbreit-Leftwich & York, 2007; Hsu, 2010). Teacher perceptions play a large role in the successful adoption of any technology initiative (Mundy, Kupczynski & Kee, 2012). Those that impact technology integration range from confidence in the reliability of the hardware or software, a teacher’s digital identity, awareness of a digital divide between students and teachers, and degree of optimism that technology will improve the classroom experience (Goode, 2010; Hsu 2010; Kay, Knaack & Petrarca, 2009; Royer, 2002; Wang, 2002).

Educators’ first experiences with classroom technology often generate frustration and lead to reports of curriculum dissonance, hardware or software malfunctions, and a lack of preparation and training for teachers and students (Ertmer, 2000; Gibson & Hart, 1997; Tobin, 2015; Wilson, Notar & Yunker, 2003). These initial experiences have colored the perceptions of
many teachers. Teachers use their own experience as the script in their own teaching (Stigler & Hiebert, 2009)—a script that is obsolete and ineffective because many teachers were educated and excelled in the traditional classroom with an immature technology presence, where memorizing was learning and mathematical standards were less developed. Nevertheless, research has shown that they still value the learning opportunities that digital tools offer, even with the barriers that can prevent successful implementation (Ertmer, Addison, Lane, Ross & Woods, 1999; Wilson, Notar & Yunker, 2003; Quinn, 1998).

With all of these obstacles, there is a notion that teachers are resistant to technology as a rule. However, research describes a more nuanced and promising picture. For almost as long as technology has been in classrooms, educators have appreciated its promise to enhance student learning (Mundy, Kupczynski & Kee, 2012; Quinn 1998). Ertmer et al., (2007) reported that many teachers believe digital tools can be useful in the classroom as long as they feel confident using them. The challenge is how to ensure teachers see themselves as proficient technology users.

Savery (2002) observed that teachers gained confidence more quickly using technology for administrative tasks, grades, attendance, and communication, but the energy barrier was higher and the growth slower for using it directly during classroom instruction. And Royer (2002) found that when teachers were directly involved in purchasing and setting up a specific technology in their classrooms, they were more likely to use that technology. This supports Hsu’s (2010) findings that the better trained a teacher was in the use of a specific technology the more likely the technology would be used during instruction.

The increasing prevalence of digital tools in all aspects of the educational community has made it increasingly difficult for teachers to ignore their presence. At minimum, elementary
teachers are currently teaching a student population of digital natives who have very different living experiences. Teachers are no longer able to use their personal formative technology-free educational experiences as a point of reference (Prensky, 2006). This means that they need to construct their students’ experiences from the events of the last five to 10 years, not as children having formative educational experiences that are similar to the teacher (Warschauer, 2007). In a math approach that requires the understanding of student thinking, it is important that the teachers are considerate of this digital divide that often exits between students and teachers (Goode, 2010; Loges & Jung, 2001). All of these factors impact the perceptions of teachers with respect to using technology to support math discussions with students. These factors must be accounted for in the implementation of any new technology in the classroom, as they greatly impact the likelihood for a success.

**Conclusion**

There is increasing pressure on educational leaders to improve the quality of math instruction in American schools. Research indicates that classrooms need to move away from teacher-centered instruction to instruction that is considerate of student thinking and the math knowledge students possess before they even arrive. The best way to access this student knowledge is through productive math discussions. Fortunately, there has been considerable research on developing this kind of instruction, culminating with the development of CGI. This teacher development program has been found to be effective with various populations in rural, suburban, and urban public schools. Nevertheless, changing the instructional approach of an entire school can be a daunting task for school leaders. Finding strategies that alleviate the burden of adopting this process could help initiate change.
Employing digital tools to encourage better student math instruction while streamlining the resources needed to implement a CGI environment could be the stimulus needed to instigate a change of instructional approach in a school. Many researchers agree that simple white-board apps have matured enough that they can be used by K–2 students. But, even with access and support, the lack of transformative change indicates that other important factors are at play. The technology perceptions of teachers can be a deciding factor in the success of the adoption.

To date, there has not been a study of the CGI approach on an independent school population with access to sufficient digital tools across all grade levels. Indeed, independent schools have had limited exposure to CGI, even though they have more flexibility to deviate and experiment with curriculum and practice than many public schools. The small size of many independent schools and their relative flexibility gives them greater opportunity to try out progressive ideas (Tavangar, 2014). At the same time, in contrast to many large public districts (Keengwe, Onchwari & Wachira, 2008), independent schools typically have ample technology resources, allotted time, and reduced class size. Research on this population will provide insight into how teachers’ perceptions of educational technology impact their ability to have productive math conversations using digital tools without the limitations of resources and time. This knowledge will help school districts have more practical expectations of how to design professional development that encourages better student-centered math discussion with the help of digital tools.
Chapter 3:

Methods

Research Questions and Study Summary

The following research question guided the study: *How does using a technology tool during math instruction—in particular, one that facilitates a counting activity and that can also record student work—change K–2 teachers’ perceptions of their ability to have math discussions with their students?* It was further guided by three subquestions:

1) How do teachers perceive the impact of using this technology on engaging with students?

2) What do teachers report as ways this technology is supportive of math discussions?

3) What do teachers report as the challenges when using this technology to have math discussions?

To answer these questions, I first conducted a professional development session with study participants on the basic tenets of CGI. Since it is too large of a task to incorporate all the facets of CGI at once, teachers focused on a single CGI-designed activity, Counting Collections, during the research period. I administered a survey of baseline teacher technology attitudes, and then teachers ran the Counting Collection activity five different ways. The activity was flexible enough that it could be modified iteratively, varying how the technology was being used. The first two iterations were scripted, while the remaining three were modified according to teacher feedback. Following all five iterations, I met with the teachers in a second focus group and facilitated a discussion about their experiences and the strategies they had observed in their
classes. Shortly after this meeting, I interviewed each teacher individually about his or her experience.

**Overview of Study**

This study investigated the perceptions of K-2 teachers on the impact of iPads on student math discussions. Data was gathered at an independent school over a seven-month period from August 2016 – February 2017 consisting of a pre-study survey, bi-weekly teacher journal entries, two focus groups and individual interviews with all of the participating teachers. The initial survey at the start of the study gives a basic snapshot of the teacher’s general attitudes about how technology impacts math instruction and student learning. Even with a small sample of nine educators, there is a variety of grade levels, backgrounds, personalities and attitudes that allowed each educator to interact with the study in a distinct way. The emergence of common results is more compelling because of the differences between the participants and makes it more likely these findings would be observed in other populations as well.

There are three types of data included in this study, journal entries, focus groups and interviews. The data is coded to identify common statements from all the teachers and each of these statements was scored for the intensity of the statement. The scores ranged from a one for a passing mention of an assertion to a three for a vivid in depth description of an issue. The following criteria were used for the weighting:

1 - Passing Reference, brief, little analysis or reflection

2 - Reference with simple analysis or reflection. Lacking specific details

3 - Reference with analysis or reflection, supporting details or specific example cited

The journal responses were done every other week immediately after the activity. There were two focus groups, one at the midpoint of the study and one at the completion of the study.
The final data collected were interviews with the individual teachers. All interviews were completed within three weeks of the last focus group. The data from journal entries is cited separately from the interview and focus group data because of the differences in the types of responses in these sets of data. The journal entries tend to be short and focus on the immediate response of the teacher to a specific iteration of the activity. The responses in the interviews and the focus groups were not tied to a specific activity and there was more time and space for responses. The teacher responses in focus groups and interviews tended to discuss the study as whole rather than focusing deeply on a single experience. Thus, the total volume and diversity of the data in the focus group/interview data (320 references) is much larger than the total for the journal entries (60). Because of this disparity a reference in the journal entry is not given the same consideration as a reference in the focus group or interview. The researcher believes it better illuminates the findings to differentiate when a reference is from a journal entry versus a focus group or an interview in the summary tables.

There is a plethora of different ideas and perspectives found within the gathered data. These perspectives were given a category and elevated to a finding by evaluating how many of the nine teachers referenced the category, how many total references of this category occurred in entire data set, the average weighted response about that category. Each of the findings discussed here is referenced at least once by at least seven teachers, referenced at least 15 unique times in the total data set, and the weighted average of all the references is 2.00 or greater.

The research questions that guided this study focused on teacher perceptions. As such, the methods of data collection included opportunities to learn what teachers were thinking and how they described their experiences during the study (Carpenter, wt al., 2015; Masuda, Ebersole, & Barrett, 2014). A quantitative study would not have allowed for the depth of
responses needed (Franke, Battey & Kazemi, 2007; Webb, Franke, Ing, Wong, Fernandez, Shin, & Turrou, 2014). In addition, the small sample size would not have provided statistically significant data from teacher responses. For these reasons, a qualitative design was the most suitable to approach to answer this study’s research questions.

**Research Site**

**Rationale for Site**

As described in Chapter 2, there is evidence to suggest that CGI is effective on a large variety of student populations (Carpenter, Fennema & Franke, 1996; Villasenor & Kepner, 1993). The site selected for the study was a K–12 independent school located in Southern California. Independent schools, which have had limited exposure to CGI, offer a useful population to study for two reasons. First, they have more freedom to deviate from traditional approaches and to experiment with curriculum and practice (Tavangar, 2014). They are largely not under the oversight of local or federal government education departments. In addition, the small population of many independent schools provides flexibility in trying progressive ideas on which a large public school cannot risk their regulated resources. In contrast, public schools are often overwhelmed by a myriad of standards that have to be delivered in a strict 9-month time frame to a large number of students. This limits the amount of experimentation a public school can do without large scale administrative action. Finally, large public districts cannot guarantee every student access to working technology, while many independent schools have a device for each student. These factors allowed for a different implementation of CGI compared to earlier studies where educators have not had access to comparable digital tools.
Site and Sample Description

The school that participated in the study enrolls approximately 850 students in kindergarten through Grade 12. It is a competitive school that places many students into highly selective colleges. At the K–2 grade levels, teachers have class sizes range from 18 to 24 students. This school has small class sizes and ample resources devoted to mathematics education. K–2 students are supported by a reading specialist, math specialist, and technology specialist.

In total, nine teachers participated in the study. Together they were teaching approximately 120 students. Each was responsible for instructing most subjects including mathematics. There were also multiple support teachers providing additional specialties and visiting multiple classrooms to provide instruction or assist the grade-level teachers.

One of the most important support people with respect to this study is the K-2 technology integration specialist. She began in her position four years ago as a half-time librarian and half-time technology integration specialist. She is formally trained in library science and her first year at this site she was hired as a librarian and tasked with integrating technology into the elementary library program. Within two years she transitioned to a full-time K-5 technology integration specialist and was moved out of the library to her own designated office space. Her role was also changed from integrating technology into the library to integrating technology into all K-2 classrooms. Her current role on campus meant that she was involved with some of the important logistics of conducting this study because she coordinated the technology resources at this site.

Classes were not divided by ability for any subject at this grade level; they were heterogeneous with stronger and weaker math students in the same class. The head of the site
committed professional time for teachers to take part in this research during the 2016–2017 school year.

Working with one or two teachers for this study was not appropriate because findings may be confined to the specific habits and classroom populations of these teachers. It is also not helpful to study only a single grade level because teachers’ decisions may vary greatly depending on the developmental level the students. As a result, I recruited nine teachers who spanned three grade levels and represented various teaching styles. The breadth of this sample allowed me to detect common themes across grade levels, as well as outcomes that may be more specific to a particular grade level or a teaching style.

Data Collection Methods

Survey

Each grade level at the site consisted of a grade-level team with a lead teacher for that specific grade. All nine participating teachers in each grade level was surveyed using a written form prior to running the CGI counting collection activities. The seven-question Likert scale survey measured a simple inventory of the attitudes of the teachers with respect to technology and math instruction. This survey created a simple snapshot of each teacher’s technology aptitudes broken down into two domains, instruction and engagement. The results of the survey are used in the findings section to confirm that there is a diversity of individual teacher attitudes in the sample. (The survey can be found in the appendix).

Reflective e-Journal

At the conclusion of each bi-weekly activity, the participating faculty were emailed two questions that asked them to record their thoughts and reactions concerning how the activities went. The first question focused specifically on the specific iteration of the activity and the
second question was an open-ended prompt for faculty to answer as they saw fit. (Prompts for journals are found in the appendix.) Faculty had one week to answer these prompts and response time was fairly consistent with reminders from the K–5 mathematics and technology coordinators. A quick turnaround was important for two reasons: to get responses from faculty while the experience was still fresh, and to allow time to use their feedback to design the next iteration of the activity. I did not respond directly to these entries but, with permission, I shared a few excerpts during the focus groups.

**Focus Groups and Interviews**

Both focus group consisted of all nine participating grade level teachers and each focus group ran 60 minutes. The audio of the focus group was recorded and field notes were taken. The discussion protocol focused on teachers’ experiences and how they perceived the impact of the iPads on math discussions. At the end of the focus group session teachers were given the opportunity to add anything that they were not able to share during the session.

I conducted one-on-one interviews following the final focus group and a preliminary analysis of the journal responses. I interviewed all 9 participants and asked them to elaborate on their experiences during the study. The interview protocol was designed to investigate common themes and contradictions that emerged in the journal responses. Interviews took place on campus and ranged from 45 to 60 minutes.

When teachers are confronted with new instructional approaches, their thinking is impacted in multiple ways. Focus groups and interviews that account for previous responses from e-journaling help to outline the thought process of teachers as they interacted with and applied the CGI material. In addition, surveys alone would have been too narrow to illuminate complex thought processes; follow-up questions were necessary to develop a deeper description
of teacher perceptions. My approach allowed me to develop a multi-faceted picture of teacher perceptions. Moreover, it was useful to compare and contrast what each teacher described immediately after an activity and after a period of time had passed. Any gaps or inconsistencies in teacher reports offered useful insights into their perceptions of the impact of iPads on math discussions.

It was important to have some data on the technological proficiency of the teachers in the study. Two teachers may give similar responses about using digital tools during the project, but the response will track differently if one teacher is a high-proficiency tech user while the other is not proficient with digital tools. Details like these are more likely to surface in an interview rather than a survey. The simple survey was only used in this study to confirm that there were a diversity of beliefs and attitudes of the teachers in the sample.

**Data Analysis**

For some research areas it is possible to construct a set of expected topics that will appear in the responses. Since the units of analysis were dependent on the complicated interactions between students and teachers while using iPads, it was useful to identify emerging ideas during the preliminary analysis of the data (Merriam, 2009). I began my analysis with codes cited in the literature (e.g., anxiety, lack of confidence, lack of preparation, surprise, frustration, etc.) and adjusted them as details begin to emerge during the bi-weekly e-journaling. I used these responses to generate protocols addressing these ideas for the two focus groups. By the time the participants were interviewed, the themes were clearly defined and the final interview protocol was tuned to address these ideas.

Using different data types to triangulate results helped give insight into the factors that affect teachers’ perceptions about how iPads impact student math discussions. Data were coded
to identify common statements from all the teachers, and each of these statements was scored for the intensity of the statement. The scores ranged from a 1 for a passing mention of an assertion to a 3 for a vivid, in-depth description of an issue. This scoring approach allowed me to simultaneously analyze the breadth of the data and get an understanding of the depth of specific contentions reported by the teachers.

Since there were two weeks between each activity, collecting and coding the e-journals allowed me to adapt the next iteration of the activity based on teacher feedback. This constant iteration made activities more engaging for the teacher and the student, creating a better environment for interesting math conversations to happen. I constructed teacher perceptions by triangulating the multiple types of data. The final interview was the most sustained individual interaction with the participating teachers. As the interview was coded, I looked for consistency or variations by comparing teacher descriptions of their perceptions during interviews with the focus group and journal entries. This comparison of real-time responses and responses after a period of time gave me a better picture of how teacher perceptions were impacted by experience in the long term. Put another way, collecting and analyzing data prior to, during, and after the experiment allowed more specific insight into the perceptions of the teachers and how their math conversation played out during the process (Merriam, 2009).

Validity and Reliability

My own bias is that external factors besides class size, government oversight, and resource access play an important role in math instruction. I made an effort to counteract this bias by piloting my protocols with both public school and independent school educators. The feedback from these two groups gave insight into how the protocols were being interpreted and
helped me make sure that data gathered from these instruments would be useful to educators working in both settings.

Many educators reading this study may comment that the environment at this site does not have very much in common with most other schools due to several factors. The site has small class sizes, ample resources, and minimal state oversight, so governmental requirements like the Common Core are not a looming issue. I addressed these concerns by describing my sample and analyzing the data to emphasize the commonalities between the teachers at my site and other K–2 teachers.

I have personally observed and engaged in K–2 math instruction in both public and independent settings, and I believe that there are many similarities in the populations that may be overlooked. My opinion is shared by several colleagues who have also had the opportunity to work in both settings. They agree that there are many similarities and observe that educators cite similar challenges, particularly with respect to K–2 math instruction. They feel strongly that many effective practices can be shared between public and independent schools. As a result, my interview protocol focused on common experiences and challenges faced by K–2 math teachers that can be useful for educators in both domains.

An attitude that I have encountered is an enthusiasm for trying new techniques, but a lack of optimism that another math professional development experience will ultimately impact instruction. However, previous experiences have not resulted in any serious repercussions from the school leadership, so I feel that teachers’ answers and behaviors are likely to be authentic. I have not observed or heard any reports of the director reprimanding teachers over math instruction, so I believe that teachers were likely to speak honestly about their experiences.
I have confidence that any changes to math instruction can be more directly connected to my actions, but the impact may also be muted by the fact that there is not much explicit pressure from the leadership to improve math practice. I minimized this limitation by gradually building trust with my participants by visiting classrooms and demonstrating my commitment to the project. This helped generate buy-in from teachers. In other words, they were more likely to contribute if they felt they were part of a team of educators working on my project.

The small sample of nine teachers did limit my ability to generalize findings to a broader population of K–2 teachers. It would be very persuasive to expand this study to a larger site with dozens of teachers, but with the resources available it would not have been possible to process such a large amount of data efficiently. The next best option was to use a site with a representative selection of multiple K–2 teachers in a resource-rich independent school. Nevertheless, I used this smaller number of participants as representative of a K–2 environment by having at least three teachers from each grade participate. Each had a unique perspective on math instruction at that level. An advantage of a smaller sample is that I was able to give a more in-depth description of each teacher’s profile and provide a comprehensive analysis of their perceptions. This would not be possible with a larger sample and the resources at hand. This representative sample of all K–2 grade levels helps give readers deeper insight into the results of the study and better equip them to apply the findings to their own sites.

**Ethical Issues**

The ethical issues associated with my study are typical for the type of research I undertook. There were two main issues. First, I am a supervisor at the site. As the mathematics chair, I am assigned to the upper school (Grades 9–12), but I work with the K–8 math team throughout the year. The K–2 teachers report to and are evaluated by the K–5 math curriculum
supervisor. This administrative structure gave me access to the K–2 population but no direct authority over K–2 decision making.

Even though I do not evaluate K–2 teachers, I am part of the school leadership and do evaluate other teachers. It was therefore possible that teachers would feel pressured to participate in my study or feel that their jobs were at risk if they did not. They might also feel that certain responses would be preferred, which would corrupt the data I was gathering. To minimize this problem, I framed my research with the teachers as co-collaborators in the study. I wanted them to understand that they were the experts on describing what was happening in their classrooms, and that only authentic responses would help the school and the students. By framing the study in this way, I believe they more readily participated and were encouraged to provide candid responses.

Second, I will report my findings to the lower school head. Since this is a small school, the head of school will know who did and said what, even if names are changed. Again, this could have put pressure on K–2 teachers to participate or make them feel they were at risk of losing their jobs if they declined. It was important to give teachers confidence that they could speak honestly with me and minimize their risk of harm. I kept all meetings confidential and did not conduct any interviews until I had received written consent. I used pseudonyms for transcription purposes. I made sure that all digital files were password protected and all written materials were kept in a locked file cabinet.

Unfortunately, as I noted above, because this is a small school it may still be possible for identities to be determined when the findings are shared. To ensure my participants were not harmed when findings were shared, I clearly explained in the consent form how the findings would be disseminated. I carefully went over the form to make sure participants understood what
was being recorded and what could be used in my research. I also emphasized that my report and dissertation would be publicly available to the director and head of school. I did my best to make sure the participants understood the research process to help minimize any harm or surprises that could be caused when finding were shared.

I met with the director of the lower school about the methods and goals of my study and she was very supportive. Other teachers at the site described the director as someone with confidence in people once she decides to move forward with a project. She is not a leader who micromanages, and she therefore gave me a good deal of freedom to conduct the research. It was important, however, that I updated her regularly on the project to avoid surprises. In addition, since some professional development time was allocated for my project, the leadership of the lower school was motivated to make it as useful as possible. It was helpful for leadership to be invested in my project but I was careful that the enthusiasm did not create ethical issues with my study.
Chapter 4:

Findings

Introduction

Findings from this study will be shared in the following manner. First, the finding and relevant part of the research question is stated. Quotes and a deeper description of the finding are given. The category or theme of the code that led to this finding is described. The data source(s) of these findings (journal entries, focus groups or interviews) is given. A description is given of what kind of data is included and not included in the category or theme. Specific examples are summarized that inform the finding, with reference to values given in Tables 2 and 3 about how many unique teachers referenced this finding and the total number of references in the data. Finally, a deeper description of the finding is given through quotes from the various participants.

Sample Demographics

The background of the nine participants is summarized in Table 1. Participants were identified as KA-2C, with kindergarten teachers KA, KB, and KC, first grade teachers 1A, 1B, and 1C, and second grade teachers 2A, 2B, and 2C. These data indicate that the sample of participants represents a diversity of backgrounds including number of years teaching, number of years at the current site, grade levels taught, and state teaching credentials.

Three participants are in their first or second year at this site, and participants have an average of almost 5 years at this site. Eight of nine participants have 9 or more years of teaching experience. The least experienced teacher has five years teaching, with the most having 22 years. The participants average over 12 years of teaching experience. Five of nine participants reported having state teaching credentials, with three participants credentialed in California.
Seven of nine participants have taught grade levels other than their current assignment, spanning TK through grade 5. Of the seven participants who have taught other grade levels, four have taught three different grade levels, including their current assignment.

**Table 1.** Summary of participants’ background. The participant ID (left column) is mapped to the current teaching assignment (KA-2C). The average total years teaching experience and number of years at the current site is given in the bottom row.

<table>
<thead>
<tr>
<th>Participant ID</th>
<th>Current Grade Level</th>
<th>Total Years Teaching Experience</th>
<th>No. Years at Current Site</th>
<th>State Credential</th>
<th>Other Grades Taught</th>
</tr>
</thead>
<tbody>
<tr>
<td>KA</td>
<td>K</td>
<td>12</td>
<td>12</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>KB</td>
<td>K</td>
<td>11</td>
<td>4</td>
<td>–</td>
<td>2, 5</td>
</tr>
<tr>
<td>KC</td>
<td>K</td>
<td>22</td>
<td>7</td>
<td>CA</td>
<td>2, 3</td>
</tr>
<tr>
<td>1A</td>
<td>1</td>
<td>18</td>
<td>6</td>
<td>FL</td>
<td>2</td>
</tr>
<tr>
<td>1B</td>
<td>1</td>
<td>9</td>
<td>4</td>
<td>CA, CT</td>
<td>2</td>
</tr>
<tr>
<td>1C</td>
<td>1</td>
<td>5</td>
<td>2</td>
<td>CA</td>
<td>–</td>
</tr>
<tr>
<td>2A</td>
<td>2</td>
<td>9</td>
<td>6</td>
<td>–</td>
<td>1</td>
</tr>
<tr>
<td>2B</td>
<td>2</td>
<td>15</td>
<td>1</td>
<td>MD</td>
<td>K, 4</td>
</tr>
<tr>
<td>2C</td>
<td>2</td>
<td>9</td>
<td>2</td>
<td>–</td>
<td>TK, K</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>12.2</td>
<td>4.9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Survey Findings**

The pre-study survey was administered to the teachers, the results of which are shown in Table 2, demonstrates a diversity of self-reported attitudes about technology and engagement. Teachers consistently agreed that technology helps students work collaboratively and that their teaching practices utilize technology, as evidenced by responses to questions 1 and 2. The statement ‘Technology has helped my students work more collaboratively’ received an average response of 3.8, with 7 of 9 teachers responding with a 4 (agree) and three responding with a 3 (neutral). The statement ‘Technology has decreased my students’ engagement in their learning’ received an average score of 2.0. Two outliers responded with a 5 (strongly agree) and 3 (neutral), while the remaining 7 responses received either 1 (strongly disagree) or 2 (disagree).
The five remaining survey items have a greater spread of responses among the participants. This gives the researcher confidence that there is a diversity of attitudes in this sample with respect to using technology during class instruction, as shown in Figures 1 and 2. In Figure 1, each participant’s response is given a spoke (labeled KA-2C) and clockwise around the spoke is a colored bar representing their response to questions 1-7. Colors are coded to the length of the bar, ranging from strongly disagree (short, yellow) to strongly agree (long, blue). The diversity of the spoke for each participant indicates the diversity of attitudes represented in this sample.

<table>
<thead>
<tr>
<th></th>
<th>Technology has helped my students work more collaboratively.</th>
<th>KA</th>
<th>KB</th>
<th>KC</th>
<th>1A</th>
<th>1B</th>
<th>1C</th>
<th>2A</th>
<th>2B</th>
<th>2C</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>3.8</td>
</tr>
<tr>
<td>2</td>
<td>Technology has decreased my students’ engagement in their learning.</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2.0</td>
</tr>
<tr>
<td>3</td>
<td>Technology can support me to differentiate my math instruction.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>3</td>
<td>4</td>
<td>4.2</td>
</tr>
<tr>
<td>4</td>
<td>I am able choose the technology appropriate to the teaching process with my classes.</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>4.1</td>
</tr>
<tr>
<td>5</td>
<td>My teaching is more student-centered and interactive when technology is integrated into instruction.</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>3.4</td>
</tr>
<tr>
<td>6</td>
<td>Material that students learn via technology is not as internalized as well as material that is learned in a traditional (analog) manner.</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>3.2</td>
</tr>
<tr>
<td>7</td>
<td>My teaching practices utilizes the use of technology skills to support instruction.</td>
<td>4</td>
<td>5</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>4.2</td>
</tr>
</tbody>
</table>

Table 2. Pre-study survey of participants KA-KC. Participants were asked to rate their level of agreement from 1 (strongly disagree) to 5 (strongly agree) for the following statements. Scoring options were allowed in integer values of 1 to 5. The rightmost column gives an average score across all nine responses.

The diversity of attitudes is important because if all these responses indicated consensus among teachers in the sample, then the findings would most likely only apply to a teacher that
matches this profile. With this variety of responses to this survey it is more likely that findings in this study are applicable to a wider range of teachers.

This diversity is also visible in Figure 2 in which teacher responses to the pre-study survey are grouped by topic. Teachers rated their level of agreement from 1 (strongly disagree) to 5 (strongly agree) in integer values of 1 to 5. The top chart shows responses to questions 3, 4, and 7 relating to teacher attitude. The bottom chart shows responses to questions 1, 2, 5, and 7 relating to teacher perceptions of how technology influences student learning. These charts indicate that the nine participants do not share similar attitudes or viewpoints on how technology influences student learning.

*Figure 1.* Summary of participants’ responses to the pre-study survey (see Table 2). Each participant’s response is given a spoke (labeled KA-2C) and clockwise around the spoke is a colored bar representing their response to questions 1-7. Colors are coded to the length of the bar, ranging from strongly disagree (short, yellow) to strongly agree (long, blue).
Figure 2. Teacher responses to the pre-study survey tabulated in Table 1, grouped by topic. Teachers rated their level of agreement from 1 (strongly disagree) to 5 (strongly agree) in integer values of 1 to 5. The top chart shows responses to questions 3, 4, and 7 relating to teacher attitude. The bottom chart shows responses to questions 1, 2, 5, and 7 relating to teacher perceptions of how technology influenced student learning.
Journal, Interview, and Focus Group Data

Journal entries, focus groups, and interviews were coded for reference to seventeen topics. The data is presented in two tables, configured identically. Table 3 shows results from interviews and focus groups and Table 4 shows results from journals. In each table, references are organized into three groups: Challenges, Engagement, and Discussions. The references in bold type are presented and discussed in this thesis. For each participant, coded KA-2C, three columns of information are given. The left column cites the number of unique references made to this topic. The middle column cites the sum of the scores assigned to each reference. Each reference was scored 1, 2, or 3, details of which are discussed in the text. The right column cites the average response weight, which is the sum (middle column) divided by the number of references (left column). Aggregated data summarizing all participant responses is presented in the rightmost columns. ‘Unique References’ gives the number of participants who made a reference in this category (between 1-9). ‘Total references’ is the number of references made by all participants. ‘Total weight’ is the sum of all weighted references. ‘Average weight’ is the average weighted responses calculated from the total weight divided by number of unique references.

Tables 5 and 6 provide an alternative representation of the data in Tables 3 and 4 in the form of ‘heat maps’ that use color to indicate the significance of a given value. These tables summarize findings across focus groups, interviews, and journals. Each topic is listed along the left, and each column represents the response from a participant’s KA-2C.

In Table 5, each square represents the number of references made to this topic by the participant. These data correspond to the first column of information provided in Tables 3 and 4. Number of references ranged between 0 and 7. The darkest red color indicates the most
Table 3. Summary of data from interviews and focus groups. Data was coded for reference to topics listed in the table. References are organized into three groups: Challenges, Engagement, and Discussions. The references in bold type are presented and discussed in this thesis. For each participant, coded KA-2C, three columns of information are given. (Left) Number of unique references. (Middle) Sum of the scores assigned to each reference. Each reference was scored 1, 2, or 3, details of which are discussed in the text. (Right) Average response weight – the sum (middle column) divided by the number of references (left column). Aggregated data is presented in the rightmost columns. Unique References gives the number of participants who made a reference in this category (between 1-9). Total references is the number of references made by all participants. Total weight is the sum of all weighted references. Average weight is the average weighted responses calculated from the total weight divided by number of unique references.

<table>
<thead>
<tr>
<th>Interview/Focus Group</th>
<th>KA</th>
<th>KB</th>
<th>KC</th>
<th>1A</th>
<th>1B</th>
<th>1C</th>
<th>2A</th>
<th>2B</th>
<th>2C</th>
<th>Unique Ref.</th>
<th>Total Ref.</th>
<th>Total Weight</th>
<th>Avg. Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Technology Integration Specialist</strong></td>
<td>3</td>
<td>7</td>
<td>2.3</td>
<td>2</td>
<td>6</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>2.3</td>
</tr>
<tr>
<td><strong>Student iPad Proficiency</strong></td>
<td>2</td>
<td>5</td>
<td>2.5</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td><strong>Classroom Approach</strong></td>
<td>3</td>
<td>4</td>
<td>1.3</td>
<td>2</td>
<td>3</td>
<td>1.5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>10</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td><strong>Student Developmental Level</strong></td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>13</td>
<td>2.6</td>
<td>4</td>
</tr>
<tr>
<td><strong>Schedule Management</strong></td>
<td>4</td>
<td>7</td>
<td>1.8</td>
<td>4</td>
<td>7</td>
<td>1.8</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>6</td>
<td>2</td>
<td>3.1</td>
</tr>
<tr>
<td><strong>Scope &amp; Sequence</strong></td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>12</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td><strong>Motor Skills</strong></td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>1.5</td>
<td>2</td>
<td>6</td>
<td>3</td>
<td>1.3</td>
</tr>
<tr>
<td><strong>School Tech History</strong></td>
<td>2</td>
<td>6</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Obsolete Technology</strong></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Excitement</strong></td>
<td>2</td>
<td>5</td>
<td>2.5</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>1.5</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Creativity</strong></td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>6</td>
<td>14</td>
<td>2.3</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td><strong>Focus/Distraction</strong></td>
<td>2</td>
<td>5</td>
<td>2.5</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td><strong>Digital versus Analog</strong></td>
<td>4</td>
<td>6</td>
<td>1.5</td>
<td>5</td>
<td>14</td>
<td>2.8</td>
<td>2</td>
<td>3</td>
<td>1.5</td>
<td>4</td>
<td>6</td>
<td>1.5</td>
<td>4</td>
</tr>
<tr>
<td><strong>iPad Features - Audio Rec.</strong></td>
<td>3</td>
<td>8</td>
<td>2.7</td>
<td>4</td>
<td>9</td>
<td>2.3</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td><strong>iPad Features - Drawing</strong></td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>7</td>
<td>17</td>
<td>2.4</td>
<td>3</td>
<td>7</td>
<td>2.3</td>
<td>2</td>
<td>3</td>
<td>1.5</td>
<td>3</td>
</tr>
<tr>
<td><strong>iPad Features - Digital Pictures</strong></td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
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<td>2</td>
</tr>
<tr>
<td><strong>Group Work</strong></td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>8</td>
<td>16</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>
Table 4. Summary of data from journals. Journal entries coded for reference to topics listed in the table. References are organized into three groups: Challenges, Engagement, and Discussions. The references in bold type are presented and discussed in this thesis. For each participant, coded KA-2C, three columns of information are given. (Left) Number of unique references. (Middle) Sum of the scores assigned to each reference. Each reference was scored 1, 2, or 3, details of which are discussed in the text. (Right) Average response weight – the sum (middle column) divided by the number of references (left column). Aggregated data is presented in the rightmost columns. Unique References gives the number of participants who made a reference in this category (between 1-9). Total references is the number of references made by all participants. Total weight is the sum of all weighted references. Average weight is the average weighted responses calculated from the total weight divided by number of unique references.
references, with white indicating no references, as indicated by the scale bar at the bottom. On the right-hand side of the table, a histogram depicts a sum of the number of all references made to this topic by all participants across focus groups, interview, and journals. This representation of the data allows for a quick visual assessment of what topics evoked the most discussion. It is clear that focus groups and interviews provided more information than journals. Participants spent considerable time discussing the first few listed topics, with several participants discussing these more than others. The discussion of iPad features and digital versus analog was discussed frequently by all participants, and references to these topics appeared in focus groups and interviews, as well as journal entries. The histogram at the far right also provides a quick indication of the most commonly discussed topic (digital versus analog), and the least discussed topic (obsolete technology).

In Table 6, each square represents the sum of the weight of all references made to this topic by the participant. These data correspond to the second column of information provided in Tables 3 and 4. Reference weight sum ranged between 0 and 17. The darkest blue color indicates the most heavily weighted, with lighter colored squares indicating references with less weight, and white indicating no references to the topic. On the right-hand side of the table, a histogram depicts a sum of the weight of references made to this topic across all participants during focus groups, interviews, and in journals. These data have a strong correlation to the number of references depicted in Table 5. This makes sense that a topic discussed frequently by a participant (number of references) would have a strong correlation to the level of detail provided in this discussion (the weight of the reference). This representation of the data provides an indication of what topic or topics was of primary concern to a given participant. For example, participant KA discussed many topics with relatively equal weight given to the topics, while
participant KB gave the most detailed attention to the topics of digital versus analog, creativity, and the iPad features of audio recordings and drawing. The histogram at the far right is similar to the one in Table 5, indicating that detailed discussions tended to focus on the iPad features and the topic of digital versus analog.

Table 5. Summary of number of references to each finding across focus groups, interviews, and journals. Each topic is listed along the left, and each column represents the response from a participant KA-2C. Each square represents the number of references made to this topic by the participant. Number of references ranged between 0 and 7. The darkest red color indicates the most references, with white indicating no references, as indicated by the scale bar at the bottom. On the right-hand side of the table, a histogram depicts a sum of the number of all references made to this topic by all participants across focus groups, interview, and journals.
**Table 6.** Summary of weighted references to each finding across focus groups, interviews, and journals. Each topic is listed along the left, and each column represents the response from a participants KA-2C. Each square represents the sum of the weight of all references made to this topic by the participant. Reference weight sum ranged between 0 and 17. The darkest blue color indicates the most heavily weighted, with lighter colored squares indicating references with less weight, and white indicating no references to the topic. On the right-hand side of the table, a histogram depicts a sum of the weight of references made to this topic across all participants during focus groups, interviews, and in journals.
Research Question

Findings Research Question Part (A): Impact on Engagement

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*Table 7.* Summary of findings relating to excitement. For participants KA-2C, the left column represents the number of references to this theme and right column represents the total score of all references to this theme. The four rightmost columns summarize data for all participants.

Finding A1 (“They loved being the star of the show”) – Teachers report using the iPad had a direct influence on the excitement of the students while they performed the activity, impacting math discussions. Teachers report that the enthusiasm of students could increase the amount of discussion that happens during a counting collection activity. During an activity that included a section for students to record their voice, Teacher 1C noted, “The kids were excited to record and I think this excitement motivated them to say more than they normally would.” Teacher KA used the audio recording capabilities to interview the students about their thinking, and also enlisted a classroom aid to interview students. Teacher KA said, “When they recorded their voice…we got richer information from them by actually interviewing them. It was like "What did you count? How did you count? Why did you count that way? Can you show me that you counted?...They loved it. They loved being the star of the show.” These interviews were shared between teacher KA and the aid, giving the classroom teacher a more accurate picture of how the math conversations went without the classroom teacher having to interview every student.
One observation reported by five of the participants was that the student excitement was generated by the combination of using the iPad and the activity itself, and not only because students were using the iPad. Teacher 2B described students’ relationship with iPads: “They're really comfortable with iPads…I would say most have one at home.” While teacher KC said, “Adding the iPads in for my kids wasn't any big deal. We're doing math on the iPads. We do math on the iPads almost every day.”

There are multiple references across all data sources (journal entries, focus groups and interviews) to how the students’ level of excitement impacts the activity and the types of math conversations they are having. The findings related to this topic are shown in Table 7. References for this category are identified when the teachers describe the excitement of the student with respect to the activity. References in this category were identified by teacher using specific vocabulary (excitement, happy, jazzed, etc). These references were also identified when teachers describe student behavior that indicates excitement. For example, a teacher’s description of trouble with student behavior because the students did not want to wait to share their audio recordings is placed into this category, even though excitement is not explicitly referenced. This category does not include the teacher’s personal feelings about how exciting the activity is or value judgements on whether the students should be excited or not. In the focus groups and interviews there are 18 unique references to this topic from eight of the nine teachers. This category is referenced five times in the journal entries by four different teachers.
Finding A2. Creativity

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Table 8. Summary of findings relating to creativity. For participants KA-2C, the left column represents the number of references to this theme and right column represents the total score of all references to this theme. The four rightmost columns summarize data for all participants.

Finding A2 ("I didn't know they could do that") – Teachers report that students were more likely to be creative when using a specific iPad app. Teachers were surprised when students displayed math thinking on the iPad and in discussions that had not been explicitly taught. Teacher KC describes the impact of using a white board app for the activity. Students had used the same in other domains previously, where creativity is more traditionally expected. “I was surprised by my group on how they were able to use [the iPad] this way for math and I think is because of the app that we've been using…and they've been using [this app] a lot, so I think the novelty part had worn off….it was cool to see them use it in a math way and to use it as a tool and to be more creative.”

Teacher 1A also identified how the specific application that the iPad used allows students to be more creative, “I think [this app] got them away from the world of just playing a game. They were actually able to create something, show their learning, show their creativity, instead of blasting rockets, and playing Bingo.”

Teacher KB describes how the tool provided to students, in this case the iPad, allowed them to explore and engage in creative math thinking:
And it's so open ended, they're like, "Okay." And they count it. "Show me another way to count it," and as soon as you say ... "Well, you tell me." "Nope. Just explore. And here's some tools for you." And they kind of look at it, and they'll play with it, and there's just this exploration, and sometimes they use the iPad in a way that wouldn't help them. But at least it's getting that mind wheel ... those wheels turning, that creative thinking, that problem solving.

Two teachers reference how some students began to use more abstract number representations because of the extra time it took to draw concrete objects. Teacher KA said:

> Usually you had to teach them how to do symbolic drawings...kind of showing them how to represent it but I had some kids who automatically were able to [use symbolic drawings] but then there's still some artists who wanted to draw every eraser detail.

Many teachers referenced students’ increased creativity when using the iPads during the activity. References appear in the focus groups and interviews about seeing unexpected representations and about surprising math discussions during the activity. Findings for references in this topic are shown in Table 8. Teachers report that the level of creativity is impacted by the format of the iteration of the activity. The least amount of creativity was reported when students used virtual manipulatives to count and move virtual objects on the iPads instead of concrete manipulatives. Several teachers discuss students moving from contract representations (drawing the item) to abstract representations (slash marks) more easily on the iPad instead of the paper. Many of the references in this category are identified by teachers using the words ‘creativity’ or ‘surprise.’ Other data in this category included teachers describing student displaying skills or using representations that had not been previously taught or seen before. Data not included in this category are references where the teachers gave direct
instruction or the student practiced skills that had been explicitly modeled by the teacher. For example, one teacher described her surprise about how well the students were grouping on an iPad after she directly modeled grouping. This type of reference is not included in this category. There are 15 unique references in this category from the focus groups/interviews.

There are 15 unique references in this category from the focus groups/interviews.

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Table 9. Summary of findings relating to focus/distraction. For participants KA-2C, the left column represents the number of references to this theme and right column represents the total score of all references to this theme. The four rightmost columns summarize data for all participants.

Finding A3 ("It was a two-edged sword") – Teachers report the presence of the iPad could cause distraction in some students but could also increase focus in other students. Some teachers discuss math conversations being inhibited because students are focused on creating their drawing of their collection on the iPad. Teacher 1C said in a journal response, “I thought there was actually less math conversation when the iPad was introduced, because they were so focused on drawing on the iPad.” Teacher KC suggested it is easier to manage the students when they were focused and working on their iPad. Teacher KC said, “It was a two-edged sword. It was very helpful that the kindergartners didn't get stuck, that I wasn't running around the room trying to get them where they were supposed to be. They were all engaged. I don't know how much I would say that they got out of it by not doing it by themselves.” Teacher 2C said he also felt that the distraction of the iPad occasionally led to miscounting of the items and he would have to tell the students to count again. Teacher 2A discussed a strategy to convert
these potential distractions into increased focus. Teacher 2A describes students’ increasing engagement by having students decorate their counting collection iPad answers with downloaded images and backgrounds:

[students] get to pick the color of my background or they’ve learned how to Google search so they can get a picture of the football player they really like and put him as their background…It’s a fine line because then you have kids sometimes who focus so much on the football player that then they’re not doing their work or my favorite…The whole point is that I need to see the math.

The impact of the iPads on student focus or distraction is discussed in all data sources. The findings related to this topic are shown in Table 9. There is not consensus in the data about whether the iPads helped improve focus or were a distraction, but eight of the nine teachers discuss this issue. Distraction and focus is an issue that all teachers have to deal with, especially early elementary teachers, so references around this category were explicit. Teachers would use the words ‘focus’ and ‘distraction’ directly in the reference, making it straightforward to identify. There were also some references of students getting “stuck” on a non-productive task or that teachers would have to break up a group of students who did not work together well. These references were also placed in this category. Discussions of the student having trouble with the mathematics or unable to complete the specific task is not placed in this category because this is not described as directly caused by student distraction. Also, distractions such as the iPad having too many games or students misplacing their iPad were not included in this category as they are not directly connected with math conversations. In the focus groups and interviews there are 14 unique references of this topic from eight of the nine teachers. This category is also referenced four times in the journal entries by two different teachers.
Findings Research Question Part (B) : Supportive of Discussions

Finding B1. Digital versus Analog

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Table 10. Summary of findings relating to digital versus analog tools. For participants KA-2C, the left column represents the number of references to this theme and right column represents the total score of all references to this theme. The four rightmost columns summarize data for all participants.

Finding B1 (“they've shown their thinking on paper before but now they can record their voice.”) – Teachers reported differences in math discussions while using the iPad and evaluated these differences by contrasting them with an analog experience. Teacher 1A had one of the strongest views in the study on looking at the iPads as simply a replacement for paper. She also espoused a common technology fear that digital work is easily lost, saying “I didn't feel that iPads were needed. I think paper and pencil would have worked better with this activity…paper and pencil give the students a better option for editing their work without a concern for deleting it.” Teacher 1B also used paper as the criteria to measure the success of the iPad during an activity, saying “I don't think what they actually produced on the iPad was that much different from what they produced on the paper.”

Teacher 2B discussed using the iPad as a tool to improve future paper recording, as opposed to the iPad being a standalone tool to complete the activity. She said, “I wanted to come back to the paper later and maybe they would have recorded more efficiently on the paper having done it on the iPad.”
An example of a teacher utilizing the unique capabilities of the iPad is teacher 1C. She tried to get the students to use the iPad differently than paper by suggesting they use the copy and paste iPad feature to save time, something that would be impossible to so with paper, reporting “I would try and get them to copy [their objects] instead of drawing to save time.”

There was a spectrum of responses from only wanting a paper replacement to what can the iPad do that paper cannot, but every teachers evaluated the iPad’s performance with respect to paper.

In discussions about the activities, teachers consistently compare the iPad experience to using analog paper, both in the iPad’s shortcomings and its advantages. References about paper vs iPad appeared in all data sources and are reported in Table 10. These comparisons were given by all nine teachers, and represent the highest volume of all findings with 35 unique references (see Table 3). This category is referenced five times in the journal entries by four different teachers. Data for this category were constrained to direct comparisons between paper and the iPad. A simple description of the paper or iPad experience in isolation is not included in this category.

In many of the references in this topic, the iPad is being assessed by teachers on how well it can replace paper and any shortcomings by the iPad is a detriment. The tone of many of the comparisons made by the teachers is that the iPad should at least be able to do everything paper can do, and if it cannot do it and do it better, teachers expressed less motivation to use the iPad.
Finding B2. iPad Features

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Table 11. Summary of findings relating to features of the iPad. For participants KA-2C, the left column represents the number of references to this theme and right column represents the total score of all references to this theme. The four rightmost columns summarize data for all participants.

Finding B2 (“It took so much less time, they had more time to actually do math!”) – Teachers perceived the options of the iPad as helping make math conversations more efficient. Even with a tendency to compare the iPad to paper, all teachers in the study acknowledge the shortcomings of paper recording. Reported shortcomings include disorderly student work, messy erasures, too much time, papers getting lost/crumpled, and paper size constraints. Some of the strongest feedback about using the iPad for conversations related to how the unique features of the iPad could diminish one or more of these shortcomings and allow teachers to engage in math discussions with students more efficiently. References to this topic appeared in all three data sources and are reported in Table 11.

Features like iPad drawing, audio recording, and digital photos were discussed by the teachers as giving them a different way to access a student’s thinking. Data for this category is
identified by a specific reference to the iPad feature and how it impacted the activity. References where the teacher did not give an analysis of the feature is not included in this category. For example, teacher KA reported that one student discovered a laser rainbow marker font on the iPad to draw their picture. Teacher KA only described this as “very cool”. Since KA did not discuss if the font impacted discussion or activity in some way, this reference was not included in this category. Seven teachers referenced using iPad drawing 18 total times, seven teachers referenced using iPad audio recording 21 total times, and seven teachers referenced using iPad digital pictures 18 total times. Since the teachers interacted with each feature differently, a description and quotes for iPad drawing, audio and digital pictures will be given separately to differentiate the teacher perceptions.

**Supportive of Discussions - iPad Drawing.** Teacher KB described students’ use of the iPad drawing feature led to a spontaneous discussion of how to use number frames, a topic that KB thought she would have to show students before they could use the concept:

I didn't show them how to use the ten frame, but I said, "This is a tool you need to use today." And it was nice to see how they used the iPad, and how they figured out, and how they showed their work, and it taught ... then when they were showing their thinking, it became a whole lesson of, how do I draw a ten frame? So then they were practicing drawing it on the iPad, so there was so much different higher level thinking happening, and there was so much exploration that was happening without a teacher telling them.

Multiple teachers described surprises when asking students to draw how they are thinking about the math. Teacher KC’s expressed amusement that one student took a literal approach to showing their math thinking by drawing a stick figure with a thought bubble above it. Teacher
IC describes the ease with which students could erase and edit their work making their pictures easier to understand:

One thing that was really surprising was that when I had them show on paper, if they made a mistake they got started to erase or it would start to get messy and when they were showing their thinking, it's so easy to erase on the iPad that a lot of kids would start something and it wouldn't work and it was easy for them to erase, so their work was really easy to see.

Teacher KA discusses how when students were drawing on the iPads they were more likely to look around at other students’ work and experiment with different strategies:

they need to somehow show you through a picture…on the iPad it’s a lot more for creating pictures versus paper…they’d see friends doing it, they're drawing groups, so they're just going to draw groups. But maybe that friend is making a group of five, in which they can count, whereas they want to make it to look different, so they're doing a group of three.

*Supportive of Discussions - iPad Audio Recording.* Teachers describe how the audio added a different way to show thinking and discuss math as compared to a static drawing or picture, even if the teachers were not certain how to best use the new information provided by audio. Teacher KB describes how using audio for students who may be weak in writing gives the teacher better access to their math thinking, “I think having the voice component for the iPad is pretty powerful to have the kids talk and explain their thinking…where some kids can't write, and can't read, so giving them the flexibility where they can record and use their voice is really powerful.” Teacher IC found the audio “very helpful so that every student could be recording their own thinking” but was concerned when “some students still did not draw exactly what they
say they did…writing their answer and then some picture that did not match the explanation or show how they got to their answer.”

Supportive of Discussions - Digital Picture. The iPads in this study have the capability for teachers and students to take quick pictures of whatever they are doing. Teachers who made use of this feature consistently identified this feature as a time saver, but reported that they learned more about student thinking from the student’s drawings. Teacher 1C describes how being able to look at a digital picture allowed her to get more quickly to discussing math with her students:

Because the picture took so much less time, they had more time to actually do math…they had already physically done it, and they were able to get through a lot more ways to count because it was so much easier to just take the picture, put it on a page, record what they did, and then move on to another way.

Teacher 2A decided to shift from students drawing their math thinking to having students take digital photos, conceding that some great thinking was demonstrated in the drawings but it can be too time consuming: “They started drawing in the iPad and it was organic in that way, which was a really cool thing to…I liked that everyone's was different. I wish I had more time to delve into the conversations about it but the [digital iPad] pictures were just easier.”
Finding B3. Group Work

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Table 12. Summary of findings relating to group work. For participants KA-2C, the left column represents the number of references to this theme and right column represents the total score of all references to this theme. The four rightmost columns summarize data for all participants.

Finding B3 ("I did everything in pairs. I think if I were to do it again I would do some of the activities individually.") – Even with class sets of iPads, teachers chose predominantly to have students work in groups when running the activity. Teachers discuss deciding to have students work in groups instead of alone in terms of achieving goals that were not directly related toward having discussions about student math thinking. When asked by the researcher, “What do you see and hear? What kind of math conversations?” teacher 2C described what he perceived as a productive activity without discussing math at all:

They were not arguments, which was good for me to see. They would take turns. They were very good about taking turns and what's interesting to see sometimes, you know with a slightly strong personality would generally take over so that was sometimes a little troublesome…you'd like to see the other student have their voice be heard too… A big piece of this is socio-emotional development, learning to work with someone.

Teacher KC had her class complete the activity with each kindergartener paired up with a kinderpal, a visiting second grader and suspects that the math discussions suffered in this setting. She described the activity as follows:
They were paired with their kinderpals, which was cool for a lot of reasons. It was interesting to see them be that model and helper. I feel like they were really great in helping with the iPad, but I don't know that they were that helpful with, "Oh remember we are going to try a different way now." Or, "How can we explain about it."

Teacher 1C described a limitation she perceived of always doing the activity in groups:

I did everything in pairs. I think if I were to do it again, I probably would do at least one of the ones, one of the activities, individually. It was definitely easier for me to get around to everyone do it in pairs, and I like forcing the collaboration piece of it, but I would have liked to see what was going on with each individual student.

During professional development training for participating teachers about how to run the activity, teachers were given the option to have the students count individually or work in groups. Each teacher piloted the activity independently and in groups during the training. Teachers were also shown video examples of the activity being completed by students individually, and video of students completing the activity in groups. For the duration of this study, a class set of iPads were always available to teachers, giving them the choice of giving one device to every student. Thus, it was strictly a teacher decision to have students work in groups. Feedback from the journal entries indicates that almost all the actual counting was completed in groups. Some teachers did have the students record their thinking on their own iPad independently, but the physical act of counting occurred in pairs.

References to the group work topic is identified by teachers talking about students assigned to work in pairs or in groups in the activity. It does not include situations where students initiated a conversation, got help on their own, or joined another student at a work station. Group work in this topic means that the students were assigned to their group by the
instructor prior to the start of the activity. Table 12 shows the findings for this topic. In the focus groups and interviews there are references from all nine teachers and 19 unique references. This topic is referenced nine times in the journal entries by five different teachers.

Findings Research Question Part (C) : Challenges

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Table 13. Summary of findings relating to the technology integration specialist. For participants KA-2C, the left column represents the number of references to this theme and right column represents the total score of all references to this theme. The four rightmost columns summarize data for all participants.

Finding C1 (“the biggest thing if you want to do something like this with iPads is having someone like her” – The K-2 technology integration specialist was reported by teachers as playing a prominent role in minimizing a variety challenges that can prevent teachers from iPads to have math discussions. Teacher 2A summarizes the K-2 technology integration specialist as follows:

I think the biggest thing if you want to do something like this with iPads is having someone like [the K-2 technology integration specialist]. Part of why this went well…is that kids have so much experience already with the apps and with iPads… I think that kind of experience that the kids had, that took years for her to build up. I remember when she came 4 years ago and just campaigned for us to get iPads. Then we had the cart and then she was coming into classrooms, checking in with teachers. Without forcing it on
anybody. Was just saying, "Hey here's a school project. I hear you're doing this, why
don't we try it? Why don't we try this? I'll run it. You watch." She did everything to really
help build the trust in teachers, build the enthusiasm and then help incorporate it into the
curriculum. I think that piece…is extremely important.

Teacher KA shares a similar sentiment of the impact of the K-2 technology integration specialist:
I just think that's a whole separate [iPad] piece where we need to feel comfortable and the
kids need to feel comfortable. I think if we interested in integrating that tech piece with
CGI it's the same as integrating tech with anything else. There's a whole tech curriculum
and there's a whole process involved and getting people on board and it doesn't happen
overnight. From an administrative perspective, I think hiring someone like [the K-2
technology integration specialist], really thinking about how she can get that buy in from
teachers. She sends everybody all this stuff and kids are using iPads all over the place and
there isn't any kind of resistance. I think teachers feel much more confident using
technology in the classroom.

When discussing challenges that teachers report when using iPads to have math
discussion, a strong pattern emerges about the role of the K-2 technology integration specialist at
this site. Teachers at all grade levels consistently report that the K-2 technology integration
specialist played an important role in diminishing the challenge of using technology in all
learning domains, not just mathematics. The role of the K-2 technology integration specialist in
this study was in helping with logistics and preparation of the iPads to use with the activities. She
often visited classrooms during the running of the activities to make sure the technology was
working properly, and she made sure all apps were downloaded and in good working order for
the activities.
Teachers described the K-2 technology integration specialist as using a diverse set of strategies to reduce barriers to teachers adopting technology in the classroom. This included writing a K-2 technology scope and sequence, attending all grade level meetings, meeting with teachers individually, researching and installing new apps, fixing and maintaining all technology, adapting technology for specific curricula, getting additional funding for technology initiatives, and keeping the central school leadership informed about technology use. All of these actions diminished challenges that would be expected normally appear without her intervention.

Table 13 summarizes the references to the work of the K-2 technology integration specialist to help limit challenges. This topic was referenced by all nine teachers a total of 26 times in focus groups and interviews. She was not mentioned in any of the journal entries.

Table 14. Summary of findings relating to student iPad proficiency. For participants KA-2C, the left column represents the number of references to this theme and right column represents the total score of all references to this theme. The four rightmost columns summarize data for all participants.

Finding C2 (“Oh, my gosh, it can take forever!”) – Teachers report that the students’ proficiency in using the iPad can be an impediment to having math discussions.

Teacher 1B described how the students’ trouble using the iPad features detracted from the math conversations: “I mean it took away from the counting and the conversations. Like, the kids who
lost an item because they moved it too far away, or they tapped on the blue dot and made it too tiny so it went away. It was frustrating.”

Teacher 1C questioned the common viewpoint that students are tech savvy by describing students struggling to use the iPad efficiently: “Like, they are supposed to know so much about iPads and so much about technology…but sometimes, oh, my gosh, it took forever.”

Teacher KA describes the simple frustration of students trying to take pictures of their counting collection, “They take a lot pictures, sometimes there's 95 blurry pictures. It is a process.”

Some teachers spoke in general terms about how much time students spend on iPads as an ostensible demonstration of their proficiency with iPads, but reported a non-trivial number of students got stuck during an activity because of limited iPad proficiency. Iterations of the activity to place where the students needed to use multiple features on the iPad including drawing, audio recording, and taking digital photos. Students needed a certain level of iPad proficiency to be able to use all of these features without trouble. According to the teacher reports, a large number of students had deficiencies with certain iPad skills and these deficiencies had a negative impact on the math discussions during the activity. Problems reported by teachers included students taking too long to figure out how to access specific iPad features, not using features correctly, and students not being able to record their work into the iPad accurately.

References to this topic are reported in Table 14. This topic was reference in the interviews and focus group, and also appeared prominently in journal responses. Student iPad proficiency was referenced in interviews and focus groups by eight teachers a total of 19 times. Five teachers reference student iPad proficiency in their journal responses a total of eight times.
Finding C3. Classroom Approach

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Table 15. Summary of findings relating to classroom approach. For participants KA-2C, the left column represents the number of references to this theme and right column represents the total score of all references to this theme. The four rightmost columns summarize data for all participants.

Finding C3 - “Sometimes, we just have a block on some things. And some people who have an iPad block, they’re not gonna see, well, how can I use this, could we make this better? Or different” – The types of challenges with having math discussions that teachers describe are related to the teachers’ description of their own classroom approach. Every math discussion by students in this study happened in a classroom setting, and every classroom has a unique approach constructed by the teacher. The teachers in this study describe a variety of different approaches when they describe their classroom.

Teacher 1A believed it was very important to give students choices, “Some kids really liked using [the iPad], and some preferred to use the paper. I think in that situation, it's okay to give them the choice.” Later in the interview Teacher 1A stated he followed the instructions for the activities but “didn't feel that iPads were needed” for all of the activities and that he “would never stop a child from [trying a non-iPad] strategy, because that may be the strategy that they're ready for. I don't want to belittle them and have them feel that they're not good at math.”

Teacher 1B described her classroom as “structured” and expressed frustration with integrating the activity into her daily schedule: “You kind of have to stay really structured and
organized to fit [the activity].” Later in the interview, Teacher 1B elaborated on what she felt were shallow math conversations and a lack of value in the utility of multiple student strategies for counting:

I didn't feel like I was having the conversations that I wanted to have. I felt like doing the same activity again and again kind of limited the conversations I could have. The kids already knew what to do or didn't. I felt like I was either guiding them too much or…they basically already knew what to do… There weren't really many more conversations to have. You can say, okay, now do it a different way, but they knew it wasn't as efficient as the first way they had chosen.

Teacher 2B described her approach as not having specific expectations for the activity, and believes this led to better math conversations: “Don't look at it like "Oh my gosh. I have to use an iPad to practice counting with my kids." Look at it as a learning opportunity for you and your students because you're going to learn a lot about personalities. You're going to learn about grouping. I learned a lot about how the students grouped and counted differently.”

Teacher 1C acknowledged that she would have never tried to use iPads the way they were used in the study: “I think if I didn't have to do it, I would have just been like, "We're just gonna do paper, guys." She said that the professional development training gave her confidence to try the counting collection activities: “We got training on [running the activities] and I felt confident, and I had the time to think about it…. I need to be confident with what I'm doing with them, so they can be confident in what they're doing.”

Teacher descriptions of their classroom approach range from a traditional direct-transmission classroom where many of the students’ experiences are scripted and surprises are
frowned upon to classrooms to an open-ended constructivist classroom where teachers embraced disarray and described comfort with unexpected student outcomes.

This topic was identified differently than the other challenges in this report. In references to topics C1 (technology integration specialist) and C2 (student iPad proficiency), teachers often explicitly identified the challenge and discussed them. The topic of classroom approach was identified by teacher description of their success or struggles in the context of how they run their classroom. For example, a teacher identified frustration with an activity or acknowledged that the math conversations did not go well using the iPads and would discuss the impact that their classroom approach may be having on the activity. Data included in this sample included direct comparisons by the teachers between the counting collection activity and another activity or lesson by the teacher, usually a successful lesson. Data also included is teacher reporting of the shortcoming in the activity and how it could be fixed with respect to their own classroom culture. Data not included in this data set would be general descriptions by teacher’s philosophy about teaching or technology, without direct referencing to the counting activity. Simple criticisms of the activity that were not directly connected to classroom culture are also not included. For example, criticism of the types of objects in the collections or the size of the bin were not included in this data. References to this topic are shown in Table 15. There were 25 unique references to this challenge from eight different teachers in the focus groups and interviews. This challenge was not mentioned in the journal entries.
Chapter 5:

Discussion

This chapter begins with a brief overview of the goal of the study and then discusses the three key findings of this study. These findings are discussed in reference to how teachers reported engaging with the tools to support math discussions and how this fits in with the research about how teachers perceive changing practice with respect to technology. Next, this chapter describes the implications of these findings with respect to improving the design of professional development to improve the use of digital tools to support math discussions with students. The chapter concludes with a brief discussion of the limitations of this study and some suggestions for possible future work on this topic.

Overview of Study Goals

Many researchers agree that simple white board apps on iPads have matured enough that they can be used by K-2 students (Dhir, Gahwaji, & Nyman, 2014; Domingo & Gargante, 2016; Hassler, Major & Hennessy, 2015). The lack of transformative change in schools with ample access and support for technology indicates that other important factors are at play (Ertmer, 2012). This research investigates ways to improve math instruction at the early elementary level using a digital tool to support math discussions.

Research suggests that better student math discussions can improve math learning, but many teachers struggle to have productive student math conversations (Artzt, Armour-Thomas, Curcio, & Gurl, 2015; Webb, et al., 2014). It seems intuitive that digital tools can facilitate teachers to have better math discussions by giving students novel ways to communicate their math thinking.
However, if teacher perceptions of integrating a new technology into the classroom are not taken into consideration, teacher practice in unlikely to change.

**Key Findings**

There were three key findings in this study identified by their recurring presence across all data types and the large cumulative weighting observed in Tables 3 and 4. First, teachers reported differences in math discussions while using the iPad, but evaluated these differences by contrasting them with an analog experience. Second, the teachers’ descriptions of the types of student math discussions that took place while using the iPad where connected to the overall classroom approach of the teacher. Third, teachers described how internal and external barriers impacted their ability to use the iPads to have productive math discussions with students.

**Connections to contemporary research**

The findings of this study are consistent with three important theories about how teacher integrate technology into their practice. First, research has reported a difference in technology integration and use by teachers who adhere to a direct-transmission approach versus teachers who have a constructivist orientation (Bain & McNaught, 2006; McGrail, 2005; Staub & Stern, 2002; Wozney et al., 2006). This sample included teachers who described using a direct-transmission approach for the activity and other teachers who described using a constructivist approach. These two types of teachers described different math discussions using the iPads. Second, the way the teachers perceived the role of the iPad as a tool impacted the types of math discussions that occurred during the activity. Teachers who described the iPad as a basic instruction delivery tool reported different math discussions then teachers who viewed the iPad as open-ended medium for communication of thought. These reports were consistent with research investigating how teachers perceive classrooms tools and how they should be adopted.
and used in the classroom (Hokanson & Hooper, 2000; Smeets, 2005). Third, educational researchers find that it is useful to distinguish between two types of barriers, first-order and second-order, that impact the integration of technology into the classroom (Hew & Brush, 2007; Ertmer, 1999; Mueller, Wood, Willoughby, Ross & Sprecht, 2008). Ertmer (1999) described the two types of barriers that impact teachers mature use of technology in the classroom. First order barriers are external to the teacher and include resource access, training, and technical support. Second order barriers are internal to the teacher and include teachers’ confidence, beliefs about how students learned, and the perceived value of technology to the teaching/learning process (Ertmer, 2012). Teachers reported the impact of both types of barriers in this study.

**Teacher Change - Direct-Transmission Verses Constructivist Approach**

Instructional change is a complicated process. Teachers interpret all professional development and change initiatives through a lens that is informed by their individual network of knowledge and beliefs about teaching and learning (Buchanon, Burts, Bidner, White, & Charlesworth, 1998; Fang, 1998). Teachers tend to adopt new classroom practices based on whether the new program’s principles are consistent with their personal beliefs. Teachers with traditional instruction habits tend to prefer direct-transmission techniques, while teachers who align themselves with more constructivist beliefs tend to use student-centered inquiry strategies (Peterson, Fennema, Carpenter & Loef, 1989; Yocum, 1998). Peterson et al. found that elementary school teachers’ perspectives about teaching mathematics were consistent with the instructional goals self-reported by the teachers, their choice of instructional methods, and their content and beliefs about the role of teachers and students (1989). In this study, the way the teachers decided to use manipulatives for math discussions and use iPads to support these
discussions correlated with their preference for a direct-instruction approach or a constructivist approach.

**Contrasting the reported approach of two teachers in the study**

None of the nine teachers in this study only used direct instruction techniques or only used constructivist approaches. Instead teachers used a mix of both, with some teachers describing a reliance on direct-transmission techniques and others leaning more heavily on constructivist strategies.

Teacher 1B described using direct-transmission techniques during the activities more explicitly than the other eight teachers in the sample. Teacher 1B followed directions strictly and never deviated or explored other ways to use the iPad to support math discussions during the later activities, like most of the other teachers did.

After the first activity, she emailed to say that she was not sure what was being asked of her and she did not think that she was doing the activity correctly. Teacher 1B described her math conversations with the iPads as struggles. She reported that she felt she was over guiding the students and that she “was not having the conversations I wanted to have with the students” and that “the iPads limited the conversations I could have with students.”

Teacher 1B reported students finishing very quickly and that the iPads actually slowed them down because they were not finding efficient ways to show their thinking like they could on paper. An important note here is that teacher 1B was not a low ability tech user. During the interview, she showed me other work she had done with technology that she described as ostensibly better than what was being done with the counting collection activity. She experimented the least with the iPads during the study and made it clear to me that she thought
using the iPad in this way was a waste of time, that an analog approach would be much more efficient.

Teacher 2A relied on a constructivist approach for the activities. Teacher 2A consistently reported rich and surprising math conversations with her students and she made efforts to be innovative with her technology use in the classroom. She has attended multiple conferences on educational technology and she was the teacher the farthest along in using the unique features on the iPad. Even during the initial runs of the activity, she had to be reminded several times to run the activities in the same way as everyone else because she had expanded the activity to include other technology pieces that were not part of the study. She was very gracious and followed directions for the all activities afterwards, but later stated that she felt constrained by some of the structure of the study.

Teacher 2A described different struggles than teacher 1B. Teacher 2A lamented that there were too many great conversations in her classrooms for her to keep track of particular occasions when she was using the iPad. She reported that engaging kids in conversation using analog tools was a challenge because they would lose interest as an activity was repeated. She said this was not a problem with the iPads because students could express their thinking in different ways. She talked about students using multiple pages to explain their thinking, taking time-lapse photos, or retrieving images from the web to help them explain the counting process. She repeated several times in the interview that she would learn so much about the students’ thinking by using these features that it never got boring for her or the students.

The descriptions of the student math conversations reported by these teachers 2A and 1B were very divergent, but are consistent with research about how teacher perspectives can impact the interpretation of new practices in the classroom. Even though both teachers were following the
same prompts, Teacher 2A reported rich math discussions and surprising insights into student thinking iPad, while teacher 1B often described the kids as being bored because they finished too quickly and did not observe anything novel about student thinking during the activities.

**Consistencies among teachers with respect to teaching approach**

The kindergarten teachers (KA, KB, and KC) skewed toward a constructivist approach with the activities. These three teachers described varying levels of excitement about the quality of math discussions with students, and showed the most enthusiasm about using these activities the following school year. The first and second grade teachers also reported varying level of utility from the activities, but were less enthusiastic as a group about incorporating the activities into the curriculum after the conclusion of this study.

During the individual interviews with the kindergarten teachers, they discussed more explicitly the skills they wanted their students to sharpen during the academic year. The teachers reported that improving skills was important for their students as they prepare them for the first grade. These teachers described the counting collection activity as useful in improving these types of skills. This behavior is consistent with the skill-based instruction of many kindergarten classrooms, compared with increasing content expectations as students progress through elementary school.

In interviews with the first and second grade teachers, there was more discussion of specific content that these students need to master so they can be successful as they move forward in school. These teachers appreciated the engagement of the counting collection activities, but voiced concern that students were only reviewing previous content knowledge and not learning anything new. Teachers at the first and second grade level were more likely to insert
formal content into the activity that was currently being taught in the math curriculum (number bonding, grouping, etc).

**iPads as an Instruction Delivery Tool Versus a Medium for Thought**

Clark (1983) argued that instruction can be presented with almost any media method, and describes media as basic vehicles that deliver instruction. This viewpoint only requires two media methods to deliver the same instructional content, and does not offer a rigorous means for comparing the potential opportunities that arise uniquely from different media methods (Sitzmann, Kraiger, Stewart, & Wisher, 2006; Cobb, 1997). Viewing iPads as merely a delivery instruction vehicles is not effective for utilizing their full potential, it is only using a new medium to deliver an old method.

If teachers define the iPad narrowly as a tool whose only purpose is to deliver instruction to the student, they are severely limiting the capacity of the iPad (Hokanson & Hooper, 2000). Hokanson & Hooper (2000) argue that viewing a digital tool this way only uses the communication capabilities and its representative functions. It fails to take advantage of the creative potential of the iPad that gives students the opportunity to construct knowledge by investigating across various types of media, audio, drawings, images and writing.

Clark’s work (1983) referred to the definition of a tool as something designed to achieve a specific task. Using this fundamental definition, if two different tools successfully complete the same task they are equivalent. Another definition of a tool is adopted from biology, “a medium that is conducive to growth” (Alberts et al., p. 456). It is also possible to view an iPad as a cognitive medium, “a medium that provides an environment for intellectual growth” (Hokanson & Hooper, 2000, p. 548). This alternate definition of a tool changes the perspective of how technology can be used in the classroom. Viewing the iPad as a medium used for students to
construct knowledge can change the way students think and learn by providing diverse ways for students to interact with their learning environment, i.e. the unique features of the iPad.

**Comparison of iPad use between teachers to support math discussions**

In this study, participants described using iPads as both rote vehicles for instruction delivery and as a medium for creative thought. Teacher 1C used the iPad repeatedly to take pictures of the students’ counting collections so she could refer back to it while having math discussions with her students. The students used the digital image to describe their thinking while having discussions with the teacher. Teacher 1C is leaning heavily on the representational feature of the iPad to reproduce an exact image of the collection. This image is a stand-in for the actual counting collection that the teacher was not present to see. Teacher 1C placed high value on this feature, and it was one of her favorite parts of using the iPad because she felt it made her more efficient with her time. She was able to have the math discussions with the students without the presence of the manipulatives. She did not report differences between discussions using this approach versus discussions in the presence of the manipulatives.

Teacher KC described enjoying the open-endedness of math discussions while using the iPads. She said her students could often find a first way to count something, but were confused when asked to find a second way to count the items. The students would ask questions of how to count a second way and teacher KC described her response as follows:

I would say ‘you tell me…here is a tool for you, just explore” And they kind of look at it, and they'll play with it, and there's just this exploration, and sometimes they use the tools in a way that wouldn't help them. But at least it's getting that mind wheel ... those wheels turning, that creative thinking, that problem solving.
The tool definition that teacher KC is referring to here falls more in line with a cognitive medium, one that provides an environment for intellectual growth. This kind of exploration is not possible with many analog tools and would not be possible with an iPad if the teacher used the iPad only as an instructional delivery device.

**Teacher experience and tool use**

Educators are critical to student learning, thus they play an important role in either supporting or inhibiting technology integration. Some researchers have focused on how the increasing prevalence of digital tools has increased teacher familiarity with technology, but it has not helped teachers attain the mastery they need to fully integrate technology (Abrami, 2001; Wozney et al., 2006). Abrami (2001) suggested that teachers may not be using the full potential of digital tools because they need multiple years of technology skill training to gain the mastery needed in the classroom.

The data in this study seems to refute these conclusions. Most of the teachers in this sample had been skill building with iPads for four years prior to this study, since the K-2 integration specialist arrived and integrated iPads as the sole technology tool in their classrooms. All teachers in this study had lengthy training on the iPad. Despite this, some described using iPads as a direct-transmission tool while others utilized the iPads for more discovery and exploration to stimulate math discussions. This discrepancy suggests that different teachers have different perceptions of what kind of a tool the iPads is and how it should be used. These perceptions impacted the types of math discussions they would have with their students.

**Findings with respect to the two-barrier perspective of technology use**

The findings of this study dovetail well with the two barriers described by Ertmer (1999) impacting technology integration. The third finding about the work of the K-2 integration
specialist connects directly to overcoming first order barriers. The other two key findings about teachers comparing iPads to an analog experience and the impact of teacher approach on math discussions using iPad are connected to second order barriers.

Reports by teachers in this study are consistent with the review of integration barriers by Hew & Brush (2007). They analyzed studies from 1995-2006 and ranked the barriers most frequently cited by teachers. The most cited were: “1) resource access 2) teachers’ knowledge and skills and 3) teachers’ attitudes and beliefs” (Hew & Brush, 2007, p.424). The key finding relating to the role of the K-2 technology integration specialist was supportive of the first two items described by Hew & Brush (2007). The integration specialist ensured that all iPads were in good working order and accessible for teachers. She also worked with teachers to help them get the knowledge and skills to use the iPads effectively. The remaining two findings would fall under teachers’ attitudes and beliefs. Teachers’ evaluation of the iPad experience and how teachers’ classroom approach impacted math discussion with iPads are both internal factors.

It may not be surprising that a technology support person can improve the iPad experience in a classroom. The useful findings here are the specificity in the various ways that teachers report the role of the K-2 technology integration specialist in improving the classroom iPad experience. The K-2 technology integration specialist was viewed by teachers as responsible for a diverse array of actions that all served to improve the overall technology experience, not just for mathematics. Below is a list of tasks undertaken by the K-2 technology integration specialist, as reported by teachers, that was perceived to help them more easily integrate technology into the classroom:

- Maintain all hardware and software
- Craft a unified technology philosophy for the school
• Write a K-2 technology scope and sequence that includes input of the teachers
• Attend all grade level meetings
• Meet and check-in with teachers individually
• Identify new apps and other technology experiences that match teacher strengths
• Write proposals for outside funding for technology initiatives
• Manage relationship between school leadership and faculty

This list is consistent with many of the themes cited in the literature as being important for successful technology integration into the classroom: hardware upkeep, clear school vision, and consistent teacher support (Hew & Brush, 2007; Pelgrum, 2001; Sang, 2010).

Many common teacher complaints about technology implementation were considerably suppressed during the study as a result of the K-2 technology integration specialist’s support of the tasks listed above. The impact of the K-2 technology integration specialist on this study was not directly related to the math discussions in the classroom, but served to allow teachers to work with the iPads without the presence of many common impediments and provided consistency across classrooms for how iPads were used. For example, all teachers already knew how to access the microphone for the audio portion and how to take and save a digital photo on the iPad. This helped diminish contamination of the activity by any number of outside factors not directly related to using a digital tool to support math discussions.

Impact of Teacher Beliefs and Attitudes on Changing Practice

The influence of teacher beliefs and attitudes on instructional practice has been well-documented for over 30 years (Mahlios, Massengill-Shaw, & Barry, 2010; Tabachnick, 1984; Vacc & Bright, 1999). These studies show that attitudes and perceptions have a strong influence on teachers’ instructional practice in the classroom and on what teachers learn from professional
development experiences. Unfortunately, many educational policy makers view change as a linear process in which instructional practices are mandated from the top down, and teachers will promptly accept and adopt them (Guskey, 2002). Many educational reform initiatives that use a top-down approach fail because they have little or no impact on changing teachers’ beliefs and attitudes, particularly when they involve technology adoption (Carney et al., 2016; Cohen & Ball, 1990; McGrain, 2005).

Despite enthusiasm around the educational promise of technology, many policymakers and school leaders fail to recognize that technology does not have unique powers to change teaching practices. Top-down mandates will have little effect on teacher beliefs and attitudes about technology (Niederhauser & Stoddart, 2001). In interviews, some teachers described the new role of the K-2 integration specialist as pivotal for improving technology use in the classroom because this person attempted to take into account the teachers’ unique aptitudes and beliefs.

**Implications of Findings**

**iPads compared to other educational innovations**

This study suggests that integrating digital tools into practice is fundamentally different than integrating new analog tools. Teachers need a different training approach to integrate digital tools effectively into instruction— an approach that incorporates teacher perceptions of how technology will impact their instruction.

The modern teacher is expected to integrate new tools and strategies as a requirement of their position. The successful integration of digital tools requires a unique approach to be successful (Ertmer, Ottenbreit-Leftwich, Sendurur, & Sendurur, 2012). Many teachers, when integrating a new practice, try to compare it to something they already know and use preexisting strategies. This is consistent with strong cultural script that teachers are tied to about what
teaching looks like in a specific educational system (Hiebert & Stigler, 2000). Teachers struggle to construct what learning looks like with technology because this script strains to accommodate the presence of digital tools because of their recent emergence. This requires teacher to construct new approaches for incorporating technology in their classroom.

The iPad was released by Apple in March of 2010, and not specifically marketed as an educational tool. In a very short time, it has become extremely popular with over 300 million iPads sold since 2010. Almost immediately after its release, iPads were regarded as a promising technology for classrooms even though there were not specifically designed for the education sector (Murphy, 2011).

The iPad is a new tool for the classroom and it is unique when compared to other historical innovations in education. When students began taking standardized tests or when the western literary canon was retooled in English classes, teachers may have been upset and confused by these changes, but could grasp the intended impact of the change. These innovations, and many others in education, were designed for specifically for this sector and typically required many years until they reached a mature use. Digital tools designed for home use like the iPad are being thrust into classrooms before they have been thoroughly field tested. Because of the popularity of iPads, teachers are being expected to utilize them on a much faster timeline and with less vetting than other educational innovations.

Recent technology innovation in education is much more challenging for educators to fully grasp because this type of innovation moves quickly, and its impact has been hard to predict (Mundy, et al., 2012; Murray & Olcese, 2011). The relationship educators have with technology is complex and is often connected with work, identity, and power. Scholars vigorously debate the impact and long term consequences of how technology is being used in
classrooms, without a clear consensus of the final outcome for technology’s role (Carr, 2012; Falloon, 2015; Suppes, Liang, Macken, & Flickinger, 2014). It is in this uncertain atmosphere that teachers and school leaders must make instructional decisions about what is best for student learning with respect to technology.

Supporting math conversations in a new way with iPads

Teachers in this study reported seeing unique behaviors by the students when using the iPads, supporting the claim that iPads create different learning opportunities. Teachers who were too invested in viewing the iPad as a paper replacement were often not as receptive to these new student behaviors. Two examples of teachers identifying new behaviors on the iPads that were not present on paper are: teacher 1A discussed a student audio recording not matching the written work, and teacher KC observed students using representations that had not been taught yet. The challenge the teachers have is how they engage with this new information coming from the student, and how they use it to have better math discussions. A teacher with less experience in this domain may just shrug their shoulders and ignore the behavior as an anomaly. A teacher who views the iPad as a cognitive medium that can reveal different insights about student thinking would use this information to build a more detailed picture of how that student is constructing their math knowledge.

Ideally, teachers should be aware that iPads can create unique opportunities for them to notice things in more detail. The iPad allows the teacher to be more attentive of the student’s thinking, leading to better math discussions. The fact that teacher’s reported noticing some of these details is encouraging. The iPad is indeed creating these unique opportunities as intended. The challenge suggested by this study is how to position teacher to recognize these opportunities and integrate them into their instruction to support better math discussions. The teachers’
description of students’ conversations with the iPads suggests that the device allowed teachers to access certain details of student thinking that are not easily observed when working in an analog setting. Teachers with access to these additional aspects of student thinking are able to construct a richer and more detailed picture, and are more likely to report better math conversations with students.

**Improving Professional Development Around New Technologies**

Teachers have been integrating new tools and practices into their instruction via professional development since the beginning of formalized education, but it does not mean schools have mastered the best techniques to improve teacher practice (Guskey, 1986; Morrison, 1926). Professional development is most frequently designed to initiate change in three areas: (1) teachers’ beliefs and attitudes, (2) teachers’ classroom practices, and (3) student learning outcomes (Garet, Porter, Desimone, Birman, & Yoon, 2001; King & Newmann, 2001). Initiating change in these three areas becomes even more complicated when it involves technological innovation (Ertmer, 2012; Lawless & Pellegrino, 2007).

The first attempts at designing professional development evolved from the early change theorists like Lewin (1935) whose work was rooted in therapeutic models. These models espoused classroom change as initiated by a change in beliefs and attitudes. Lewin’s ideas led to a linear model of teacher change that begins with a change in teachers’ beliefs and attitudes and culminates in a change of student learning outcomes, as shown in Figure 3.
More recent research suggests that the assumptions of this model are inaccurate, and that teachers’ beliefs and attitudes are impacted by changes in classroom practice and learning outcomes (Huberman & Miles, 1984). Considerate of this research, Guskey (2002) created an alternative model to describe teacher change via professional development. He placed teacher changes in beliefs and attitudes as the culminating step of the teacher change process, as seen in Figure 4. Guskey argued that significant change in teachers’ beliefs and attitudes occurs mostly after teachers change their practices and observe improvements in their student learning.

Figure 3. Model of Teacher Change Via Lewin (1935)

Figure 4. Guskey’s model of teacher change (2002)
Other researchers have adapted Guskey’s model further, and posit that while teacher change still culminates with a change in teachers’ beliefs and attitudes, the initial processes are cyclical (Rogers, 2007), such as shown in Figure 5.

![Figure 5. Rogers’ cyclical model of the process of teacher change (2007)](image)

The important pivot of the alternative models depicted in Figures 3 and 4 is the professional development experience itself does not change beliefs and attitudes, but rather the experience of observing positive outcomes as a result of a change in practice can lead to a revision of beliefs and attitudes. Simply put, teachers believe it works because they have seen it work.

The findings of this study are consistent with the models that culminate with a change in teachers’ beliefs and attitudes after a change in practice and observing student outcomes. This study began with a professional development session on the basics of CGI and how to run the activities. The feedback on the professional development was positive, but resistance to the activity and questions about why classroom time was being devoted to this project were still observed. Before the study started, several teachers were excited about trying something new,
but seemed skeptical about anything productive coming from the experience. During the focus groups and final interviews, the majority of the teachers identified something unique occurred in their classroom as a result of the activities. The teachers were doing something different in the classroom, and they observed unique behaviors by their students during math discussions.

Because of the brief duration of this study and the limited amount of training with respect to CGI, any authentic change in teachers’ beliefs and attitudes cannot be confirmed. However, it is observed that the teachers’ descriptions of the impact of the activity were different before and after the study.

A question heard in many of the final interviews related to the future fate of these activities. The tone of these queries indicated that teachers were curious to learn more. Many teachers reported that this had been a good use of their class time. The kindergarten teachers were most enthusiastic about continuing the activities next year, while the first and second grade teachers said they would do the activities again if they could fit them into their schedule.

Observing even small changes in such a short study makes a case for educational leaders to account for teacher perceptions when designing professional development experiences for technology integration. The features of iPads may indeed offer new ways to observe student thinking and to engage in math discussions, but if teachers are not receptive they will not make the best use of these features.

It is not enough to train teachers on how to use features such as audio recording or taking digital pictures, teachers must be receptive to new interactions with students. Teachers need to rethink and restructure their practice to include the digital tool seamlessly into their instruction. The findings of this study suggest two approaches to enhance professional development with respect to technology integration to support math discussions.
First, professional development could help teachers to be sensitive to classroom learning experiences that may at first appear to be anomalies, but in fact manifestations of the unique features of the tool. One approach to professional development could be to share multiple case studies of teachers discovering new features through interactions with students. This could appeal to teachers who prefer direct-transmission approaches and teachers who have more constructivist orientation. For example, in this study, more than one teacher reported surprise when students working on their iPad added extra pages because they ran out of room. When the students presented this work to the teacher, the students swiped between the pages like a slide show. This is a moment where the iPad is being used in a way that paper cannot. Depending on the perspective of the teacher, they can resist this change and instruct students to limit their work on the iPad to one slide because that is how paper works, or they can begin to view the iPad as a unique tool that has this capability. Showing teachers case studies of how these features can appear unexpectedly during instruction may help teachers identify and utilize these features in later lessons, independent of their instructional approach.

A second consideration for designing professional development would be to give consideration to how teachers view the iPad. It may be viewed as a delivery instruction tool or as a cognitive medium for learning. Depending on the teachers’ perspective, different teachers may react to the same professional development in completely different ways.

Many technology professional development sessions feature a fully realized, rich, learning experience with a digital tool that utilizes the technology features in a unique way. Some teachers immediately adopt this new technology use, while other teachers do not perceive the iPad this way and gain very little from the time spent in professional development. Teachers
who view the iPad used in a way that conflicts with their perception of the role of the iPad as a tool are less likely to adapt their practice.

For professional development to have the most impact, leadership should be sensitive to the fact that many teachers who struggle to use technology often do not view the iPad as a unique tool. A common approach is to have professional development led by an ‘alpha user’ who has fully embraced technology as a creative tool. This can create a disconnect when trying to train teachers and give support that is helpful. Understanding that less mature users may view the tool in a different way gives insight into how to design professional development and how to answer questions more productively.

Independent of a teacher’s instructional orientation, it is important for them to appreciate that an iPad, because of its design, offers a wide array of uses that may not immediately be obvious and will manifest themselves over time if the teacher permits it. Professional development that aspires to empower teachers to use digital tools effectively needs to help teachers be sensitive to the new experiences that will be happening in the classroom with the introduction of digital tools. It takes practice and training to be aware of these new uses and be able to utilize them effectively during instruction. It is useful for teachers to view iPad utilization as a growth process that evolves over time.

**Limitations of Study**

First, this research was limited by its small sample size and the brevity of the study. The nine teachers in this study gave tantalizing glimpses of possible larger themes, but there is also the possibility that one or more teachers in this study are not representative of the normal teacher population. At minimum, this research would give some starting points to look for when embarking on a larger study on this topic.
Second, this study used an iterative process for the activity, allowing the iPad to be used in different ways to support math discussions in the classroom. This approach was useful because it exposed teachers to a wide variety of iPad features, and it was possible to gather data on teachers’ perceptions of how these different features supported student math discussions. A limitation of this approach is that teachers never repeated the same iteration of the activity, and may never have become comfortable with any particular approach.

Trying things for the first time in a classroom is one of the larger anxieties of being a teacher. The uncertainty about what will happen is the most intense for the first attempt, and diminishes with each future attempt as teachers accrue experience. Part of teachers’ reported perceptions were most likely impacted by consistently having to try something new each iteration. It would be interesting to see how additional practice and familiarity with the activities would impact the perceptions of the teachers during a longer duration study.

Finally, the role that technology plays now and into the future is a large and complex topic in education. Digital tools are becoming increasingly prominent in the classroom. Researchers speculate about how digital tools can impact change in education, but their actual impact on the classroom thus far has been far from predictable (Ertmer et al., 2012; Murray & Olcese, 2011). These findings are applicable to the state of technology as of 2017, but because iPads were only introduced in 2010, there is not a large amount of compelling data to extrapolate with confidence about the future. The iPad, with its adjustable touch screen interface that untethers users from a keyboard, opens up possibilities that are still being discovered. There is a reasonable chance this technology is still in its initial phase of expansion and has not settled into a stable form yet. In ten-years time, iPads may play an entirely different role in education, and
we may look back at 2017 and be flabbergasted at the futility of our initial attempts to utilize this technology effectively.

**Recommendation for Future Research**

This study illuminates interesting questions that deserve more investigation. This study presented a spectrum of attitudes toward the use of digital tools to support math discussions. This study did not permit the observation of the evolution of these attitudes. It would be interesting to track several teachers over time to see how their attitudes change after sustained experiences with technology. This study suggests that teachers have a variety of perspectives of the iPad’s role in the classroom. It would be useful to catalogue these perspectives and see what themes and patterns emerge over time.

This research suggests ways to adapt professional development to better support teachers’ use of technology during math discussions. It would be informative to train teachers on the same technology skills, but train some teachers with traditional professional development and train others teachers with a professional development that is considerate of the complicated perceptions teachers have about technology. This provides the opportunity to measure any differences in teachers’ approach and attitudes with respect to using technology to support math discussions.
APPENDICES

Appendix A: Pre-Study Survey

1) Technology can support my students to explain their ideas.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

2) Technology has decreased my students’ engagement in their learning.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

3) My teaching is more student-centered and interactive when technology is integrated into instruction.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

4) Technology can support me to differentiate my math instruction.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

5) Technology makes it harder for students to focus on learning.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

6) I am able choose the technology appropriate to the teaching process with my classes.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

7) Technology has helped my students work more collaboratively.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

8) My teaching practices emphasize teacher uses of technology skills to support instruction.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>
Appendix B: Journal Entry Prompts

**Activity 1** – Students used physical manipulatives but no iPad

Describe something that happened during the activity that was unexpected, worked very well, or did not work well.

How were you able to support the students to explain their math thinking? What went well? What did not go well?

OPTIONAL: Write any additional comments here that you would like to share.

**Activity 2** – First iPad Activity

Describe something that happened during the activity that was unexpected, worked very well, or did not work well.

What happened to your math conversations with students when they used Book Creator to record their math thinking? (What about the conversations were the same and what changed compared to the first activity with no digital tools?)

OPTIONAL: Write any additional comments here that you would like to share.

**Activity 3** – Second iPad Activity

Describe something that happened during the activity that was unexpected, worked very well, or did not work well.

What did you change during the second activity and what happened to your math conversations with students as a result of that change? (What about the conversations were the same and what changed compared to the second activity?)

OPTIONAL: Write any additional comments here that you would like to share.

**Activity 4** – Third iPad Activity

Describe something that happened during the activity that was unexpected, worked very well, or did not work well.

Describe any similarities and differences in your math conversations when the students counted their objects on the iPads. (What about the conversations were the same and what changed compared to when the students previously used physical manipulative to count?)

OPTIONAL: Write any additional comments here that you would like to share.

**Activity 4** – Fourth iPad Activity
Briefly describe how you ran the final activity and why you decided to run it this way.

Describe something that happened during the activity that was unexpected, worked very well, or did not work well.

How did the way you decided to run the final activity impact the student math conversations?

OPTIONAL: Write any additional comments here that you would like to share.
Appendix C: First Focus Group Script and Questions

INTRODUCTION
Good afternoon and welcome. Thanks for taking the time to join our discussion of cognitively guided instruction and digital tools. My name is Derek Weisel and I am here in my capacity as a graduate student researcher for UCLA.
You were invited here today because you are all K-2 teachers who have had the experience of using counting collections and digital tools to have math discussions with students. I want to tap into these experiences and hear your opinions and perspectives.

There are no wrong answers. I expect that you will have differing points of view. That is okay. You do not have to agree. Please feel free to share your point of view even if it differs from what others have said. I really want to hear what you have to say but you can stop participating in the group whenever you want without penalty. Please feel free to ask questions at any time.
The session will not last longer than 45 minutes. You have probably noticed the devices on the table. I am recording the session because I do not want to miss any of your comments. People often say very helpful things in these discussions, and I want to make sure we capture everything. I will not use any names in my research, and we will keep what you say confidential.

I have 5 questions to ask. My job is to listen to you and to make sure everybody has a chance to say what he/she wants to say. You do not need to respond directly to me all the time. If you want to follow-up on something someone else said, you want to agree, or disagree or give an example, feel free to do that. I am interested in hearing from everyone so if you are talking a lot, I may ask you to give others a chance. And if you are not saying much, I may call on you. I just want to make sure all of you have a chance to share your perspectives.

If you have a cell phone, please put it on the quiet mode and if you need to answer please step out to do so. Feel free to get up and get more refreshments or snacks during the discussion. Let’s begin.

QUESTIONS

1) I’d like to start by getting a feel for the kinds of math conversations you have been having in your classes running doing counting collections. Let’s go around and have each person share something that went well during the activities. Has anything surprised you so far during the study? Explain why was it a surprise?

2) Can someone share a particularly good math discussion you had with a student while using iPads during these activities?

Probe: Could this discussion have happened without the presence of digital tools?

3) So thinking more about these math discussions. Can you tell me about a time where you were aware of the presence of the iPads during the discussion for better or for worse?
4) So we have talked quite a bit about iPads and math discussions. Can someone describe the relationship— as you see it— between using the iPad and having a math discussion with students.

Probe: How does it help or hurt these conversations?

Probe: Can someone share a conversation or experience that would not have happened without the iPad?

5) Is there anything else you would like to mention that has not come up in our discussion. (if not, thanks)
Appendix D: Second Focus Group Script and Questions

INTRODUCTION

Good afternoon and welcome. Thank you again for taking the time to join our discussion of cognitively guided instruction and iPads. My name is Derek Weisel and I am back in my capacity as a graduate student researcher for UCLA. You were invited for a second time today because you are all K-2 teachers who have finished multiple counting collection activities using iPads. I want to tap into these experiences and hear your opinions and perspectives.

Just like last time, there are no wrong answers. I expect that you will have differing points of view. That is okay. You do not have to agree. Please feel free to share your point of view even if it differs from what others have said. I really want to hear what you have to say but you can stop participating in the group whenever you want without penalty. Please feel free to ask questions at any time.

The session will not last longer than 45 minutes. You have probably noticed the devices on the table. I am recording the session because I do not want to miss any of your comments. People often say very helpful things in these discussions, and I want to make sure we capture everything. I will not use any names in my research, and we will keep what you say confidential.

I have 5 questions to ask. My job is to listen to you and to make sure everybody has a chance to say what he/she wants to say. You do not need to respond directly to me all the time. If you want to follow-up on something someone else said, you want to agree, or disagree or give an example, feel free to do that. I am interested in hearing from everyone so if you are talking a lot, I may ask you to give others a chance, And if you are not saying much, I may call on you. I just want to make sure all of you have a chance to share your perspectives.

If you have a cell phone, please put it on the quiet mode and if you need to answer please step out to do so. Feel free to get up and get more refreshments or snacks during the discussion. Let’s begin.

So now that you have completed all of the activities and journal entries I would like to hear about how using CGI and iPads in different ways impacted your ability to engage in math conversations with students. We will begin talking about the iPad experience and then transitioning to talking about CGI and math conversations.

QUESTIONS

1. First I’d like to talk about the activities. The first activity was analog while all others used iPads. Can you tell me what you remember about the differences between doing the analog activity and then using iPads?

   Probe: How did the iPads make running the activities easier or more complicated?

2. We did several different activities that used the iPad. Which one do you think was the most effective eliciting good math conversations? Why? Which was the least helpful? Why?
Probe: How would you describe the impact of the iPad on the CGI activities? Did it make them easier or harder? How?

3. Describe a specific conversation with a student remember that you believe was prompted by using the iPad.

Probe: Describe a time where your discussion went down an unexpected path because of the presence of iPads.

Probe: Describe a time when the iPad was an important tool for facilitating discussion.

Probe: All of you had the students share their thinking with you during the iPad activities. Describe how you think those conversations may have been different if not using the iPads?

4. Can you tell the time you felt most frustrated during the activities? Why?

Probe: When we were starting the activities. During my conversations some folks voiced concern that iPads made the activity more complicated and inhibited the math conversations with students. That the activity was better without them. Now that you have done multiple activities what us your take on that outlook?

Probe: Can you talk about a time where you felt the iPad was getting in the way of learning?

Probe: Is there something you wished had been done to make using the iPads during the lesson easier?

5. So overall, how do you feel the presence of the iPads impacted your ability to have these CGI math discussions?

Probe: If you could put your finger on one thing that influenced you the most in terms of integrating technology in your classroom, what would that one thing be?

Probe: Would you recommend using iPads with counting collections to another Poly-like School? Why or why not?

6. Is there anything else you would like to mention that has not come up in our discussion. (if not, thanks)
Appendix E: Final Interview Protocol

INTRODUCTION

Good afternoon and welcome. Thank you again for taking the time to discuss cognitively guided instruction and iPads. My name is Derek Weisel and I am back in my capacity as a graduate student researcher for UCLA.

You were invited for an interview today because of your experiences with CGI and iPads. I’d like you to focus on the experiences during the project that you’ve learned the most from, something that others might find instructive if they were embarking on a similar project.

Just like the focus group, there are no wrong answers. I expect that you will have a unique point of view. That is okay. Please feel free to share your point of view even if it differs from what you think others have may have said. I really want to hear what you have to say but you can stop participating in the interview whenever you want without penalty. Please feel free to ask questions at any time.

The interview will not last longer than 45 minutes. You have probably noticed the devices on the table. I am recording the session because I do not want to miss any of your comments. People often say very helpful things during interviews, and I want to make sure I capture everything. I will not use any names in my research, and we will keep what you say confidential.

1) What is your current position?
   -How long have you been at this school?
   -Have you held the same position the entire time?
   -What is your experience teaching prior to starting at this school

2) What motivates you to be a teacher?
   -what part of your job are you most passionate about?

3) Have you ever been asked to pilot or incorporate an outside program like CGI/iPad experience before in any subject? How did that come about?
   -what role did admin/school leadership play in this?
   -did you feel it was successful? Why or why not?

4) How did this CGI/iPad experience compare with similar outside programs that either have been piloted or asked to incorporate in your classroom?

5) So now that everything is finished with CGI/iPad what stands out to you about entire experience?
   -What parts of it were the most worthwhile? Why?
   -What parts of the experience do you think will stay with you the longest? Why?
   -Did any parts of the experience feel like a waste of time?
6) You conducted several different counting collection activities. Tell me how they went.
- What worked? Why?
- What didn’t? Why?
- Which iteration worked best? Why?
- Which iteration was least successful? Why?

7) Can you tell me what the math conversations were like during the activities w iPads?
- During what activities did you give the best conversations? Why?
- Can you tell me during which activity when you observe the most creativity and engagement when having math conversations with students?
- Can you tell me about your impressions of using iPads versus using no technology during the counting collections?
- What iPad activity was most effective? Why?

8) Can you describe a specific incident that sparked significant growth for you during the activities?
- Can you tell me about a conversation you had with a student during the counting collection activity that surprised you? What was surprising?
- Did you see any patterns in the types of conversations you had with students?

9) Can you tell me about the time(s) you were most frustrated during the project?

10) Can you talk about experiences you may have observed that may have been unique to your grade level?
- What are things you adapted with the activities to help them work with your class compared to your team?

11) Can you tell me what role your grade level team of teachers played in how you ran the activities?
- Was your grade level team helpful or not a factor during the activity?
- Can you tell me about the roles each teacher played on your grade level team?

12) How did meeting with the entire K-2 impact your counting collection experience?
- Was it helpful? If not what could make it better?
- What did you find most useful?
- Did anything you hear in the meeting surprise you?
- Did you disagree with anything in the meeting?

13) If you were going to do this project again next year what would you do differently and why?
- Did the PD help? How?
- How did the way the project was structured impact you?

14) If I were to run this lesson next year with a new set of K-2 teachers what hints or suggestions would you give them about the experience?
- What do you wish you knew before you started? Why?
-how do you think their experience might turn out differently if you

15) If someone was doing the same project said they were excited to do CGI but they were worried about the iPad piece what would you tell them?

16) Is there anything else you would like to share or add on to?
References


